411-6 Sealing Cracks for Epoxy Injection.

After cleaning, drill injection port holes using a swivel drill chuck and hollow drill bits, including a vacuum attachment which will remove dust and debris generated during drilling. Determine the spacing of the injection port holes by the size of the crack and the depth of the crack in the concrete substrate. Generally, space the injection ports from 4 to 8 inches apart. Determine the actual spacing of injection ports by field trials. Drill the holes to a minimum depth of 5/8 inch, exercising care in aligning the hole along the plane of the crack so that the hole follows the crack for the full 5/8 inch depth.

Insert the injection ports in the drilled holes approximately 1/2 inch, allowing for a small reservoir below the injection port.

After cleaning the cracks and drilling the injection port holes, seal the crack surface and the injection ports with suitable epoxy.

411-7 Epoxy Injection.

Inject the epoxy in accordance with the epoxy manufacturer's instructions. Determine the actual injection procedures and pressures in field trials, based on crack widths and depth into the substrate and sufficiency of the results.

411-8 Cleaning After Epoxy Injection.

Clean concrete surface areas of excess epoxy materials and injection ports after completing the epoxy injection work. Clean in a manner which will not damage the concrete by scraping, light sand blasting, grinding, use of solvents, or any other appropriate method approved by the Engineer. Clean excess materials so that no epoxy material or injection ports extend beyond the plane surface of the concrete.

411-9 Acceptance.

Drill three cores located in each day's work as directed by the Engineer. Take drilled core samples containing representative crack sizes. The Engineer will accept the epoxy injection work represented by the core samples when the core samples indicate that 90% of the crack void greater than 0.006 inch wide is filled with epoxy resin and the concrete of the core sample is bonded through the crack into a unit.

Reinject epoxy injection work which does not satisfy the acceptance criteria, and correct it as necessary at no expense to the Department. Install additional injection ports as required to achieve satisfactory reinjection of epoxy resin.

After the epoxy injection work is completed and accepted, fill the core holes with an epoxy mortar consisting of one part by volume epoxy injection resin and four parts by volume clean, dry sand. Supply the sand in moisture proof bags. Do not use previously opened bags of sand for making epoxy mortar. The Contractor may use one part by volume epoxy material for sealing with one part by volume clean, dry sand in lieu of the above.

411-10 Method of Measurement.

411-10.1 Epoxy Material: The quantity to be paid will be the volume, in gallons, authorized, injected, and accepted.

411-10.2 Inject and Seal Crack: The quantity to be paid will be the length, in feet, authorized and accepted, measured along the approximate centerline of the sealed crack.

411-11 Basis of Payment.

411-11.1 Epoxy Material: Price and payment will be full compensation for all work specified in this Section, including furnishing the epoxy material, and miscellaneous related costs, storage, handling, etc.

411-11.2 Inject and Seal Crack: Price and payment will constitute full compensation for furnishing all labor, equipment, incidentals and materials (except epoxy), for cleaning and sealing the crack, and all labor and equipment for injecting the crack.

411-11.3 Payment Items: Payment will be made under:

Item No. 411-	1-	Epoxy Material - per gallon.
Item No. 411-	2-	Inject and Seal Crack - per foot.

SECTION 413
SEALING CRACKS AND CONCRETE STRUCTURE SURFACES

413-1 Description.

Seal concrete surfaces and cracks in concrete using materials, surface preparation, and application of penetrant sealers and high molecular weight methacrylates (HMWM) as specified in this Section and in accordance with the manufacturer recommendations. Consult with the FDOT State Materials Office (SMO) in the event of conflict between the manufacturer's recommendations and this Specification. Perform surface preparation and application to all areas as shown in the Plans or as directed by the Engineer.

413-2 Penetrant Sealers.

413-2.1 Materials: Use alkylalkoxysilane penetrant sealers, with 40 percent solids and active materials dispersed in water that meet the following:

Table 413-1
Physical Properties of Penetrant Sealers

Appearance	White, or light gray color or fugitive dye
VOC content (EPA method 24)	Less than 350 g/l
Flash Point (ASTM 3278)	Greater than 200°F SETA
Resistance to Chloride ion penetration AASHTO T 259 and T 260	Less than 0.52 pounds/yd3(criteria of 1.5) at 1/2 inch level; 0.00 pounds/yd3 (criteria of 0.75) at 1 inch level
Water absorption test (ASTM C642)	0.50% maximum/48 hours; 1.5% maximum/50 days
NCHRP 244	
Series II - cube test	
Water weight gain	85% reduction minimum
Absorbed chloride	87% reduction minimum
Series IV - Southern climate	
Absorbed chloride	95% reduction minimum
Scaling resistance (ASTM C672)	(non - air - entrained concrete) 0 rating "No Scaling" (100 cycles)

413-2.2 Surface Preparation for Penetrant Sealer:

413-2.2.1 General: Prepare concrete surfaces to receive a penetrant sealer in accordance with these Specifications dependent on whether the surfaces are of recently cast concrete (new construction) or of existing concrete.

413-2.2.2 Surface Preparation for New Construction: Remove substances such as dust, grime, dirt, curing compounds, form oil, debris, etc. by water blasting, light sandblasting, wire brushing, or other methods acceptable to the Engineer, all in accordance with the penetrant sealer manufacturer's recommendations. When using cleaning methods other than water blasting, wash the cleaned surfaces with water meeting the requirements of Section 923, as a final cleaning operation.

413-2.2.3 Surface Preparation for Existing Concrete: Remove substances such as dust, grime, dirt, stains, mineral deposits, oil, bituminous materials, debris, and all other

deleterious material by using water blasting equipment of sufficient operating capacity and pressure, all in accordance with the penetrant sealer manufacturer's recommendations.

413-2.2.4 Cleaning Equipment: Use approved water blasting equipment to clean existing concrete surfaces. Use water blasting equipment which is specifically manufactured to clean concrete surfaces. Use equipment that has a minimum rated nozzle capacity of 6,000 psi using the spray head proposed for use in the work.

413-2.2.5 Water for Blasting: Use water meeting the requirements of Section 923.

413-2.2.6 Concrete Surface Cleaning Operation: Exercise sufficient care during the cleaning operation to minimize the removal of the concrete matrix. Furnish hand tools, power grinders, and other similar equipment to remove materials which cannot be removed by water blasting without abrading the concrete matrix beyond acceptable limits. Wash concrete surfaces cleaned by methods other than water blasting with water blasting equipment as the final cleaning operation.

Limit the duration of water blasting to provide a light abraded surface. Do not allow surface abrasion to exceed 0.016 inch. The Engineer will not require further cleaning of stains still apparent after abrading to a depth of 0.016 inch. Avoid exposure of coarse aggregate by water blasting.

Reclean concrete surfaces which become contaminated before applying the penetrant sealer at no expense to the Department prior to applying the penetrant sealer.

413-2.3 Application of Penetrant Sealer Materials: Apply the penetrant sealer only to surfaces which have been prepared in accordance with these Specifications and approved by the Engineer. For application of the penetrant sealer, meet these Specifications and the penetrant sealer manufacturer's recommendations.

Prior to application of any penetrant sealer, cure concrete for a minimum of 21 days.

Apply penetrant sealer no later than ten days after completion of the surface preparation and prior to any contamination of the prepared surfaces as determined by the Engineer.

413-2.3.1 Application Equipment: Apply the penetrant sealer using any suitable air or airless sprayer with an operating pressure of approximately 20 psi.

413-2.3.2 Application Limitations: Apply the penetrant sealer material only when the ambient air temperature is between 50 and 90ºF. Apply the penetrant sealer only to concrete surfaces which have dried a minimum of 48 hours after water from any source last contacted the concrete surfaces. Do not apply the penetrant sealer when winds are blowing 25 mph or more, during rainfall, or when water spray or mist is present.

413-2.3.3 Application: Apply the penetrant sealer only to concrete surfaces that have been prepared in accordance with the requirements and limitations set forth in these Specifications. Determine the actual coverage rate in square feet per gallon on the basis of field trials. Conduct a field trial to determine coverage rate at the beginning of any penetrant sealer application operation. Conduct additional confirmation field trials at a frequency of once for every 5,000 ft^2 applied, each production day of application, or when the character of the work changes, whichever is sooner. For each field trial, determine the optimum coverage rate for 500 ft^2 of surface area. Maintain the penetrant sealer application rate between 155 and 225 ft^2 covered per gallon of penetrant sealer used. Apply the penetrant sealer in a uniform manner

without puddling and skips. Redistribute any penetrant sealer which is applied and subsequently puddles in low areas over the concrete surfaces by use of a squeegee.

Begin the application of the penetrant at the lowest elevation and proceed upward toward higher elevations unless otherwise approved by the Engineer.

Maintain operating pressures in the sprayers used for application of the penetrant sealer material sufficiently low so that atomization or misting of the material does not occur. Saturate cracks to refusal when used as crack sealer per 400-21.

413-2.4 Control of Materials:

413-2.4.1 Packaging and Identification: Deliver the penetrant sealer to the project in unopened, sealed containers with the manufacturer's label identifying the product and with numbered seals intact. Ensure that each container is clearly marked by the manufacturer with the following information:

1. Manufacturer's name and address.
2. Product name.
3. Date of manufacture.
4. Expiration date.
5. LOT identification number.
6. Container serial number.

413-2.4.2 Manufacturer's Certification: Submit to the Engineer a certification conforming to the requirements of Section 6 from the manufacturer, confirming that the penetrant sealer meets the requirements of this Section. Do not incorporate these materials into the project until the Engineer has accepted and approved the certification for the material. Submit such certification for each LOT of material delivered to the project. In each certification, identify the serial or LOT numbers of the containers certified.

413-2.4.3 Materials Sampling for Tests: The Engineer may require samples from each LOT or container of materials delivered to the project or from containers at the point of use. When samples are required, furnish samples in accordance with the Engineer's instructions.

413-2.4.4 Storage of Materials: Store materials delivered to the job site in original unopened containers within an appropriate storage facility. Use a storage facility that provides protection from the elements, and safe and secure storage of the materials.

413-2.4.5 Unused Material in Opened Containers: Do not return unused material in opened containers to storage for later use. Either apply such material to appropriate areas on concrete surfaces or remove and dispose of it at offsite locations provided by the Contractor.

413-2.5 Acceptance: The Engineer will accept penetrant sealer application when it is determined that the Contractor has properly cleaned all surface areas to be sealed and has applied the penetrant sealer within the required rates of application.

413-3 High Molecular Weight Methacrylate (HMWM).

413-3.1 General: Perform the surface preparation and application of a high molecular weight methacrylate to seal cracks on horizontal and slightly sloped concrete surfaces as approved by the Engineer. Applications on bridge decks and other riding surfaces will require the addition of sand over the treated areas to increase the surface friction number (FN) measured as described by AASHTO T242.

The rate of application (ft^2 of concrete per gallon) and the application method and equipment to achieve a minimum average penetration of 1 inch must be approved by the SMO

prior to commencement of work based on the size, depth and the internal condition of cracks. Submit a written sealer application plan based on the above described crack characteristics for approval by the SMO. In addition, provide a minimum of 14 days advanced notice so that personnel from the SMO may be present at the beginning of work to evaluate the cracks and submit final approval of the application rate if such is requested by the Engineer. Make arrangements with the material manufacturer to provide an on-site technical representative with a minimum of ten previous projects with experience in the application and formulation of the methacrylates for the initial application and certify that the mixing ratio, application methods, and sand broadcasting are correct and in accordance with their recommendations. The representative shall then visit the site to provide quality assurance observations every two weeks for applications lasting longer than two weeks.

Maintain a daily log of used resin material to be verified by the Engineer. Include the drum or container identification number in the log as well as the date and location of use. Retain the containers at the jobsite until the Engineer verifies its use and authorizes removal from the site.

413-3.2 Materials: Use a methacrylate system that has a three component formulation consisting of methacrylate monomer, cumene hydroperoxide (CHP) initiator, and cobalt promoter. The methacrylate system cannot contain wax. Use a HMWM system that is approved by the Department and included on the Department's Approved Product List (APL). Manufacturers seeking evaluation of their products must submit an application conforming to the requirements of Section 6 along with the following documentation:

1. Manufacturer's material installation instructions showing the product can be installed in accordance with this Section.

2. Independent laboratory test data and results showing the product has been tested in accordance with the requirements of this Section and meets the requirements.

3. Qualification of their on-site representatives.

413-3.2.1 Properties: Use a methacrylate system that meets the following physical and performance requirements:

Table 413-2 Physical Properties of Methacrylate System	
Density (ASTM D1481)	8.5 - 9.0 lb/gl at 77° F
Flash Point (ASTM D93)	> 200°F (Pensky Martens CC)
Odor	Low
Bulk Cure Speed	3 Hours @ 73°F (max.)
Surface Cure	8 Hours @ 73°F (max.)
Gel Time[(1)]	60 minutes (max.) @ 73.4 ± 1.8°F
Tack Free Time	4-6 Hours (max.) (at 72°F and 50% Relative Humidity
Compressive Strength (ASTM D695)	6,500 psi (min)
Tensile Strength (ASTM D638)	1,300 psi (min)
Shear Bond Adhesion (ASTM C882)	600 psi (min)
Elongation[(2)] (ASTM D638)	Report
Physical Properties of Methacrylate monomer (Part A)	
Viscosity (ASTM D2196, Method A)	14-20 cps using Ultra Low Adapter

1. Use a test method capable of measuring the gel time to the nearest 0.5 minute. 2. Do not use methacrylate with elongation less than 20% for concrete decks supported by steel girders.

The monomer shall have a shelf life of no less than 12 months and shall be no more than 8 months old at the time of application. Provide each container shipped to the job site with the following information on a manufacturer's label: manufacturer's name, product name, LOT or batch number, date of production, and drum serial number. Identify the catalysts by their generic classification and provide the date of manufacture.

413-3.2.2 Sand: Use uniformly graded 6-20 (or similar), clean, bagged, blast sand for spreading over the applied polymer on bridge decks and other riding surfaces. Certify that the sand has a maximum moisture content that does not exceed 0.25% and that the maximum amount of dust or other material that may pass through a No. 200 sieve -200 content) is not greater than 0.75%.

Store the sand at a location that will preserve the above described conditions and characteristics of the sand until applied.

413-3.2.3 Identifier: Use methacrylates with a fluorescent dye when applying methacrylate over previously sealed cracks. The fluorescent dye shall be part of the manufacturer formulation and be clearly fluorescent under a UV light source provided by the Contractor.

413-3.3 Surface Preparation:

413-3.3.1 Cleaning: On the day of application, thoroughly power sweep the area to be treated to remove all dust, dirt or debris present. On bridge decks and other riding surfaces, use a tractor mounted (or similar) power broom with non-metallic bristles suitable for the intended purpose.

Use a power vacuum after sweeping when sealing cracks on grooved bridge decks. Re-clean the deck as necessary immediately prior to the application as debris may be blown back onto the work area by adjacent traffic or other means.

If present, remove oils and oil based substances from the concrete surface using an approved solvent.

413-3.3.2 Containment: Provide adequate containment to prevent the sealer material from flowing beyond the designated area of application. Plug any drain holes or openings within the work area. Prevent airborne material from dispersing onto open traffic lanes or outside the work area.

413-3.3.3 Raised Pavement Markers (RPMs): Protect by masking or clean after application, all existing RPMs affected by the application of the methacrylate. Alternatively, remove and replace such RPMs as indicated in the Contract Documents.

413-3.4 Application:

413-3.4.1 Equipment: Apply the methacrylate material according to the manufacturer's specifications using mobile equipment capable of distributing material on large areas of decks and riding surfaces. Apply the material by hand using adequate containers for isolated or localized applications.

413-3.4.2 Mixing: Mix the methylmethacrylate material following the manufacturer's specified mixing proportions for the catalysts. Perform the initial mixing by equally dividing the resin to be used into two separate containers. In all instances, mix the initiator (CHP) at the HMWM manufacturer's specified volume with 50% of the monomer resin in one container and the cobalt promoter at the HMWM manufacturer's specified volume with the other 50% in the second container. After properly blending, combine the two resins and mix as per manufacturer's instructions. For spray bar application, mix the activator/resin blend and

the promoter/resin blend through a static mixer in the feed line located ahead of the material distribution bars where polymerization would start. Calibrate the valves to the static mixer to ensure a one to one mixing ratio of the two blends.

413-3.4.3 Polymer Application (Mobile Distribution): Distribute the monomer uniformly over the work area using a pressure nozzle or spray head distribution bar system. Provide feed to the distribution bar(s) using positive displacement pumps moving equal amounts of the two monomer blends from two calibrated drums.

Calibrate the equipment to mix the two monomer blends to the recommended ratio (by volume) within plus or minus 5%. The discharge volume shall be calibrated to the moving speed to provide a discharge rate capability ranging from 50 to 200 square feet per gallon at a pressure ranging from 15 to 60 psi.

The typical application rate of the material is approximately 100 square feet per gallon. Prior to application of the monomer, the SMO will approve the final production application rate based on the internal characteristics of the cracks as determined from Contractor supplied cores that the Engineer approves as being representative of the overall cracking conditions.

413-3.4.4 Polymer Application (Localized Distribution): Distribute the material by hand over the work area using pails or other suitable containers adequate for the size of the area. This only applies to localized small areas or areas where the use of mobile distribution equipment would be considered impractical as approved by the Engineer.

Do not re-use containers or mixing paddles fully or partially contaminated with polymerized methacrylate.

413-3.4.5 Sealing of Cracks: Regardless of the method used to apply the material over the concrete surface, work the material back and forth over the cracks to maximize the amount of material to be absorbed by the cracks. Move the material over the cracks using brooms, squeegees or paint brushes as appropriate, based on the size of the area. Commence this operation immediately after distributing the material on the concrete surface. Continue this operation until no additional material is flowing inside the cracks or the material begins to exhibit signs of polymerization.

Do not distribute material over areas larger than what the available personnel can effectively work over the cracks within the limits of the pot life.

413-3.4.6 Sand Distribution: Apply sand over the monomer treated area within a timely period following the application of the polymer based on the manufacturer's recommendations for the existing conditions. Use equipment that will produce a uniform distribution of the sand over the treated area. If wheel mounted, use a sand spreader that has pneumatic tires compatible with the treatment material such that no tire footprints are left on the deck surface.

Use an initial application rate of 1.0 (plus or minus 0.05) pounds of sand per square yard of treated area and adjust the rate as necessary to produce a friction number (FN) of no less than FN40R greater than or equal to 35 at 7 days. If friction numbers below those specified are obtained, completely remove all loose sand from the surface and re-apply the polymer at a rate of 150 square feet per gallon and spread additional sand as necessary to achieve the specified friction numbers. Remove the surface material by grinding, shot blasting, or other approved method if satisfactory friction values are not achieved. Friction tests must be conducted in accordance with AASHTO T242, using the ribbed tire option. Secure the services of an

independent enterprise with prior experience on roadway friction testing with the equipment described to perform the friction tests.

413-3.5 Opening Riding Surfaces to Traffic: Protect the sand covered area from vehicular traffic until the polymer has fully cured. After curing, power vacuum to remove excess sand from the riding surface, before opening to traffic.

413-3.6 Acceptance Tests: Verify penetration of the methacrylate into the cracks by extracting a 2 inch diameter core (1-1/2 inch deep) for every 1,000 square feet or less (if application is less than 1,000 square feet) of sealed concrete. Use caution to prevent cutting the reinforcing steel. Frequency of verification may be reduced by the SMO with the concurrence of the Engineer.

Test curing on the treated area using a cotton strand or cotton ball. Consider the material fully cured and ready for traffic when polymer does not adhere to the cotton ball when pressed against the treated surface and then pulled away. Obtain approval from the Engineer prior to reopening area to traffic.

413-3.7 Limitations: Apply the material only under weather conditions recommended by the manufacturer and when no rainfall has occurred during the previous 48 hours and no rain is expected for the next 6 hours following completion of the application.

413-4 Method of Measurement.

Prestressed, precast items designated in the Plans to be sealed with penetrant sealer, will not be measured for separate payment. The Contractor shall include the cost of cleaning, sealing, and applying penetrant sealer with the cost of the prestressed, precast items. For cast-in-place surfaces to be sealed with penetrant sealer, the quantities to be paid for will be the volume, in gallons, of penetrant sealer as determined by use of the field measured area satisfactorily sealed divided by the approved application rate based on field trials, and the area, in square feet, of cleaning and sealing concrete surfaces as determined by field measurement, completed and accepted.

Quantities of high molecular weight methacrylate to be paid will be based on the volume in gallons of monomer resin material (not including the promoter, initiator, and fluorescent dye) actually used to seal the cracked surfaces at the approved application rate, and the dimensions of the treated areas in square feet.

The area of application will be computed based on the plan dimensions of concrete surface sealed with methacrylate. For localized application, the Engineer will determine the method of measurement that most accurately reflects the area of application in square feet.

413-5 Basis of Payment.

Prices and payments will be full compensation for all work specified in this Section, including cleaning, furnishing and applying the material required to satisfactorily clean and seal cracks and designated surface areas, testing, and miscellaneous related costs including storage, handling, etc.

No additional compensation will be made for material, reapplication or removal due to Contractor error, or to correct deficient friction values.

Payment will be made under:

Item No. 413-149-	Penetrant Sealer - per gallon
Item No. 413-151-	Methacrylate Monomer - per gallon
Item No. 413-154-	Cleaning and Sealing Concrete Surfaces - per square foot

SECTION 415
REINFORCING FOR CONCRETE

415-1 Description.

Furnish and place steel and fiber reinforced polymer (FRP) reinforcing of the quality, type, size, and quantity designated. Obtain all FRP reinforcing bars from a producer on the Department's Production Facility Listing.

415-2 Materials.

Meet the following requirements:

Steel Bar Reinforcement	931-1.1
Steel Welded Wire Reinforcement	931-1.2
FRP Bar Reinforcement	932-3

415-3 Protection of Material.

415-3.1 Steel Reinforcing: Store steel reinforcement above the surface of the ground, upon platforms, skids, or other supports, and protect it from mechanical injury and surface deterioration. Ensure that the steel reinforcement is free from loose rust, scale, dirt, paint, oil, and other foreign material prior to incorporation into the work.

415-3.2 Fiber Reinforcing Polymer (FRP) Reinforcing: Store FRP reinforcement above the surface of the ground, in boxes or upon platforms, skids, or other supports, and protect it from mechanical injury and direct exposure to UV light. Ensure that the FRP reinforcement is free from dirt, paint, oil, and other foreign material prior to incorporation into the work.

415-4 Bending, Splicing, and Cutting.

415-4.1 Steel Reinforcing: Fabricate reinforcing bars as prescribed in the CRSI Manual of Standard Practice. Shop bend the reinforcement cold to the shapes indicated in the Plans. Do not bend the reinforcement to shape in the field. Minor bending adjustments may be performed in the field with the approval of the Engineer.

Do not hot bend or straighten, weld, or thermal cut reinforcing steel.

415-4.2 Fiber Reinforcing Polymer (FRP) Reinforcing: No field fabrication of FRP reinforcing bars is permitted except tying and field cutting per ACI 440.5. Do not bend or straighten, couple, thermal cut, or shear cut FRP reinforcing bars.

415-5 Placing and Fastening.

415-5.1 General: Unless otherwise specified in the Contract Documents, the tolerance for bar spacing is plus or minus 1 inch from the plan position and the tolerance for concrete cover is minus 1/4 inch or plus 1/2 inch from the plan dimensions. Construct all tie patterns referenced by this Section in accordance with the CRSI Manual of Standard Practice.

415-5.2 Concrete Blocks for Spacing: Use precast concrete blocks to space and support the reinforcing bars. Use concrete blocks with a strength equal to or greater than the concrete in which they are to be placed and have wires cast into them for fastening to the reinforcing bars. Moist-cure the blocks for at least three days.

Submit a certification verifying the class of concrete used to fabricate the concrete blocks, and identifying the batch and load of concrete from which the concrete blocks were cast.

415-5.3 Tying:

415-5.3.1 Steel Reinforcing: Tie steel reinforcing using pliable steel wire that readily bends and twists without breaking and that provides a tie of sufficient strength to hold the steel reinforcing in its proper position. Tie stainless reinforcing steel using plastic coated pliable steel wire; or stainless steel wire meeting the requirements of ASTM A276, UNS S31600.

Non-metallic fasteners for steel reinforcing may be used in precast concrete products upon approval by the appropriate District Materials Office (DMO).

415-5.3.2 Fiber Reinforcing Polymer (FRP) Reinforcing: Tie FRP reinforcing using self-locking plastic straps; or plastic coated pliable steel wire that readily bends and twists without breaking and that provides a tie of sufficient strength to hold the FRP reinforcing in its proper position.

415-5.4 Splices: Where splices are authorized, rigidly clamp the bars or tie them in a manner meeting the Engineer's approval. Use the lap splice length as shown on the Plans.

415-5.4.1 Steel Reinforcing: Do not use welded splices for steel reinforcing except as specifically authorized by the Engineer and meeting the requirements of AWS D 1.4 Structural Welding Code - Reinforcing Steel.

Use mechanical couplers or splice devices for steel reinforcing that are listed on the Department's Approved Product List (APL).

415-5.4.2 Fiber Reinforcing Polymer (FRP) Reinforcing: Do not use mechanical couplers for FRP reinforcing. Use lap splices only.

415-5.5 Footings:

415-5.5.1 Supports: Support footing mat reinforcing with concrete blocks having dimensions not greater than 4 by 4 inches by plan clearance. Fasten concrete blocks to the steel using the cast-in wires.

415-5.5.2 Tolerances: Place footing mat reinforcing within 1/2 inch vertically from the plan bottom clearance and within 1 inch from the plan side clearance.

415-5.5.3 Tying: Tie footing mat reinforcing with a double-strand single tie at all intersections on the periphery and at alternate intersections within the mat.

415-5.6 Dowel Bars for Columns and Walls:

415-5.6.1 Supports and Positioning: Position dowel bars projecting into columns and walls so as to allow splicing of the vertical bars to the dowels and to tie the dowel bars in their plan position. Support the dowel bars by a rigid template such that concrete placement does not disturb their position. Support the reinforcing prior to placement of the footing concrete and do not insert dowel bars into the plastic concrete.

415-5.6.2 Tolerances: Place the dowels within 1/2 inch of their plan position and with a side clearance tolerance not exceeding 1/4 inch.

415-5.7 Verticals and Hoops for Columns:

415-5.7.1 Spacing-off from Side Forms: Space column reinforcing bars from the side forms by concrete blocks of dimensions not exceeding 2 inches by 2 inches by clearance dimension. Securely fasten each block to the reinforcing.

415-5.7.2 Tolerances and Clearance:

1. Column Verticals: Place column verticals within 1/2 inch of their plan position. Ensure that the side form clearance is within 1/4 inch of the specified clearance.

2. Column Hoops: Place every hoop within 1 inch of the plan position for the specific hoop, with no accumulation of such tolerance caused by the spacing between any

two hoops. Ensure that side form clearance for any hoop is within 1/2 inch of its specified clearance.

415-5.7.3 Tying: Tie the column hoops to the column verticals at each intersection, by a cross tie or figure 8 tie.

415-5.8 Wall Reinforcing (Not Including Dowel Bars):

415-5.8.1 Supports: Space wall reinforcing bars from the side forms by concrete blocks of dimensions not greater than 2 inches by 2 inches by clearance dimensions. Fix the spacing between wall mats by means satisfactory to the Engineer.

415-5.8.2 Tolerance: Except when necessary to clear a fixture, place reinforcing bars within 1 inch of plan position. Ensure that the number of bars in any affected unit is as specified, and place the remainder of the bars (not thus affected) within 1 inch of plan location.

415-5.8.3 Tying: Tie retaining wall reinforcing bars with a cross tie or figure 8 tie at each intersection on the periphery and at every third intersection within the mat. If workmen use the reinforcing as a ladder, provide additional ties as directed by the Engineer.

Tie noise and perimeter wall reinforcing bars with a single tie at each intersection on the periphery and at every third intersection within the mat.

415-5.9 Beams and Caps:

415-5.9.1 Supports: Maintain bottom clearances by approved heavy beam bolsters. Support additional layers of main longitudinal reinforcing bars from the lower layers by heavy upper-beam bolsters, placed directly over low supports.

Begin the spacing of beam bolsters at not more than 2 feet from the end of the beams or caps and space the additionally required bolsters at not more than 4 feet.

Use concrete blocks, having dimensions not greater than 2 inches by 2 inches by specified clearance, fastened to the reinforcing bars by the cast-in wires, for spacing the upper main longitudinal bars below the top bars. Maintain the side clearance by concrete blocks, having dimensions not greater than 2 inches by 2 inches by required clearance, fastened to the reinforcing bars by the cast-in wires.

415-5.9.2 Tolerances: Place the main longitudinal reinforcing bars so as to provide a bottom and top clearance within 1/4 inch of the plan vertical dimensions for all layers. Space the bars from side forms within 1/2 inch of the specified spacing.

Place stirrups within 1 inch of the plan position for each individual stirrup and do not allow the tolerance to accumulate.

415-5.9.3 Tying: Tie all intersecting bars with a double-strand single tie.

415-5.10 Deck Slabs:

415-5.10.1 Supports:

1. Bottom Mats: Support the bottom mat of reinforcing bars using slab bolsters or concrete blocks. Use one row of slab bolsters placed 6 inches from the edge of the slab and two rows down each deck section between beams. Do not allow the spacing between rows to exceed 4 feet, measured center to center.

Use concrete blocks 2 inches by 2 inches by clearance dimensions. Space concrete blocks 4 feet on center as a maximum.

2. Top Mats: Support the top mats of reinforcing bars by either continuous or individual high chairs. Provide high chairs along both sides of each beam and approximately 6 inches back from the edge of the beam. Place the outside row of high chairs 6 inches from the edge of the slab. If using individual high chairs, do not allow the longitudinal spacing to be greater than 4 feet.

As an alternate to the above, on prestressed beam construction, the Contractor may support the top mat of reinforcing bars on the shear connectors bent to the proper elevation with one line of high chairs centered between the beams.

3. Truss Bars: Support truss bars at each end of the top bends by continuous high chairs or by individual high chairs spaced longitudinally at not more than 4 feet.

415-5.10.2 Tolerances: Ensure that top and bottom clearances are within 1/4 inch from those shown in the Plans.

Ensure that end and bottom clearances are within 1/4 inch from those shown in the Plans.

Ensure that end and edge clearances are within 1/4 inch of the clearance specified.

Place curb bars within 1/4 inch in any direction of the plan position.

415-5.10.3 Tying: Tie all reinforcing bars in each layer with a double-strand single tie at every intersection on the periphery and at every third intersection in the interior area. Alternatively, at the Contractor's option, tie all reinforcing bars in each layer with a single-strand single tie at every intersection on the periphery and at every other intersection within the interior area. Alternatively, at the Contractor's option, if annealed soft-iron wire with uncoated diameter equivalent or greater than 16 gauge (0.062 in.) is used, tie all reinforcing bars in each layer with a single-strand single tie at every intersection on the periphery and at every third intersection in the interior area. If encountering difficulty in maintaining the reinforcing bars in position during the placing of concrete, tie additional intersections as necessary to hold the reinforcing bars secure.

415-5.11 Box Culverts:

415-5.11.1 Supports:

1. Bottom Slabs: In the bottom slabs of box culverts, provide supports for single-mat reinforcing bars and for bottom-mat reinforcing bars, including placement and spacing, as specified for footing mat steel in 415-5.5. In addition, where the Plans call for more than one mat of reinforcing bars in the bottom slab of the culvert, support the top mat away from the bottom mat, either by upper beam bolsters or by other means satisfactory to the Engineer.

2. Walls: Place, space and support the reinforcing bars in walls of box culverts in accordance with the requirements of 415-5.8.

3. Top Slabs: In the top slabs of box culverts, support the bottom mats of reinforcing bars by a row of slab bolsters 12 inches from the inside face of the walls and with additional rows of bolsters at spacings not exceeding 4 feet, center to center. As an exception, unless the Engineer deems the use of the slab bolsters as necessary to obtain proper support, the Contractor may use concrete blocks as the supporting device. Use blocks of dimensions not greater than 2 inches by 2 inches by the required clearance, with spacings not exceeding 4 feet in any direction. Fasten blocks to the reinforcing steel by the cast-in wires.

4. Truss Bars: Support truss bars as specified in 415-5.10.

415-5.11.2 Tolerances: Use tolerances in placing the reinforcing bars in box culvert slabs as specified for deck slabs in 415-5.10. Use tolerances for placing bars in walls as specified in 415-5.8.

415-5.11.3 Tying: Tie reinforcing bars in box culverts as specified for deck slabs in 415-5.10.

415-5.12 Cleaning: Before placing any concrete, clean all mortar from the reinforcement.

415-5.13 Bar Supports:

415-5.13.1 General: Provide reinforcing bar supports manufactured in accordance with all requirements of the CRSI Manual of Standard Practice. Use bar supports of adequate strength to withstand a 300 pound concentrated load without permanent deformation or breakage, with deflection less than 5% of the support height.

Ensure that no more than 5% of the reinforcing bar supports exhibit unsatisfactory performance, breakage, or permanent deformation during bar tying and/or concrete placement operations. If a bar support does not achieve this level of performance, reduce the average spacing between bar supports by 15%, or remove that product from use on the job.

Ensure that bar supports do not move during concrete placing operations. To prevent movement, tie supports to the reinforcing bars.

When using bar supports on corrugated metal stay-in-place forms, use supports specifically designed for the form being used.

For structural elements located in extremely aggressive environments, do not use metal bar supports in contact with removable forms or floor surfaces to support reinforcing bars.

415-5.13.2 Metal Bar Supports: For metal bar supports in contact with removable forms, provide supports constructed with molded plastic legs or plastic protected metal legs or bolster rails. Do not allow any portion of the bar support other than the molded plastic leg or plastic protected portion of the metal leg or bolster rail to be closer than 1/2 inch from the removable form surface for concrete to be cast.

Submit certification verifying that all metal bar supports meet the following requirements:

1. That they are manufactured from cold drawn steel wire in accordance with the wire sizes and geometrical dimensions shown in the CRSI Manual of Standard Practice, Chapter 3.

2. That the plastic used for protection of the steel legs or bolster rails has a thickness of 3/32 inch or greater at points of contact with the form work.

Provide plastic protection by a dipping operation, by adding premolded plastic tips to the legs of the support or by molding plastic to the top wire of the support. Ensure that the plastic material used for protection of steel legs does not chip, crack, deform, or peel during use.

Do not use metal bar supports to support FRP reinforcing bars.

415-5.13.3 Plastic Bar Supports and Spacers: Use non-stackable plastic bar supports and spacers. Bar supports shall be able to meet the concentrated load requirements of 415-5.13 within a working temperature range of 20 to 150°F. Spacers shall be able to provide sufficient strength to support reinforcing steel in the required position without deformation and relaxation under job conditions. For drilled shafts, use wheel spacers with a smooth perimeter surface.

Submit protection from sunlight until placed in the form and mold in a configuration which does not restrict concrete flow and consolidation.

All plastic bar supports and spacers shall have a maximum water absorption of 0.5% at 7 days as per ASTM D570. Plastic bar supports and spacers made of recycled plastic products must meet the additional requirements of Section 972.

Submit to the Engineer independent lab test data and certification verifying that the plastic spacers meet the requirements specified herein.

Use plastic bar supports listed on the Department's APL. Provide each individual bar support with an identification number unique to the particular model permanently marked on the surface as included in the APL. Manufacturers seeking evaluation of products for inclusion on the APL must submit an application in accordance with Section 6 and include certified test reports from an independent laboratory showing that the plastic bar supports meet all the requirements specified herein.

415-6 Welded Deformed Steel Wire Reinforcement.

415-6.1 General: Provide welded deformed steel wire reinforcement as shown in the Plans or as a substitute for deformed bar reinforcement when approved on the shop drawings. Propose substitutions of welded deformed steel wire reinforcement in a manner that provides a cross-sectional area per foot of welded deformed steel wire equal to that provided in the Plans for deformed bar reinforcement. Orient the deformed wires of welded deformed steel wire reinforcement in the same position as bar reinforcement detailed in the Plans. Cross wires of welded deformed steel wire reinforcement may be deformed or smooth and must have a cross-sectional area at least 35% greater than the area of the deformed wire.

415-6.2 Design: When welded deformed steel wire reinforcement is substituted for deformed bar reinforcement, ensure that the development length, splices, shear reinforcement, and distribution meet the requirements of the AASHTO LRFD Bridge Design Specifications.

415-7 Method of Measurement.

415-7.1 Reinforcing Steel: The quantity to be paid for will be the plan quantity, in pounds, of reinforcing steel, stainless reinforcing steel, or low carbon chromium reinforcing steel incorporated into the completed work and accepted, subject to any changes approved by the Engineer. The quantity will not include the reinforcing steel (all types) in any item of work for which the basis of payment already includes the steel reinforcement. No additional payment will be made for substitutions of welded deformed wire reinforcement proposed by the Contractor. No separate payment will be made for reinforcing steel (all types) in pipe endwalls. No deduction will be made from reinforcing steel (all types) quantities for encroachment of inlets and pipes in box culverts. The lengths to be used in the calculation will be the detailed lengths of bars as shown in the Plans.

415-7.2 Unit Weights of Steel Bars: The unit weights used will be CRSI Standard Reinforcing Steel Bar Weights.

415-7.3 Welded Wire Reinforcement: Where welded wire reinforcement is to be paid for by weight, the quantity to be paid for will be the product of the area, in square feet, of the welded wire reinforcement incorporated into the completed work and accepted, multiplied by the manufacturer's standard weight per square foot.

When welded deformed steel wire reinforcement is substituted for deformed bar reinforcement, the quantity to be paid for will be the quantity which would be paid for if bar reinforcement as detailed in the Plans were utilized, based on plan quantity.

415-7.4 Fiber Reinforcing Polymer (FRP) Reinforcing: The quantity to be paid for will be the plan quantity, in linear feet, of bar incorporated into the completed work and accepted, subject to any changes approved by the Engineer. The quantity will not include the FRP bar in any item of work for which the basis of payment already includes the FRP bars. The lengths to be used in the calculation will be the detailed lengths of bars as shown in the Plans.

415-8 Basis of Payment.

Price and payment will be full compensation for all work specified in this Section, including all welding, all clips, spacers, ties, mechanical couplers, etc., and wire or other material used for fastening the reinforcement in place.

If spliced bars are used when full length bars might reasonably be required, the quantity paid for will be only that which would be obtained if full length bars were used, with no allowance for lap.

Payment will be made under:

Item No. 415- 1-	Reinforcing Steel - per pound.
Item No. 415- 2-	Stainless Reinforcing Steel - per pound.
Item No. 415- 3-	Low Carbon Chromium Reinforcing Steel - per pound.
Item No. 415- 10-	Fiber Reinforced Polymer Reinforcing Bar - per linear foot.

SECTION 416
INSTALLATION OF POST-INSTALLED ANCHOR SYSTEMS AND DOWELS FOR STRUCTURAL APPLICATIONS IN CONCRETE ELEMENTS

416-1 Description.

Prepare and install post-installed anchor systems and dowels in hardened concrete as indicated in the Plans, as directed by the Engineer, and in accordance with the manufacturer's instructions and this Section.

Post-installed anchors and dowels in this Section are intended for use in structural applications where designated in the Plans.

416-2 Materials.

416-2.1 Adhesive Bonded Anchors and Dowels: Use adhesive bonding material systems which meet the requirements of Section 937 and are included on the Approved Product List (APL). Use anchors and dowels installed in positions ranging from vertically downward to horizontal.

416-2.1.1 Type HV Adhesives: Use Type HV adhesive bonding materials for all installations other than constructing doweled pile splices. Do not use Type HV adhesives as a substitute for Type HSHV adhesives.

416-2.1.2 Type HSHV Adhesives: Use higher strength Type HSHV adhesive bonding materials for installation of traffic railing reinforcement and anchor bolts into existing concrete bridge decks and approach slabs. Type HSHV adhesives may be used as a substitute for Type HV adhesives provided the length and diameter of the anchor bolt and drilled hole remain as designed for the Type HV adhesive.

416-2.1.3 Storage of Materials: Store materials delivered to the job site in the original unopened containers within an appropriate facility capable of maintaining storage conditions consistent with the manufacturer's recommendations.

416-3 Equipment.

Install adhesive-bonded anchor systems with equipment conforming to the manufacturer's recommendation for the type of system installed.

416-4 Preparing of Concrete Members.

416-4.1 Adhesive-Bonded Anchors and Dowels: Ensure that concrete members receiving adhesive-bonded anchors or dowels are structurally sound and free of cracks in the vicinity of the anchor or dowel to be installed. Unless other equipment is recommended by the adhesive manufacturer, drill holes to the diameter required by the manufacturer, but as a minimum, not less than 105% of the diameter including deformations, nor more than 150% of the nominal diameter of the steel bar anchor or dowel, using a rotary hammer drill and bit.

Use a metal detector specifically designed for locating steel in concrete to avoid conflicts with existing steel reinforcement whenever placement tolerances and edge clearances permit. Perform core drilling through existing steel reinforcement only when approved by the Engineer. Dry the drilled holes completely prior to cleaning and installing the anchors or dowels.

Clean and prepare drilled holes in accordance with the manufacturer's recommendations, but as a minimum, use oil free compressed air to remove loose particles from drilling, brush inside surface to free loose particles trapped in pores, then use compressed air

again to remove the remaining loose particles. Use a non-metallic bristle brush and avoid over-brushing to prevent polishing the inside surface of the drilled hole.

416-5 Installation Methods.

416-5.1 Adhesive-Bonded Anchors and Dowels: Remove all debris, oils, and any other deleterious material from the anchors and dowels to avoid contamination of the adhesive bonding material. Install anchors or dowels in accordance with the details shown in the Plans and the manufacturer's instructions, with particular attention to requirements and limitations due to anchor position, dampness, ambient temperature, and curing.

Use adequate quantities of the adhesive bonding material to fill the drilled hole to within 1/4 inch of the concrete surface measured after placement of the steel bar or anchor. For horizontal and downwardly inclined installations, provide temporary supports to maintain the anchors or dowels in the center of the drilled holes until the adhesive bonding material has cured.

416-6 Field Testing of Post-Installed Anchor Systems and Dowels.

416-6.1 General: Provide an independent testing agency to perform field testing of post-installed anchors or dowels under the direction of a Professional Engineer registered in the State of Florida. Submit test reports for each LOT signed and sealed by the Professional Engineer. Perform restrained static tension tests to prevent damage to the surrounding concrete. A restrained test is defined as a test conducted in accordance with ASTM E488 except that the test equipment support clearance requirements of ASTM E488 do not apply. The opening in the reaction base shall be approximately equal to the drilled hole diameter for the anchor to preclude concrete or masonry failure, but allow bond failure for the adhesive-bonded anchors and dowels. Displacement measurement for field testing is not required.

Divide the post-installed anchors or dowels into LOTs for testing and acceptance. Each LOT must contain a maximum of 100 anchors or dowels, of the same type, manufacturer, diameter, embedment length and adhesive bonding material system (if applicable) installed on the same day. Randomly select four of the anchors or dowels in each LOT for testing, except if there are three or less in the LOT, in which case, test all anchors or dowels, unless otherwise directed by the Engineer. If three consecutive LOTs have no failing tests, sample the next three LOTs at a 2% rate, rounded up to the nearest whole number, and if these LOTs have no failing tests, sample at a rate of 1%, rounded up to the nearest whole number, for the remaining LOTs unless there is a failure; however, regardless of LOT size, sample at least one anchor or dowel per LOT. For every failed field test, perform two additional field tests on adjacent untested anchors or dowels within the LOT. Continue additional field tests until no more test failures occur, or all anchors or dowels within the LOT are tested. For the next LOT after a failed LOT, randomly select four of the anchors or dowels in each LOT for testing, except if there are three or less in the LOT, test all anchors or dowels unless otherwise directed by the Engineer then conform to the sampling rate procedure above including rate reductions as appropriate for subsequent LOTs.

416-6.1.1 Adhesive-Bonded Anchors: Field test installed anchors and dowels for applications connecting traffic railings to bridge decks, approach slabs and concrete pavement using Type HSHV adhesives. The Engineer may also require field testing of installed anchors and dowels for other applications. Any field testing of installed anchors which is required by the Engineer and not quantified in the Contract Documents shall be paid for by the Department unless a failure occurs during the field testing.

Test individual anchors and dowels by proof loading in tension to 85% of the specified bond strength in accordance with Section 937 based on the nominal anchor or dowel diameter and embedment depth, but not more than 90% of the yield strength of the anchor or dowel, unless otherwise shown in the Contract Documents.

416-6.2 Removal & Replacement of Failed Test Specimens: Remove all anchors and dowels that fail the field test, in accordance with the manufacturer's recommendation and without damage to the surrounding concrete. For adhesive-bonded anchors, redrill holes to remove adhesive bonding material residue and clean in accordance with 416-4. Reinstall new anchors and dowels in accordance with 416-5. Do not reuse the failed anchors and dowels unless approved by the Engineer. Assign reinstalled anchors into new LOTs only containing reinstalled anchors or dowels of the same diameter, embedment length and adhesive bonding material system, and field test in accordance with 416-6.

416-7 Acceptance.

The Engineer will base acceptance of post-installed anchor systems on determining that the material requirements of Section 937, the installation and testing requirements of this Section and the placement requirements of the Plans have been met.

416-8 Basis of Payment.

The work specified in this Section will not be paid for directly, but will be considered as incidental work.

SECTION 425
INLETS, MANHOLES, AND JUNCTION BOXES

425-1 Description.

Construct inlets, manholes, and junction boxes from reinforced concrete as shown in the Standard Plans and the Plans. Furnish and install the necessary metal frames and gratings. Construct yard drains from concrete meeting the requirements of Section 347. Adjust structures shown in the Plans to be adjusted or requiring adjustment for the satisfactory completion of the work.

For precast structures, meet the requirements in 449-1.

425-2 Composition and Proportioning.

425-2.1 Concrete: For inlets, manholes, and junction boxes, use Class II or IV concrete, as designated in the Plans and Standard Plans and as specified in Section 346. For concrete aprons and yard drains, use concrete as specified in Section 347.

425-2.2 Mortar: For brick masonry, make the mortar by mixing one-part cement to three parts sand. Miami Oolitic rock screenings may be substituted for the sand, provided the screenings meet the requirements of 902 except for gradation requirements. Use materials passing the No. 8 sieve that are well graded from coarse to fine. Submit documentation, from a Department approved mine or a Department approved concrete plant, confirming the sand or sand substitute meets the requirements of 902-3.2.

Preblended masonry cement mortar may be used in lieu of the above-specified mortar. Deliver the product in original and unopened packages properly identified by brand name of manufacturer, net weight of package, and type. Store the material in full compliance with the manufacturer's recommendations. Material must be used within manufacturer's recommended shelf life.

425-3 Materials.

425-3.1 General: Meet the following requirements:

Sand (for mortar).....Section 902
Portland Cement.....Section 921
Water.....Section 923
Reinforcing Steel ..... Sections 931 and 415
Liner Repair Systems.....Section 948
Brick and Concrete Masonry Units.....Section 949
Castings for Frames and Gratings.....Section 962
Masonry Cement, Type M or S.....ASTM C91
Preblended Dry Masonry Cement Mortar, Type M or S .....
.....ASTM C1714

425-3.2 Gratings, Covers, and Frames: Use gratings and frames fabricated from structural steel or cast iron as designated in the appropriate Standard Plans Index. When "Alt. G" grates are specified in the Plans, provide structural steel grates that are galvanized in accordance with the requirements of ASTM A123 and hardware galvanized in accordance with the requirements of ASTM A153.

Use rigid frames and covers either 24 inches or 36 inches or optional three-piece adjustable frames and covers as indicated in Standard Plans, Index 425-001.

For three-piece adjustable frames, the inner frame may include replaceable resilient seats to support the cover. In addition, the inner frame shall indicate it is adjustable, by clearly having the word “adjustable” imprinted into the exposed portion of the inner frame so “adjustable” is visible from the roadway after installation.

425-3.3 Skimmer: Include 1.5% by weight of carbon black with plastic skimmers on french drain systems.

425-4 Forms.

Design and construct wood or metal forms so that they may be removed without damaging the concrete. Build forms true to line and grade and brace them in a substantial and unyielding manner. Obtain the Engineer’s approval before filling them with concrete.

425-5 Precast Inlets, Manholes, and Junction Boxes.

Precast inlets, manholes, and junction boxes, designed and fabricated in accordance with the Plans, the Standard Plans and Section 449 may be substituted for cast-in-place units.

425-6 Skimmers.

Furnish and install skimmers in accordance with the Plans and Standard Plans.

425-7 Construction Methods.

425-7.1 Excavation: Excavate as specified in Section 125.

Where unsuitable material for foundations is encountered, excavate the unsuitable material and backfill with suitable material prior to constructing or setting inlets, manholes and junction boxes.

As an option to the above and with the Engineer’s approval, the Contractor may carry the walls down to a depth required for a satisfactory foundation, backfill to 8 inches below the flowline with clean sand and cast a non-reinforced 8 inch floor.

425-7.2 Placing and Curing Concrete: Place the concrete in the forms, to the depth shown in the Plans, and thoroughly vibrate it. After the concrete has hardened sufficiently, cover it with suitable material and keep it moist for a period of three days. Finish the traffic surface in accordance with 522-7.2, or with a simulated broom finish approved by the Engineer.

425-7.3 Setting Manhole Castings: After curing the concrete as specified above, set the frame of the casting in a full mortar bed composed of one-part portland cement to two parts of fine aggregate.

425-7.3.1 Standard Castings: Set manhole frames in a mortar bed and adjust to grade using brick or concrete grade rings, with a maximum 12 inch adjustment.

425-7.3.2 Optional Adjustable Castings: When using a three-piece adjustable frame and cover, install the frame and cover with brick or concrete grade rings to the base course height. Make adjustments using the inner frame in accordance with the manufacturer’s installation recommendations so the inner frame and cover meet the grade and slope of the pavement surface opened to traffic.

425-7.4 Reinforcing Steel: Follow the construction methods for the steel reinforcement as specified in Section 415.

425-7.5 Laying Brick: Brick masonry may be used if the structure is circular and constructed in place, or for adjustments of rectangular risers up to a maximum 12 inches in

height. Saturate all brick with water before laying. Bond the brick thoroughly into the mortar using the shove-joint method to lay the brick. Arrange headers and stretchers so as to bond the mass thoroughly. Finish the joints properly as the work progresses and ensure that they are not less than 1/4 inch or more than 3/4 inch in thickness. Do not use spalls or bats except for shaping around irregular openings or when unavoidable at corners.

425-7.6 Backfilling: Backfill as specified in Section 125, meeting the specific requirements for backfilling and compaction around inlets, manholes, and junction boxes detailed in 125-8.1 and 125-8.2. However; for outfall lines beyond the sidewalk or future sidewalk area, where no vehicular traffic will pass over the pipe, inlets, manholes, and junction boxes, compact backfill as required in 125-9.2.2.

425-7.7 Adjusting Structures: Adjust existing manholes, catch basins, inlets, valve boxes, etc., within the limits of the proposed work, to meet the finished grade of the proposed pavement, or if outside of the proposed pavement area, to the finished grade designated in the Plans for such structures. Adjust structures prior to placement of final asphalt pavement surface layer. Adjust structures to match final pavement surface cross-slope. Use materials and construction methods which meet the requirements specified above to adjust the existing structures.

The Contractor may extend manholes needing to be raised using adjustable extension rings of the type which do not require the removal of the existing manhole frame. Use an extension device that provides positive locking action and permits adjustment in height as well as diameter and meets the approval of the Engineer. When adjusting structures in flexible pavement, restore final road surface in accordance with Standard Plans, Index 125-001.

425-8 Method of Measurement.

The quantities to be paid for will be the number of inlets, manholes, junction boxes, and yard drains, completed and accepted; and the number of structures of these types (including also valve boxes) satisfactorily adjusted. Performance Turf will be paid in accordance with Section 570.

425-9 Basis of Payment.

425-9.1 New Structures: Price and payment will be full compensation for furnishing all materials and completing all work described herein or shown in the Plans, including all clearing and grubbing outside the limits of clearing and grubbing as shown in the Plans, all excavation except the volume included in the measurement designated to be paid for under the items for the grading work on the project, all backfilling around the structures, the disposal of surplus material, and the furnishing and placing of all aprons, gratings, frames, covers, and any other necessary fittings.

425-9.2 Adjusted Structures: When an item of payment for adjusting manholes, valve boxes, or inlets is provided in the proposal, price and payment will be full compensation for the number of such structures designated to be paid for under such separate items, and which are satisfactorily adjusted, at the Contract unit prices each for adjusting inlets, adjusting manholes, and adjusting valve boxes.

For any of such types of these structures required to be adjusted but for which no separate item of payment is shown in the proposal for the specific type, payment will be made under the item of adjusting miscellaneous structures.

425-9.3 Payment Items: Payment will be made under:

Item No.425- 1-	Inlets - each.
Item No.425- 2-	Manholes - each.
Item No.425- 3-	Junction Boxes - each.
Item No.425- 4-	Adjusting Inlets - each.
Item No.425- 5-	Adjusting Manholes - each.
Item No.425- 6-	Adjusting Valve Boxes - each.
Item No.425- 8-	Adjusting Miscellaneous Structures - each.
Item No.425- 10-	Yard Drains - each.
Item No. 425- 17-	Back of Sidewalk Endwall - each.

SECTION 430
PIPE CULVERTS

430-1 Description.

Furnish and install drainage pipe and end sections at the locations called for in the Plans. Furnish and construct joints and connections to existing pipes, catch basins, inlets, manholes, walls, etc., as may be required to complete the work.

Obtain pipe culverts and drainage products from a plant that is currently on the Department's Production Facility Listing. Producers seeking inclusion on the list shall meet the requirements of Section 105.

At the beginning of each project, submit a notarized certification statement to the Engineer in accordance with Section 6. The Quality Control Manager's stamp or label on each product indicates certification that the product was fabricated in conformance with the Producer QC Plan, the Contract, and this Section. Ensure that each shipment of drainage products to the project site is accompanied with a QC signed or stamped delivery ticket providing the description and the list of the products.

When the Producer Quality Control Program is suspended by the Department, accept responsibility of either obtaining products from a plant with an approved Quality Control Program, or await re-approval of the plant. The Engineer will not allow changes in Contract Time or completion dates as a result of the plant's loss of qualification. Accept responsibility for all delay costs or other costs associated with the loss of the plant's qualification.

Construct structural plate pipe culverts or underdrains in accordance with Sections 435 and 440.

For pipe culverts installed by jack & bore, install in accordance with Section 556.

430-2 Materials.

430-2.1 Pipe: Meet the following requirements:

Concrete Pipe	Section 449
Steel Pipe	556-2.1
Round Rubber Gaskets	Section 942
Resilient Connectors*	Section 942
Corrugated Steel Pipe and Pipe Arch	Section 943
Corrugated Aluminum Pipe and Pipe Arch	Section 945
Corrugated Polyethylene Pipe	Section 948
Steel Reinforced Polyethylene Ribbed Pipe	Section 948
Steel Reinforced Polyethylene Corrugated Pipe	Section 948
Corrugated Polypropylene Pipe	Section 948
Corrugated Polyvinyl Chloride (PVC) Pipe	Section 948
Fiberglass Reinforced Polymer Pipe	Section 948
Metal Grates	Section 962
Pipe Sleeve Adapters	Section 948

*Use resilient connector products listed on the Department's Approved Product List (APL).

430-2.2 Joint Materials: Use joint materials specified in 430-7 through 430-9 according to type of pipe and conditions of usage.

430-2.3 Mortar: Use mortar composed of one part Portland cement and two parts of clean, sharp sand, to which mixture the Contractor may add hydrated lime in an amount not to exceed 15% of the cement content. Use mortar within 30 minutes after its preparation.

430-2.4 End Treatments: Meet the requirements of Section 425-3.1. For precast end treatments, meet the requirements in 449-1. Use the concrete Class designated in the Plans and Standard Plans, and as specified in Section 346 and 347.

430-2.5 Grates: Use metal gratings that meet the requirements of 962-8.

430-2.6 Filter Fabric: Use a Type D-3 filter fabric meeting the requirements specified in Section 985, and listed on the Department's Approved Product List (APL).

430-3 Type of Pipe to be Used.

430-3.1 General: Prior to the preconstruction conference, submit to the Engineer which optional pipe material from the optional materials tabulation sheet will be used. Once a pipe material is selected, do not change pipe materials without approval of the Engineer.

When the Plans designate a type (or types) of pipe, use only the type (or choose from the types) designated. As an exception, when the Plans designate reinforced concrete pipe as Class S, Class I, Class II, Class III and Class IV, the Contractor may use non-reinforced concrete pipe up to and including 36 inch in diameter.

430-3.2 Side Drain: If the Plans do not designate a type (or types) of pipe, the Contractor may use either a minimum Class I concrete pipe, corrugated steel pipe, corrugated aluminum pipe, corrugated high-density polyethylene pipe, steel reinforced polyethylene ribbed pipe, polypropylene pipe, or PVC pipe. If one of the metal types is chosen, use the minimum gage specified in Section 943 for steel pipe or Section 945 for aluminum pipe. Alternatively, when metal pipe is allowed and no future maintenance concerns exist, the Contractor may propose the pipe gage based on the Department's Drainage Manual and Culvert Service Life Estimator for approval by the Engineer. When extending existing pipes, construct the pipe extensions of the same size and kind as the existing pipe. Extensions of existing pipes, whose materials are no longer produced, shall be extended with the most similar pipe material available.

Non-reinforced concrete pipe may also be substituted for concrete pipe in side drains, subject to the provisions of 430-3.1.

430-4 Laying Pipe.

430-4.1 General: Lay all pipe, true to the lines and grades given, with bells upgrade and spigot end fully entered into the bell. When pipe with quadrant reinforcement or circular pipe with elliptical reinforcement is used, install the pipe in a position such that the manufacturer's marks designating "top" and "bottom" of the pipe are not more than five degrees from the vertical plane through the longitudinal axis of the pipe. Do not allow departure from and return to plan alignment and grade to exceed 1/16 inch per foot of nominal pipe length, with a total of not more than 1 inch departure from theoretical line and grade. Take up and relay any pipe that is not in true alignment or which shows any settlement after laying at no additional expense to the Department.

Do not use concrete pipe with lift holes except round pipe which has an inside diameter in excess of 54 inches or any elliptical pipe.

Repair lift holes, if present, with hand-placed, stiff, non-shrink, 1-to-1 mortar of cement and fine sand, after first washing out the hole with water. Completely fill the void created by the lift hole with mortar. Cover the repaired area with a 24 inch by 24 inch piece of filter fabric secured to the pipe.

Follow the manufacturer's instructions, to secure the filter fabric to the pipe, until the backfill is placed and compacted.

Do not cut or drill into or through the corrugations or ribs of plastic pipe except when necessary to meet the dimensional requirements shown in the Plans.

When installing pipes in structures, construct inlet and outlet pipes of the same size and kind as the connecting pipe shown in the Plans. Use the same pipe material within each continuous run of pipe. Extend the pipes through the walls for a distance beyond the outside surface sufficient for the intended connections, and construct the concrete around them neatly to prevent leakage along their outer surface as shown on Standard Plans, Index 425-001. Keep the inlet and outlet pipes flush with the inside of the wall. Resilient connectors as specified in 942-3 may be used in lieu of a masonry seal.

Furnish and install a filter fabric jacket around all pipe joints and the joint between the pipe and the structure in accordance with Standard Plans, Indexes 425-001 and 430-001. Use fabric meeting the physical requirements of Type D-3 specified in Section 985. Extend the fabric a minimum of 12 inches beyond each side of the joint or both edges of the coupling band, if a coupling band is used. The fabric must have a minimum width of 24 inches, and a length sufficient to provide a minimum overlap of 24 inches. Secure the filter fabric jacket against the outside of the pipe by metal or plastic strapping or by other methods approved by the Engineer.

Meet the following minimum joint standards:

Table 430-1	
Pipe Application	Minimum Standard
Storm and Cross Drains	Water-tight
Gutter Drain	Water-tight
Side Drains	Soil-tight

When rubber gaskets are to be installed in the pipe joint, the gasket must be the sole element relied on to maintain a tight joint. Soil tight joints must be watertight to 2 psi. Water-tight joints must be water-tight to 5 psi unless a higher pressure rating is required in the Plans.

When laying pipes that pass through mechanically stabilized earth (MSE) reinforced fill, connect the portion of the pipe within the wall to the external portion of the pipe run only after the full height of the wall supported embankment is in place.

When Wall Zone Pipes are shown in the Plans, meet the following requirements:

1. Use resilient connectors on pipes entering and leaving drainage structures.

2. Provide a 2 to 4 inch pipe overhang beyond the drainage structure internal walls.

3. For pipes without welded joints, meet the following additional requirements:

a. Pipe joints must be watertight to 10.8 psi when pulled out 2 inches from the fully homed position in both straight alignment and 5% deflection.

b. Do not allow the gap between sections of pipe to exceed 5/8 inch for all pipe diameters.

430-4.2 Trench Excavation: Excavate the trench for storm and cross drains, and side drains as specified in Section 125.

430-4.3 Foundation: Provide a suitable foundation, where the foundation material is of inadequate supporting value, as determined by the Engineer. Remove the unsuitable material and replace it with suitable material, as specified in 125-8. Where in the Engineer's opinion, the removal and replacement of unsuitable material is not practicable, he may direct alternates in the design of the pipeline, as required to provide adequate support. Minor changes in the grade or alignment will not be considered as an adequate basis for extra compensation.

Do not lay pipe on blocks or timbers, or on other unyielding material, except where the use of such devices is called for in the Plans.

430-4.4 Backfilling: Backfill around the pipe as specified in 125-8 unless specific backfilling procedures are described in the Contract Documents.

430-4.5 Plugging Pipe: When existing pipe culverts are to be permanently placed out of service, fill them with flowable fill that is non-excavatable, contains a minimum 350 pounds per cubic yard of cementitious material and meets the requirements of Section 121 and/or plug them with masonry plugs as shown in the Plans. Install masonry plugs that are a minimum of 8 inches in thickness, in accordance with Standard Plans, Index 430-001.

When proposed or existing pipe culverts are to be temporarily placed out of service, plug them with prefabricated plugs as shown in the Plans. Install prefabricated plugs in accordance with the manufacturer's recommendations. Do not fill or construct masonry plugs in any pipe culvert intended for current or future service.

430-4.6 End Treatment: Place an end treatment at each storm and cross drain, and side drain as shown in the Plans. Sod around end treatments in accordance with Standard Plans, Index 570-001.

430-4.6.1 U-Type Concrete Endwalls: Construct in accordance with the Plans and Standards Plans, Indexes 430-010 through 430-012 and Index 430-090.

430-4.6.2 Flared End Sections: Construct in accordance with the Plans and Standard Plans, Index 430-020. Use precast flared end sections only.

430-4.6.3 Mitered End Sections: Construct in accordance with the Plans and Standard Plans, Indexes 430-021 and 430-022. Construct mitered end sections for corrugated high-density polyethylene (HDPE) pipe, polypropylene (PP) pipe, steel reinforced polyethylene ribbed (SRPE) pipe and polyvinyl-chloride (PVC) pipe as specified in Section 948 and as detailed in the Standard Plans.

430-4.6.4 Straight and Winged Concrete Endwalls: Construct in accordance with the Plans and Standard Plans, Indexes 430-030 through 430-040.

Provide end treatments for corrugated polyethylene pipe, polypropylene pipe, and PVC pipe as specified in Section 948, or as detailed in the Plans.

430-4.7 Metal Pipe Protection: Apply a bituminous coating to the surface area of the pipe within and 12 inches beyond the concrete or mortar seal prior to sealing, to protect corrugated steel or aluminum pipe embedded in a concrete structure, such as an inlet, manhole, junction box, endwall, or concrete jacket.

Ensure that the surface preparation, application methods (dry film thickness and conditions during application), and equipment used are in accordance with the coating manufacturers' published specifications.

Obtain the Engineer's approval of the coating products used.

430-4.8 Pipe Inspection: For pipes installed under the roadway, inspection is to be conducted when backfill reaches 3 feet above the pipe crown or upon completion of the stabilized subgrade. For pipe installed within fills, including embankments confined by walls, inspection is to be conducted when compacted embankment reaches 3 feet above the pipe crown or the finished earthwork grade as specified in the Plans. Prior to conducting the inspection, submit to the Engineer an inspection schedule for dewatering the installed pipe, and the removal of all silt, debris, and obstructions. Submit pipe inspection videos and reports to the Department for review prior to the continuation of paving.

For pipe 48 inches or less in diameter, submit to the Engineer the video files and reports using low barrel distortion video equipment with laser profile technology, non-contact video micrometer and associated software. For all pipe types, provide a Pipe Observation Summary Report for each pipe run that shall include:

1. Actual recorded length and width measurements of all cracks within the pipe.
2. Actual recorded separation measurement of all rigid pipe joints.
3. Detailed written observations of leaks, debris, or other damage or defects.

For flexible pipe types, submit a Pipe Ovality Report for each pipe run that includes:

1. Representative diameter of the pipe.
2. Pipe deformation/deflections measurements with the 5% deflection limit clearly delineated.

Laser profiling and measurement technology must be certified by the company performing the work to be in compliance with the calibration criteria posted at: https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/construction/engineers/environmental/laser-profiling-calibration-criteria.pdf. Reports submitted in electronic media are preferred.

For pipe larger than 48 inches, submit to the Engineer a detailed visual inspection summary report for each pipe run, including photos, locations and details of deficient cracks, joint separations, infiltration, and damage.

The Engineer may waive this requirement for side drains and cross drains which are short enough to inspect from each end of the pipe.

430-4.8.1 Video Report: Provide video files via digital media (DVD, flash drive, or other) or by online digital distribution with a minimum standard resolution of 720 x 480. Use a camera with lighting suitable to allow a clear picture of the entire periphery of the pipe. Center the camera in the pipe both vertically and horizontally and be able to pan and tilt to a 90-degree angle with the axis of the pipe and rotating 360 degrees. Use equipment to move the camera through the pipe that will not obstruct the camera's view or interfere with proper documentation of the pipe's condition.

The video image shall be clear, focused, and relatively free from roll, static, or other image distortion qualities that would prevent the reviewer from evaluating the condition of the pipe. The video will include identification before each section of pipe filmed. The identification will include the project number, the structure number corresponding to the structure number in the Plans for the project, size of pipe, the date and time, and indicate which pipe is being filmed if multiple pipes are connected to the structure. Notes should be taken during the video recording process. Submit these notes along with the video.

Move the camera through the pipe at a speed not greater than 30 feet per minute. Mark the video with the distance down the pipe. The distance shall have an accuracy of one foot per 100 feet. Film the entire circumference at each joint. Stop the camera and pan when necessary to document and measure defects. Position the camera head perpendicular to all defects requiring measurement by the video micrometer.

430-4.8.2 Reinspection: At any time after reviewing the submitted pipe inspection reports, the Engineer may direct additional inspections. If no defects are observed during the reinspection, the Department will pay for the cost of the reinspections in accordance with 4-3. If defects are observed, the reinspection and all work performed to correct the defects will be done at no cost to the Department. Acceptance of all replacements or repairs will be based on video documentation of the completed work prior to Final Acceptance.

430-5 Removing Existing Pipe.

If the Plans indicate that existing pipe is to remain the property of the Department, collect and stack along the right-of-way all existing pipe or pipe arch so indicated in the Plans to be removed, or that does not conform to the lines and grades of the proposed work and that is not to be re-laid, as directed by the Engineer. Take care to prevent damage to salvageable pipe during removal and stacking operations.

430-6 Placing Pipe Under Railroad.

430-6.1 General: Construct pipe culverts under railroad tracks in accordance with the requirements of the railroad company.

Perform all the shoring under the tracks, and sheeting and bracing of the trench, required by the railroad company or deemed necessary by the Engineer in order to ensure safe and uninterrupted movement of the railroad equipment, at no expense to the Department.

430-6.2 Requirements of the Railroad Company: Install pipe using methods required by the railroad company and shown in the Contract Documents.

When the general method of installation required by the railroad company is indicated in the Plans, do not alter such method, or any other specific details of the installation which might be indicated in the Plans, without receiving approval or direction from the railroad, followed by written approval from the Engineer.

430-6.3 Notification to Railroad Company: Notify the railroad company and the Engineer at least ten days prior to the date on which pipe is to be placed under the railroad tracks.

430-6.4 Placing Pipe by Jacking: Obtain the Engineer's and the railroad company's approval of the details of the jacking method to be used, when placing pipe through the railroad embankment, before the work is started.

430-6.5 Use of Tunnel Liner: When the railroad company requires that a tunnel liner be used for placing the pipe in lieu of the jacking method, the Department will pay for the tunnel liner material separately in cases where the Contract Documents do not require the use of a tunnel liner. For these cases the Department will reimburse the Contractor for the actual cost of the liner, delivered at the site. The Department will base such cost on a liner having the minimum gage acceptable to the railroad.

430-7 Specific Requirements for Concrete Pipe.

430-7.1 Sealing Joints: Seal the pipe joints with round rubber or profile gaskets meeting the requirements of Section 449. Ensure that the gasket and the surface of the pipe joint, including the gasket recess, are clean and free from grit, dirt, and other foreign matter, at the time

the joints are made. In order to facilitate closure of the joint, application of a vegetable soap lubricant immediately before closing of the joint will be permitted. Prelubricated gaskets may be used in lieu of a vegetable soap lubricant when the lubricating material is certified to be inert with respect to the rubber material.

430-7.2 Laying Requirements for Concrete Pipe with Rubber Gasket Joints: Do not allow the gap between sections of pipe to exceed 5/8 inch for pipe diameters of 12 inches through 18 inches, 7/8 inch for pipe diameters of 24 through 66 inches, and 1 inch for pipe diameters 72 inches and larger. Where minor imperfections in the manufacture of the pipe create an apparent gap in excess of the tabulated gap, the Engineer will accept the joint provided that the imperfection does not exceed 1/3 the circumference of the pipe, and the rubber gasket is 1/4 inch or more past the pipe joint entrance taper. Where concrete pipes are outside of these tolerances, replace them at no expense to the Department. Do not apply mortar, joint compound, or other filler to the gap which would restrict the flexibility of the joint.

430-7.3 Field Joints for Elliptical Concrete Pipe: Use either a preformed plastic gasket material or an approved rubber gasket to make a field joint.

430-7.3.1 Plastic Gasket: Meet the following requirements when field joints are made from preformed plastic gasket material:

430-7.3.1.1 General: Install field joints in accordance with the manufacturer's instructions and the following:

430-7.3.1.2 Material: Meet the requirements of 942-2.

430-7.3.1.3 Joint Design: Ensure that the pipe manufacturer submits details to the Engineer regarding configuration of the joint and the amount of gasket material required to affect a satisfactory seal. Do not brush or wipe joint surfaces which are to be in contact with the gasket material with a cement slurry. Fill minor voids with cement slurry.

430-7.3.1.4 Primer: Apply a primer of the type recommended by the manufacturer of the gasket material to all joint surfaces which are to be in contact with the gasket material, prior to application of the gasket material. Thoroughly clean and dry the surface to be primed.

430-7.3.1.5 Application of Gasket: Apply gasket material to form a continuous gasket around the entire circumference of the leading edge of the tongue and the groove joint, in accordance with the detail shown on Standard Plans, Index 430-001. Do not remove the paper wrapper on the exterior surface of the gasket material until immediately prior to joining of sections. Apply plastic gasket material only to surfaces which are dry. When the atmospheric temperature is below 60ºF, either store plastic joint seal gaskets in an area above 70ºF, or artificially warm the gaskets to 70ºF in a manner satisfactory to the Engineer.

430-7.3.1.6 Installation of Pipe: Remove and reposition or replace any displaced or contaminated gasket as directed by the Engineer. Install the pipe in a dry trench. Carefully shape the bottom of the trench to minimize the need for realignment of sections of pipe after they are placed in the trench. Hold to a minimum any realignment of a joint after the gaskets come into contact. Prior to joining the pipes, fill the entire joint with gasket material and ensure that when the pipes are joined there is evidence of squeeze-out of gasket material for the entire internal and external circumference of the joint. Trim excess material on the interior of the pipe to provide a smooth interior surface. If a joint is defective, remove the leading section of pipe and reseal the joint.

430-7.3.2 Rubber Gasket: Meet the following requirements when field joints are made with profile rubber gaskets:

430-7.3.2.1 General: Install field joints in accordance with the manufacturer's instructions and the following:

430-7.3.2.2 Material: Meet the requirements of 942-4.

430-7.3.2.3 Joint Design: Ensure that the pipe manufacturer submits details to the Engineer regarding configuration of the joint and gasket required to effect a satisfactory seal. Do not apply mortar, joint compound, or other filler which would restrict the flexibility of the gasket joint.

430-7.4 Requirements for Concrete Radius Pipe:

430-7.4.1 Design: Construct concrete radius pipe in segments not longer than 4 feet (along the pipe centerline), except where another length is called for in the Contract Documents. Join each segment using round rubber gaskets. Ensure that the pipe manufacturer submits details of the proposed joint, segment length and shape for approval by the Engineer, prior to manufacture.

430-7.4.2 Pre-Assembly: Ensure that the manufacturer pre-assembles the entire radius section in his yard, in the presence of the Engineer, to ensure a proper fit for all parts. At the option of the manufacturer, the Contractor may assemble the pipe without gaskets. Consecutively number the joints on both the interior and exterior surfaces of each joint, and make match marks showing proper position of joints. Install the pipe at the project site in the same order as pre-assembly.

430-8 Specific Requirements for Corrugated Metal Pipe.

430-8.1 Field Joints:

430-8.1.1 General: Make a field joint with locking bands, as specified in Article 9 of AASHTO M36 and AASHTO M196M for aluminum pipe. For aluminum pipe, fabricate bands from the same alloy as the culvert sheeting.

When existing pipe to be extended is helically fabricated, make a field joint between the existing pipe and the new pipe using one of the following methods:

1. Cut the new pipe to remove one of the re-rolled annular end sections required in Sections 943 or 945, or fabricate the pipe so that the re-rolled annular section is fabricated only on one end. Use either a spiral (helical) band with a gasket or a flat band with gaskets as required by 430-8.1.2 (2) to join the pipe sections.

2. The Contractor may construct a concrete jacket as shown on Standard Plans, Index 430-001.

430-8.1.2 Side Drain, Storm and Cross Drain, and Gutter Drains: Where corrugated metal pipe is used as side drain, storm and cross drain, or gutter drain, use a rubber or neoprene gasket of a design shown to provide a joint as specified in 430-4.

Use a gasket of one of the following dimensions:

1. For annular joints with 1/2 inch depth corrugation: either a single gasket a minimum of 7 inches by 3/8 inch or two gaskets a minimum of 3-1/2 inches by 3/8 inch; and for annular joints with 1 inch depth corrugations: either a single gasket a minimum of 7 inches by 7/8 inch or two gaskets a minimum of 3-1/2 inches by 7/8 inch.

2. For helical joints with 1/2 inch depth corrugation: either a single gasket a minimum of 5 inches by 1 inch or two gaskets a minimum of 3-1/2 inches by 1 inch; and for helical joints with 1 inch depth corrugations: either a single gasket a minimum of 5 inches by 1-1/2 inches or two gaskets a minimum of 3-1/2 inches by 1-1/2 inches.

3. Such other gasket designs as may be approved by the Engineer.

If, in lieu of a single gasket spanning the joint, two gaskets are used, place these individual gaskets approximately 2 inches from each pipe end at the joint. When two gaskets are used, seal the overlapping area on the coupling band between the gaskets consistent with the joint performance specified. The Contractor may tuck a strip of preformed gasket material over the bottom lip of the band for this purpose. Use coupling bands that provide a minimum circumferential overlap of 3 inches. As the end connections on the coupling band are tightened, ensure that there is no local bending of the band or the connection. Use precurved coupling bands on pipe diameters of 24 inches or less.

Use flat gaskets meeting the requirements of ASTM D1056, designation 2C2 or 2B3. In placing flat gaskets on pipe prior to placing the coupling band, do not stretch the gasket more than 15% of its original circumference. Use circular gaskets meeting the requirements of ASTM C361. Do not stretch the circular gasket more than 20% of its original circumference in placing the gasket on pipe. Use preformed plastic gasket material meeting the composition requirements of 942-2.2.

Apply an approved vegetable soap lubricant, as specified for concrete pipe in 430-7.1.1.

430-8.1.3 Alternate Joint: In lieu of the above-specified combination of locking bands and flat gaskets, the Contractor may make field joints for these pipe installations by the following combinations:

1. Use the metal bands as specified in Article 9 of AASHTO M36M that are at least 10-1/2 inches wide and consist of a flat central section with a corrugated section near each end, designed to match the annular corrugation in the pipe with which they are to be used. Connect the bands in a manner approved by the Engineer, with a suitable fastening device such as the use of two galvanized 1/2 inch diameter bolts through a galvanized bar and galvanized strap, suitably welded to the band. Use a strap that is the same gage as the band.

Where helically corrugated pipe is to be jointed by this alternate combination, ensure that at least the last two corrugations of each pipe section are annular, and designed such that the band will engage each pipe end with the next-to-outside annular corrugation.

2. For these bands, use a rubber gasket with a circular cross-section of the "O-ring" type conforming to ASTM C361. Use gaskets having the following cross-sectional diameter for the given size of pipe:

Table 430-2
Non-SI Units

Pipe Size	Gasket Diameter
12 inches through 36 inches (with 1/2 inch depth corrugations)	13/16 inch
42 inches through 96 inches (with 1/2 inch depth corrugations)	7/8 inch
36 inches through 120 inches (with 1 inch depth corrugations)	1-3/8 inches

Use preformed gasket material to seal the overlapping area on the coupling band between gaskets.

3. Use channel band couplers in helical pipe with ends which have been reformed and flanged specifically to receive these bands. Use channel band couplers that are of a two piece design, are fabricated from galvanized steel stock conforming to AASHTO M36, have

2 inch by 2 inch by 3/16 inch angles fastened to the band ends to allow for proper tightening, and meet the following:

Table 430-3 Non SI Units	
Band Thickness	Pipe Wall Thickness
0.079 inch	0.109 inch or lighter
0.109 inch	0.138 inch or heavier
3/4 inch wide	0.109 inch or lighter
1 inch wide	0.138 inch or heavier

Furnish two 1/2 inch diameter connection bolts with each band, that conform to ASTM A307, Grade A and are electroplated in accordance with ASTM B633.

Use a gasket with the joint that is a hydrocarbon blend of butyl rubber meeting the chemical composition and physical properties of 942-2.2. Use a 3/8 by 3/4 inch gasket for pipe fabricated from 0.109 inch or lighter material and a 3/8 by 1 inch gasket for pipe fabricated from 0.138 inch and heavier material.

The Contractor may use a flange band coupler without the gasket for all applications other than side drain, storm and cross drain, and gutter drain.

Do not use the flange band coupler to join dissimilar types of pipe.

The Contractor may join reformed flanged helical pipe to existing annular or reformed pipe having annular ends. On non-gasketed installations, use either an annular band or an alternate joint described in 430-8.1.3. On gasketed installations, use an annular band, minimum of five corrugations in width, in conjunction with two O-ring gaskets as specified in 430-8.1.3. Use mastic material to seal the area of band overlap.

The minimum joint performance standards specified in 430-4.1 apply.

430-8.2 Laying and Shape Requirements for Corrugated Metal Pipe: Install pipe using either a trench or open ditch procedure.

Check pipe shape regularly during backfilling to verify acceptability of the construction method used. Pipe deflected 5% or more of the certified actual mean diameter of the pipe at final inspection shall be replaced at no cost to the Department. Deflection measurements are taken at the point of smallest diameter on the corrugations.

430-9 Specific Requirements for Steel Reinforced Polyethylene Ribbed Pipe, Corrugated High-Density Polyethylene Pipe, Polypropylene Pipe, and Polyvinyl Chloride (PVC) Pipe.

430-9.1 Sampling Requirements: Submit a sample of each pipe material and diameter used on each project to the Engineer a minimum of two weeks prior to the installation, provided that the pipe meets all of the following:

1. Pipe material is PVC, HDPE, steel reinforced polyethylene
2. Pipe is corrugated or ribbed
3. Pipe diameter is 12” or larger
4. Project quantity for a pipe diameter is more than 100 linear feet, unless intended for use as cross drain
5. Pipe is not perforated, unless the material is PVC
6. Pipe is intended for applications requiring 100 year design service life as defined in the Florida Department of Transportation Drainage Manual.

The length of each sample pipe section must comprise at least seven regular corrugations (not including the first three corrugations of the pipe on the bell or spigot ends).

430-9.2 Field Joints: Use gasketed joints to seal side drain, and storm and cross drain. Use gaskets meeting the requirements of Section 449. Ensure that the pipe manufacturer provides a joint design approved by the Engineer before use.

430-9.2.1 Requirements For Use In Structures With Resilient Connectors: Use pipe sleeve adapters in accordance with Section 948-2 and 948-7.

430-9.3 Installation Requirements Including Trenching, Foundation and Backfilling Operations: Check structure shape regularly during backfilling to verify acceptability of the construction method used.

Replace pipe deflected 5% or more of the certified actual mean diameter of the pipe at final inspection at no cost to the Department.

430-10 Desilting Pipe or Concrete Box Culvert.

Desilt pipe culvert and concrete box culvert as designated in the Plans.

430-11 Method of Measurement.

430-11.1 New Pipe Installed by Excavation or Trenching: The quantity of storm and cross drain pipe, storm drain trench, side drain and gutter drain pipe, installed by pipe culvert optional material - excavation or trenching, to be paid for will be plan quantity, in place and accepted. The plan quantity will be determined from the inside wall of the structure and from station/offset location for end treatments as shown in the Plans, along the centerline of the pipe.

Adjustment to bid quantities, prices and payment will not be allowed for increases, decreases, or changes in material or installation requirements due to the use of any optional pipe materials.

If adjustments are required due to Plan errors or omissions or authorized field changes, the plotted material and not the material elected would be used to establish new pay quantities.

Pipe sizes other than round (elliptical/arch) are summarized and paid for using equivalent round pipe diameter.

430-11.2 New Pipe Installed by Jack & Bore: The quantity of storm and cross drain pipe, storm drain trench, side drain and gutter drain pipe, installed by pipe culvert optional material - jack & bore, to be paid for will be the plan quantity, in place and accepted. The measurement and payment will be the plan quantity length of the casing or carrier pipe installed by jack & bore.

Carrier pipe installed through/inside the casing is paid for as pipe culvert optional material – excavation or trenching.

430-11.3 End Treatment: The quantity of all end treatments to be paid for will be the number completed and accepted. For mitered end sections, the measurement will be per each end of pipe. Sod will be paid for in accordance with Section 570.

430-12 Basis of Payment.

430-12.1 General: Prices and payments will be full compensation for all work specified in this Section, including all excavation except the volume included in the items for the grading work on the project, and except for other items specified for separate payment in Section 125; all backfilling material and compaction; disposal of surplus material; and all clearing and grubbing outside of the required limits of clearing and grubbing as shown in the Plans.

No separate payment will be made for bituminous coating, concrete collars, or concrete jackets.

No payment will be made for failed bore paths, injection of excavatable flowable fill, products taken out of service, or incomplete installations. Payment will include all work and materials necessary for jack & bore, including boring, backfilling, flowable fill, and restoration materials necessary for a complete and accepted installation.

No payment will be made for jack & bore until a Bore Path Report has been submitted to the Engineer.

430-12.2 Removing Existing Pipe: When existing pipe is removed and replaced with new pipe approximately at the same location, the cost of excavating and removing the old pipe and of its disposal will be included in the Contract unit price for clearing and grubbing.

430-12.3 Site Restoration: The cost of restoring the site, as specified in 125-11, that is disturbed, solely for the purpose of constructing pipe culvert, will be included in the Contract unit price for the pipe culvert, unless designated specifically to be paid for under other items.

430-12.4 Plugging Pipes: The cost of temporarily plugging a pipe culvert, either proposed or existing, will be incidental to the contract unit price for new pipe culvert.

The cost of filling and/or plugging an existing pipe culvert that is to be permanently placed out of service will be paid for at the contract unit price for filling and plugging pipe, per cubic yard. Price and payment will be full compensation for flowable fill, masonry, concrete, mortar, and all labor and materials necessary to complete the work.

When the project includes no quantities for new pipe culverts, and temporary plugs are required for existing pipe culverts, the cost will be considered as extra work, in accordance with 4-3.5.

430-12.5 Desilting Pipe: Desilting pipe will be paid for at the contract unit price per foot for each pipe desilted. Price and payment will be full compensation for furnishing all equipment, tools and labor, disposal of silt and debris, and all incidentals necessary for satisfactorily performing the work.

430-12.6 Desilting Concrete Box Culverts: Price and payment will be full compensation for all work required.

430-12.7 Flared End Sections: Price and payment will be full compensation for all concrete, reinforcement, toe walls, and all work and materials required.

430-12.8 Mitered End Sections: Price and payment will be full compensation for all materials, pipe, grates when required, fasteners, reinforcing, connectors, anchors, concrete, sealants, jackets and coupling bands, and all work required.

430-12.9 U-Type Endwalls: Price and payment will be full compensation for all materials concrete, reinforcement, grate, baffles, accessories, and all work required. Fencing, when called for in the Plans, will be paid for under Fencing, Type B, per foot. Rip rap will be paid for in accordance with Section 530.

430-12.10 Straight and Winged Endwalls: Price and payment will be full compensation for all concrete, reinforcement, grate, accessories, and all work and materials required.

430-12.11 Railroad Requirements: Where pipe culvert is constructed under railroad tracks, the Contract unit price for the pipe culvert will include the costs of any jacking operations and the operation of placing the pipe by use of a tunnel liner, (except as specified for unanticipated tunnel liner, in 430-6.5, where reimbursement is to be made for such unanticipated liner), and all other work necessary to meet the requirements of the railroad company, excluding

the costs of watchman or flagman services provided by the railroad company, except as provided below.

The Department will reimburse the Contractor for the actual costs of any trestle bridge work which is performed by the railroad's forces, as billed to him by the railroad, less the value of any salvage materials derived there from, whether such salvage materials are retained by the railroad company or by the Contractor. When the work of shoring and bracing is to be performed by the railroad, such fact will be stipulated in the Contract Documents and the Contractor will be required to pay to the railroad the amount of such costs, which amount will be reimbursed to him by the Department. The Contract unit price for the pipe culvert shall include the costs of all other work of shoring and bracing.

430-12.12 Payment Items: Payment will be made under:

Item No.	430- 17-	Pipe Culvert Optional Material - Excavation or Trenching - per foot.
Item No.	430- 18-	Pipe Culvert Optional Material - Jack & Bore - per foot.
Item No.	430- 94-	Desilting Pipe - per foot.
Item No.	430- 96-	Polyvinyl Chloride Pipe - per foot.
Item No.	430- 98-	Mitered End Section - each.
Item No.	430-200-	Flared End Sections - each.
Item No.	430-400-	Winged Concrete Endwalls - each.
Item No.	430- 5-	Straight Concrete Endwalls - each.
Item No.	430- 6-	U-Type Concrete Endwalls - each.
Item No.	430-830-	Filling and Plugging Pipe - cubic yard.
Item No.	430-950-	Desilting Concrete Box Culvert - per cubic yard.

SECTION 431
PIPE LINER

431-1 Description.

Rehabilitate drainage pipe by installing a pipe liner in accordance with the requirements of this Section. The Plans will indicate the location of the pipe to be rehabilitated, the material composition and the alternate liner types that may be used to rehabilitate the pipe, and the method of liner installation.

431-2 Materials.

Meet the requirements of Section 948.

431-3 Pre-installation Requirements.

Prior to installing the pipe liner, inspect the host pipe and ensure that it is clean, dry and stable. Inspect the host pipe by means of closed circuit television. The closed circuit television inspection may be augmented by a visual inspection in which persons enter a host pipe to inspect it, at no additional cost to the Department. Obtain written approval from the Engineer prior to allowing persons to enter a host pipe. Furnish all equipment necessary to inspect, remove silt and other debris, and dewater the host pipe to the satisfaction of the Engineer. Seal cracks and joints using an approved chemical grout of either acrylamide base gel, acrylic base gel, urethane base gel, or urethane base foam. Place flowable fill as directed by the Engineer to maintain the stability of the host pipe.

431-4 Installation Methods.

431-4.1 General: Install the liner using one of, or a combination of, the following methods: sliplining, inverting, pulling/pushing, spiral winding, paneling, coating, or bursting. Seal or grout the annular space between the interior of the host pipe and the exterior of the liner according to the liner manufacturer's written instructions.

431-4.2 Sliplining: Use either polyethylene, high density polyethylene, polyvinyl chloride, fiberglass, steel or aluminum pipe liner. Install the liner by joining discrete lengths, panels or segments of the pipe liner in a manhole or other access point and inserting the liner into the host pipe.

431-4.2.1 Polyethylene: Install polyethylene pipe liner in accordance with ASTM F585. The manufacturer's written instructions may be substituted for ASTM F585 with written permission from the Engineer.

431-4.2.2 High Density Polyethylene: Install high density polyethylene pipe liner in accordance with ASTM F585. The manufacturer's written instructions may be substituted for ASTM F585 with written permission from the Engineer.

431-4.2.3 Polyvinyl Chloride: Install polyvinyl chloride pipe liner in accordance with ASTM F1698.

431-4.2.4 Fiberglass, Steel or Aluminum: Install fiberglass, steel or aluminum pipe liner in accordance with the manufacturer's written instructions.

431-4.2.5 Steel Reinforced Polyethylene Ribbed Pipe: Install reinforced pipe liner in accordance with ASTM F585. The manufacturer's written instructions may be substituted for ASTM F585 with written permission from the Engineer.

431-4.3 Inverting: Install a resin impregnated felt tube pipe liner into the host pipe, and cure in place, in accordance with ASTM F1216.

431-4.4 Pulling/Pushing: Install the liner in accordance with the manufacturer's written instructions. Protect the pipe liner end using a device that uniformly distributes the applied load around the perimeter of the liner. Continuously monitor the applied load, and do not stretch the liner by more than 1% of its original length. For liner lengths of 100 feet or less, the end protection device may be omitted, with written permission from the Engineer. Do not seal the liner ends or begin grouting prior to 24 hours after liner installation.

431-4.5 Spiral Winding: Install the pipe liner in accordance with ASTM F1698 or ASTM F1741.

431-4.6 Paneling: Install the pipe liner in accordance with the manufacturer's written instructions. Limit paneling to host pipes having 90 inch or greater internal diameters. Do not place panels where a liner joint will lie along or near the crown of the host pipe.

431-4.7 Coating: Use materials and install the pipe liner in accordance with the manufacturer's written instructions.

431-4.8 Bursting: Install the pipe liner in accordance with the manufacturer's written instructions. Limit bursting to vitrified clay or concrete crossdrain or sidedrain pipe having no lateral connections or risers. Further limit bursting to locations where no part of the host pipe passes within 5 feet of any buried utility or pavement base material.

431-5 Acceptance.

Inspect the complete rehabilitation by means of closed circuit television. Obtain written approval from the Engineer prior to allowing persons to enter a host pipe. Provide the Engineer videos of all preliminary and final inspections.

431-6 Method of Measurement.

The quantity of pipe liner to be paid for will be the length, per foot, of pipe liner installed and accepted, measured along the centerline of the pipe, from end to end.

431-7 Basis of Payment.

Price and payment for pipe liner will be full compensation for furnishing and installing the pipe liner in accordance with the requirements of this Section, including all materials, labor and incidentals required to dewater and clean host pipe, dispose of all silt and debris, seal cracks and joints in the host pipe, and seal and grout the annular space between the liner and interior of the host pipe.

Price and payment for pipe liner will also be full compensation for all equipment, materials and labor required for inspections, and for furnishing videos of the inspections to the Engineer.

Payment will be made under:

Item No. 431- 1- Pipe Liner - per foot.

SECTION 435
STRUCTURAL PLATE PIPE AND PIPE ARCH CULVERTS

435-1 Description.

Construct structural plate pipe and pipe arch culverts as shown in the Plans.

Obtain pipe culverts from a plant currently on the Department's Production Facility Listing. Producers seeking inclusion on the list shall meet the requirements of Section 105.

At the beginning of each project, submit a notarized certification statement to the Engineer from a company designated representative certifying that the structural steel plant will manufacture the products in accordance with the requirements set forth in the Contract Documents and plant's approved Quality Control (QC) Plan. The QC Manager's stamp on each product indicates certification that the product was fabricated in conformance with the Contractor's QC Plan, the Contract, and this Section. Ensure that each shipment of structural plate products to the project site is accompanied with a QC signed or stamped delivery ticket providing the description and the list of the products.

When the producer's Quality Control Program is suspended by the Department, accept responsibility of either obtaining products from a plant with an approved Quality Control Program, or await re-approval of the plant.

The Engineer will not allow changes in Contract Time or completion dates as a result of the plant's loss of qualification. Accept responsibility for all delay costs or other costs associated with the loss of the plant's qualification.

435-2 Materials.

Meet the following requirements:

Steel Pipe .....Section 944
Aluminum Pipe .....Section 945
Liner Repair Systems .....Section 948

When the Plans call for bituminous coated pipe or pipe arch, meet the coating requirements of 944-4.

When other types of coating material are shown in the Plans, use a coating that consists of at least two coats of the specified material, applied at the job site. Apply the coating by brush or by spray.

435-3 Trench, Foundation, Laying, and Backfill.

Perform this work as specified in Section 430, and as follows.

Provide a foundation for the bottom plates that is of uniform density and carefully shaped to fit the lower plate of the pipe or pipe arch. Thoroughly tamp the backfill material against the remaining plates.

435-4 Assembly.

Assemble the plates to form the pipe or pipe arch structure in accordance with the diagram furnished by the manufacturer. Connect the plates by bolting tightly in all bolt holes provided.

435-5 Method of Measurement.

The quantities to be paid for will be the plan quantity, in feet, of pipe or pipe arch, installed in place, completed and accepted. The quantity will be measured along the centerline of

the structure from end to end of metal for full section structures, from average end to end at top and bottom for beveled-end structures.

435-6 Basis of Payment.

Prices and payments will be full compensation for all work specified in this Section, including all materials, backfilling, and disposal of surplus material and all excavation except the volume included in the items for grading work and for other items specified for payment in Section 125.

Payment will be made under:

Item No. 435-	Structural Plate Pipe Culvert - per foot.

SECTION 436
TRENCH DRAIN

436-1 Description.

Construct trench drain, with one of the materials listed below, for the purpose of collecting and removing surface run-off from paved areas. Furnish and install trench drain in accordance with the Standard Plans, at the locations shown in the Plans or as directed by the Engineer.

436-2 Materials.

Provide preformed channels or pipe with sufficient strength to withstand construction handling and placement of concrete backfill without deforming or deviating from line and grade. Submit certification to the Engineer from the manufacturer that the trench drain system meets the requirements of this Section.

436-2.1 Channels/Pipe: Meet the following requirements:

Steel Pipe	Section 943
Aluminum Pipe	Section 945
Polyethylene	Section 948 and ASTM D3350
Polymer Concrete	ASTM D6783
Fiberglass	ASTM D3517

436-2.2 Concrete Backfill: Use concrete that meets the requirements of Section 347.

436-2.3 Grates: Provide steel grates and supporting frames that meet the requirements of Section 962. Ductile iron frames and grates must meet the requirements of ASTM A536. Ensure that ductile iron grates and frames are compatible and from the same manufacturer. Frames must be anchored into the concrete backfill with studs bolts or lugs. Grates must have at least 30% open area and fasten securely to frames to avoid rattling, Grates must be removable for the entire channel length and have vandal resistant locking devices. Ensure that frames have a minimum of 4 inch long studs, bolts or lugs at all four corners.

436-2.4 Clean-Out covers for Type 1 Drains: Install steel or ductile iron covers that meet the requirements of Section 962.

436-2.5 Outlet Pipe: Connect outlet pipe to the trench drain with standard manufactured connectors. Unless a particular type is called for in the Plans, use any of the following types of pipe:

Concrete	Section 449
Steel	Section 943
Aluminum	Section 945
Polyvinyl Chloride	948-1.7
Polyethylene	948.2.3

436-3 Installation.

Submit to the Engineer the proposed method of installation, noting any deviation from the manufacturer's recommendations. Place concrete backfill in the trench against undisturbed material at the sides and bottom of the trench in a manner that will prevent floating or shifting of the trench drain, and will prevent voids in, or segregation of the concrete. Tamp and spade to prevent honeycombing. Form the top surface to the lines shown in the Plans. Remove any foreign material that falls into the trench prior to or during placement of concrete.

436-4 Method of Measurement.

The quantity to be paid for will be plan quantity, in place and accepted. The plan quantity will be measured from the inside wall of the structure as shown in the Plans, along the centerline of the pipe/channel. Curb placed with trench drain will be paid in accordance with Section 520.

436-5 Basis of Payment.

Price and payment will be full compensation for all work specified in this Section, including all materials, tools, equipment, concrete backfilling, outlet pipe, connections to new or existing structures and all incidentals necessary to complete the work.

Payment will be made under:

Item No. 436- 1- Trench Drain - per foot.

SECTION 440
UNDERDRAINS

440-1 Description.

Construct underdrains, underdrain cleanout structures, underdrain inspection boxes and underdrain outlet pipes in accordance with the Plans and Standard Plans, Indexes 440-001 and 440-002. Use any one of the types of pipe listed in 440-2, unless a particular type is specifically required. Use only perforated pipe, and do not use open joints.

440-2 Materials.

Meet the following requirements:

Concrete Pipe	Section 449
Filter Aggregate	Section 902
Corrugated Steel Pipe	Section 943
Corrugated Aluminum Pipe	Section 945
Polyvinyl-Chloride Pipe	Section 948
Corrugated High Density Polyethylene Pipe	Section 948
Corrugated Polypropylene Pipe	Section 948
Steel Reinforced Polyethylene Ribbed Pipe	Section 948
Filter Fabric Sock	Section 948
Geotextile Fabrics*	Section 985

*Use products listed on the Department's Approved Product List (APL).

440-3 Excavating Trench.

Excavate the trench carefully, to the depth required to permit the pipe to be laid to the grade required, and to the dimensions shown in the Plans.

440-4 Laying Pipe.

440-4.1 General: Bed the pipe firmly on the bottom of the trench, with the perforations down and joints securely made.

440-4.2 Corrugated Steel Pipe - Protection of Coating: Handle corrugated steel pipe in such a way that the zinc or aluminum coating will not be bruised or broken. Do not use pipe showing bruises or breakage of the zinc or aluminum coating.

440-4.3 Protection of Drain Inlet: Protect the influent end of the pipe in a manner which will prevent any soil from entering the drain.

440-4.4 Lateral Connections: Make lateral connections with prefabricated wyes, tees, elbows, etc., as required.

440-4.5 Underdrain Inspection Box: Construct underdrain inspection boxes in accordance with Standard Plans, Index 440-002 and the Plans.

440-4.6 Underdrain Cleanout Structures: Construct underdrain cleanout structures of in-line wye fittings and stub for access where called for in the Plans.

440-4.7 Underdrain Outlet Pipe: Use non-perforated pipe. Construct underdrain bends in accordance with Standard Plans, Index 440-002.

440-5 Placing Filter Material and Backfilling.

440-5.1 Placing Material: After laying the pipe and obtaining the Engineer's approval, backfill the trench with filter material to the lines shown in the Plans.

440-5.2 Compaction of Filter Material and Protection of Pipe: Place and compact the filter material around the pipe and for the full width of the trench, in layers not exceeding 6 inches in thickness. Take special care to avoid displacement or damage to the pipe.

440-5.3 Backfill Above Filter Material: For all types of pipe, backfill the portion of the trench above the filter material with suitable pervious material. Place and compact the material in layers not exceeding 4 inches in thickness.

440-6 Type V Underdrain Construction.

To prevent clogging of Type V underdrain from construction sediments, initially excavate the associated stormwater facilities to rough grade. After the contributing drainage area is stabilized, construct the underdrains and excavate the stormwater facilities to achieve the final elevation.

440-7 Method of Measurement.

The quantities to be paid for will be the length, in feet, of underdrain, which includes underdrain cleanout structures, measured in place, along the centerline and gradient of the underdrain, completed and accepted. The quantities to be paid for will be the length, in feet, of outlet pipe measured in place, along the centerline and gradient of the outlet pipe, completed and accepted. The quantity of underdrain inspection boxes to be paid for will be the number completed and accepted.

No separate measurement or payment will be made under this Section for underdrains associated with box culverts or the Standard Plans, Index 400-289.

440-8 Basis of Payment.

Price and payment will be full compensation for all the work specified in this section, including all materials, disposal of materials, pipe and fittings, stubbing into drainage structures, and all excavation except the volume included in the items for the grading work.

Payment will be made under:

Item No. 440- 1-	Underdrain - per foot.
Item No. 440- 70-	Underdrain Inspection Box - each.
Item No. 440- 73-	Underdrain Outlet Pipe - per foot.

SECTION 443
FRENCH DRAINS

443-1 Description.

Construct french drains, utilizing one of the authorized types of pipe, with coarse aggregate, or ballast rock when specified, and filter fabric.

443-2 Materials.

443-2.1 Pipe: Unless a particular type is specified in the Plans, pipe furnished may be any of the following types:

1. Concrete Pipe (Bell & Spigot): Slotted or perforated concrete pipe may be used. Meet the requirements of Section 449 for concrete pipe. Do not use gaskets. Fully insert the spigot in the bell, and bring home. Conform to Standard Plans, Index 443-001 for slotted pipe. Use perforated pipe having perforations equally located 360 degrees around the pipe. Use pipe having not less than 30 round perforations, 3/8 inch each, per square foot of inside pipe surface. Extend perforations to within 6 inches of the bell or spigot area. The Engineer will permit other perforations not less than 5/16 inch nor more than 3/8 inch in the least dimension if they provide an opening area not less than 3.31 in^2/ft^2 of pipe surface.

2. Corrugated Aluminum Alloy Culvert Perforated Pipe: Meet the requirements of Section 945. Use perforated pipe having perforations equally located 360 degrees around the pipe. Locate perforations either on the inside crests or on the neutral axis of all corrugations except that perforations are not required within 4 inches of each end of each length of pipe or in a corrugation where seams are located.

Provide pipe having not less than 30 round perforations, 3/8 inch each, per square foot of pipe surface. The Engineer will permit other perforations not less than 5/16 inch nor more than 3/8 inch in the least dimension if they provide an opening area not less than 3.31 in^2/ft^2 of pipe surface.

3. Corrugated Steel Perforated Pipe: Meet the requirements of Section 943. Meet the perforation requirements as specified in (2) above.

4. Bituminous Coated Corrugated Steel Perforated Pipe: Meet the requirements of Section 943. Meet the perforation requirements as specified in (2) above. Place the perforations prior to the bituminous coating. The Engineer will accept the minimum opening of not less than 3.31 in^2/ft^2 of pipe if 50% of the opening area is maintained after coating.

5. Corrugated High-Density Polyethylene (HDPE) Perforated Pipe: Meet the requirements of Section 948. Meet the perforation requirements as specified in (2) above.

6. Polyvinyl Chloride (PVC) Perforated Pipe: Meet the requirements of Section 948. Meet the perforation requirements as specified in (2) above.

7. Corrugated Polypropylene Perforated Pipe: Meet the requirements of Section 948. Meet the perforation requirements as specified in (2) above.

443-2.2 Coarse Aggregate: Meet the requirements of 901-1.4 for No. 4 stone.

443-2.3 Select Fill: Use select fill meeting the requirements of Section 911.

443-3 Excavating Trench.

Excavate the trench in accordance with Section 125 unless specific trench excavation procedures are described in the Plans.

Carefully excavate the trench to such depths as required to permit the filter fabric, coarse aggregate and the pipe to be placed in accordance with the details shown in the Plans.

443-4 Laying Pipe.

Lay all pipe conforming with the lines and grades specified in the Plans and in accordance with these Specifications. Unless otherwise specified in the Plans, set the pipe with a 36 inch minimum cover and a maximum cover of 66 inches.

443-5 Placing Coarse Aggregate and Backfilling.

After placing the pipe and without disturbing the pipe, carefully place the coarse aggregate around the pipe to a depth shown in the Plans. Fold the filter fabric over the coarse aggregate. Backfill and compact as described below.

443-5.1 French Drains Under Pavement: Fill the area above the coarse aggregate with select fill material meeting the requirements of this Section. Place and compact the select fill according to the requirements for pipe as specified in Section 125. The Department will allow use of additional coarse aggregate over the top of the pipe instead of select fill material. In this case, the filter fabric shall be extended to wrap the additional course aggregate. The top of the coarse aggregate shall not be higher than the bottom of the base, unless shown in the Plans. The Department will not pay additional costs associated with substituting coarse aggregate for select fill.

443-5.2 French Drains not Under Pavement: Fill and compact the area above the coarse aggregate according to the requirements for pipe in Section 125, unless specific procedures are described in the Plans as specified in Section 125.

443-6 Method of Measurement.

The quantity of french drains to be paid for under this Section will be the length in feet, measured in place, completed and accepted as specified on Standard Plans, Index 443-001 for french drains.

443-7 Basis of Payment.

The quantities determined as provided above will be paid for at the Contract unit price per foot for french drains. Such prices and payments will be full compensation for all the work specified in this Section and will include all materials and all excavation, and will also include sheeting or shoring, if required, the disposal of surplus material, pavement restoration, backfilling and tamping, but will not include payment for items paid for elsewhere in the specifications.

Payment shall be made under:

Item No. 443- 70- French Drains - per foot.

SECTION 446
EDGEDRAIN (DRAINCRETE)

446-1 Description.

Construct edgedrain (draincrete), and edgedrain outlet pipe as shown in the Plans and Standard Plans, Index 446-001. Use any one of the types of pipe listed in 446-2, unless a particular type is specifically required within the Contract Documents. Use only perforated pipe, and do not use open joints.

446-2 Materials.

Meet the following requirements:

Portland Cement Concrete – Class NS* .....Section 347
Coarse Aggregate.....Section 901
Portland Cement.....Section 921
Water.....Section 923
Polyvinyl-Chloride Pipe.....Section 948
Polyethylene Pipe.....Section 948
Filter Fabric**.....Section 985

*For draincrete, the concrete requirements of Section 347 are modified as follows:

Use Type I or II portland cement (no supplementary cementitious materials permitted).

Composition:

Grade of coarse aggregate (stone).... #57, #67 or #89
Maximum Water/Cement ratio 0.38
Minimum cement factor..... 385 lb/yd^3 of Draincrete
Maximum Slump Range ..... Not Applicable
Fine Aggregate.....None
Admixtures.....None

Do not use materials which contain hardened lumps, crusts, or frozen matter, or are contaminated with dissimilar material.

**Use products listed on the Department's Approved Products List (APL).

446-3 Control of Quality.

446-3.1 Concrete Design Mix: Submit the proposed design mix prior to production, on the Concrete Mix Design form, for the Engineer's approval. Use only draincrete design mixes having prior approval of the Engineer. Do not change the design mix component materials except as per 446-3.2.

The Department will verify the proposed mix design and may witness the trial batching. Meet the unit weight requirements as determined in accordance with FM 5-530, and the drain rate in accordance with FM 5-570. Also, provide one of the following with the design mix submittal:

1. Evidence from three sets of production data, either from Department acceptance tests or independently verifiable commercial mixes, that draincrete produced in accordance with the proposed design mix meets the requirements of this Section.

2. Test data from a single trial batch of 0.10 yd^3 minimum is required, which demonstrates that the draincrete produced using the proposed mix, designated ingredients, and designated water-cement ratio meets the requirements of this Section.

446-3.2 Batch Adjustment - Materials: Meet the theoretical yield requirements of the approved mix design. Inform the Engineer of any adjustments to the approved mix design. Note any batch adjustments and record the actual quantities incorporated into the mix, on the concrete Delivery Ticket/Certification form.

446-3.3 Delivery Certification: Furnish to the Engineer a complete Delivery Ticket/Certification form with each batch of draincrete prior to unloading at the site.

446-4 Construction.

446-4.1 Excavating Trench: Meet the requirements of Section 440.

446-4.2 Laying Pipe: Meet the requirements of Section 440.

446-4.3 Placement of Draincrete: Obtain the Engineer's approval before placing the draincrete. Deliver the draincrete to the site of placement in a freshly mixed unhardened state. Deposit draincrete in the form or trench by a method approved by the Engineer, to ensure uniform distribution. Do not use vibrators. Avoid displacement or damage to the pipe or filter fabric.

446-5 Sampling and Testing.

446-5.1 General: The Engineer will take random samples of the draincrete at the point of placement to determine the drain rate in accordance with FM 5-570 to determine the drain rate. A minimum of two test cylinders will be made for each LOT. A LOT represents one day's production of each mix design.

446-5.2 Acceptance of Hardened Draincrete: Meet the minimum drain rate of 6 oz/second. Draincrete not meeting the drain rate requirement will be rejected.

Remove, and replace all rejected draincrete at no cost to the Department.

446-6 Method of Measurement.

The quantity of edgedrain (draincrete) to be paid for will be the length, in feet, measured in place, along the centerline and gradient of the edgedrain (draincrete), completed and accepted. The quantity of edgedrain outlet pipe to be paid for will be the length, in feet, measured in place along the centerline and gradient of the outlet pipe, completed and accepted.

446-7 Basis of Payment.

Price and payment will be full compensation for all work, including all materials, excavation, equipment, labor and incidentals necessary to complete the work.

Payment will be made under:

Item No. 446- 1-	Edgedrain (Draincrete) - per foot.
Item No. 446- 71-	Edgedrain Outlet Pipe - per foot.

SECTION 449
PRECAST CONCRETE DRAINAGE PRODUCTS

449-1 Description.

Precast concrete drainage products hereinafter called products, may include but are not limited to, round concrete pipe, elliptical concrete pipe, underdrains, manholes, endwalls, inlets, junction boxes, three-sided precast concrete culverts, and precast concrete box culverts.

Ensure that all precast drainage products are designed and manufactured in accordance with the requirements of the Contract Documents.

Obtain precast concrete pipes, box culverts, and drainage structures from a plant that is currently on the Department's Production Facility Listing. Producers seeking inclusion on the list shall meet the requirements of Section 105.

At the beginning of each project, submit a notarized certification statement to the Engineer from a company designated representative certifying that the plant will manufacture the products in accordance with the requirements set forth in the Contract Documents and Producer Quality Control (QC) Plan. The Quality Control Manager's stamp on each product indicates certification that the product was fabricated in conformance with the Producer QC Plan, the Contract, and this Section. Ensure that each shipment of precast concrete products to the project site is accompanied with a QC signed or stamped delivery ticket providing the description and the list of the products.

When the Producer Quality Control Program is suspended by the Department, accept responsibility of either obtaining products from a plant with an approved Quality Control Program, or await re-approval of the plant. The Engineer will not allow changes in Contract Time or completion dates as a result of the plant's loss of qualification. Accept responsibility for all delay costs or other costs associated with the loss of the plant's qualification.

449-2 Materials.

Ensure that the materials used for the construction of the precast drainage products have a certification statement from the source, showing that they meet the applicable requirements of the Specifications with the following modifications:

Reinforcing Bar	Section 415
Coarse Aggregate*	Section 901
Fine Aggregate*	Section 902
Portland Cement and blended cement	Section 921
Water	Section 923
Admixtures	Section 924
Supplementary Cementitious Materials	Section 929
Gasket Material	Section 942
Blended Hydraulic Cements	AASHTO M 240
Welded Wire Reinforcement	Section 931
Wire for Site Cage Machines	Section 931
Liner Repair Systems	Section 948

*For concrete pipes the gradation requirements of concrete aggregates as set forth in Sections 901 and 902 are not applicable.

449-3 Construction Requirements.

Unless otherwise stipulated within the Contract Documents, meet the following requirements for concrete mix, product design, fabrication, transportation, and installation:

Three-Sided Precast Culverts.....Section 407
Precast Concrete Box Culvert.....Section 410
Pipe Culverts and Storm Sewers.....Section 430
French Drains.....Section 443
Inlets, Manholes, and Junction Boxes
.....Section 425 and ASTM C478
Underdrains.....Section 440 and ASTM C444
Steel Reinforced Round Concrete Pipe.....ASTM C76
Reinforced Elliptical Concrete Pipe.....ASTM C507
Non-reinforced Concrete Pipe .....ASTM C985

Meet the special requirements for the applicable pipes as described in 449-4 and 449-5.

449-4 Concrete Pipe.

449-4.1 Special Requirements for Steel Reinforced Concrete Pipe: Use pipe meeting the requirements of ASTM C76 with the modifications as described in 449-4.2. Use Special Designed pipe meeting the requirements of ASTM C655. Use Class S pipe meeting the requirements of ASTM C655. Ensure all pipes are properly marked.

449-4.2 Modifications to ASTM C76 and ASTM C507: The following supersedes the provisions of ASTM C76 and ASTM C507:

1. Ensure all materials used in concrete are certified from the source and conform to the requirements of 449-2.
2. Ensure all Joint Reinforcement requirements are in accordance with the Standard Plans.
3. When membrane curing compounds are used, ensure that the requirements of 925-2 are met and the membrane curing compounds are applied in accordance with 400-16 immediately after the pipe has been removed from the form.
4. Ensure the manufacturer has a suitable apparatus for testing each product in accordance with ASTM C497 and performs all tests outlined in ASTM C497 when requested by the Engineer.
5. Ensure that the variation of laying lengths of two opposite sides of pipe is not more than 1.04% of the diameter, with a maximum of 1/2 inch in any length of pipe, except where beveled-end pipe for laying on curves is specified.
6. Ensure that the type of wall markings is included on all precast pipes.
7. Ensure all repairs are made in accordance with Section 449-5.4.

449-4.3 Special Requirements for Non-Reinforced Concrete Pipe: Ensure the requirements of ASTM C985 are met with the following exception: Modify material requirements set forth in ASTM C985 with the material requirements set forth in 449-2. Ensure all pipes are properly marked.

449-4.4 Special Requirements for Reinforced Elliptical Concrete Pipe: Use elliptical concrete pipes conforming to the requirements of ASTM C507, except for the exceptions and modifications as specified in 449-4.2. Ensure the requirements of Table I of ASTM C507 for standard elliptical pipe, the requirements of Class HE-III and Class HE-IV of Table I of ASTM C507 for standard elliptical pipe and special elliptical pipe, respectively are met and the joint design requirements set forth in Article 7 of ASTM C443 are met.

449-4.5 Concrete Underdrain Pipe: Use perforated concrete pipe for underdrains meeting the requirements of ASTM C444, with the following modifications:

1. Strength of finished pipe: Underdrain pipe will not be required to be reinforced, and will not be tested for strength of the finished pipe. Approval of the strength of the finished pipe will be based on visual inspection and check.

2. Perforations: The perforations must be molded into the pipe at the time of fabrication, and any undue chips, fractures, incurred thereby, either in the interior of the pipe or on the periphery, which are sufficient to significantly impair the strength or efficiency, will be cause for rejection of the pipe.

Ensure the perforations are circular, and of the diameter called for below, with a tolerance of plus or minus 1/16 inch. Furnish all pipe included in any single order, or for any single installation operation, such diameter is reasonably uniform.

Table 449-1
Schedule of Perforations For Concrete Underdrain Pipe

Internal Diameter of Pipe	Diameter of Perforations *(Design)	Number of Rows	**Approximate distance between Rows	**Spacing within Rows
6 inches	3/8 inch	4	4 inches	5-6 inches
6 inches	1/4 inch	4	4 inches	4-5 inches
8 inches	3/8 inch	4	5 inches	5-6 inches
8 inches	1/4 inch	4	5 inches	4-5 inches

*1/16 inch fabrication tolerance, over and under.
**Perforations to be staggered in alternate rows. The spacing between rows must be uniform.

449-4.6 Rejection of Concrete Pipe: Specific causes for rejection of concrete pipe, in addition to any failure to meet the general requirements specified in the Contract Documents, are as follows:

1. Failure to meet the requirements listed in ASTM C76 for permissible variations in dimensions with the modifications outlined in 449-4.1 and 449-4.2.

2. Occurrence of defects listed in ASTM C76.

449-5 Requirements for Pipe Joints When Rubber Gaskets Are to Be Used.

449-5.1 Design of Joint: Use pipe joint of the bell-and-spigot type or the double spigot and sleeve type, meeting the requirements called for in the Standard Plans. Ensure the joint is so proportioned that the spigot, or spigots, will readily enter the bell or sleeve of the pipe.

Ensure the joint ring forms for forming the joint surface are made of either heavy steel, cast iron, or aluminum, and accurately machined to the dimensions of the joint. They must be a true circular form within a tolerance of 1/32 inch. Dimensional checks of joint ring form will indicate for each size pipe a length of spigot, or tongue, not more than 1/8 inch shorter than the bell, or groove, depth. The pipe will be so manufactured that joint surfaces are concentric with the inside of the pipe within a tolerance of 3/32 inch. The shape and dimensions of the joint must be such as to provide compliance with the following requirements:

1. The joint must be so dimensioned that when the gasket is placed on the spigot it will not be stretched more than 20% of its original length, or the maximum stretch length that is recommended by the manufacturer, whichever is lower.

2. The space provided for the gasket must be a groove in the spigot end of the pipe and such space, when the joint is made, it cannot be more than 110% of the volume of the gasket.

3. The joint must be designed so that when the outer surface of the spigot and the inner surface of the bell come into contact at some point on the periphery, the diametric deformation in the gasket at the point of contact cannot be greater than 50% of the normal gasket diameter, and the diametric deformation in the gasket at a point opposite the contact point cannot be less than 20% of the normal gasket diameter.

4. When the pipes are joined, there must be parallel surfaces on both the bell and the spigot, extending from the outside edge of the gasket toward the bell face for a distance of not less than 3/4 inch. These parallel surfaces cannot be farther apart than 1/8 inch, when the spigot is centered in the bell. The tapers on these surfaces cannot exceed three degrees.

5. The inside surface of the bell at the end of the bell must be flared to facilitate joining the pipe sections without damaging or displacing the gasket.

449-5.2 When Rubber Gaskets are Used: Ensure that the pipe joints have been tested at the plant hydrostatically and shown to meet the requirements of Section 6.2 of the Materials Manual, which is available at the following URL: https://www.fdot.gov/programmanagement/Implemented/URLinSpecs/Section62V2.shtm.

449-5.3 When Profile Rubber Gaskets are Used: Ensure the joint design meets the requirements set forth in Article 7 of ASTM C443.

449-5.4 Tolerances in Imperfections, and Permissible Repairs for Joint of Concrete Gasketed Pipe: Ensure that all surfaces of near-contact of the jointed pipes are free from air holes, chipped or spalled concrete, laitance, and other such defects.

Pipes showing minor manufacturing imperfections or handling injuries to the bell or spigot may be acceptable if such defects are acceptably repaired as prescribed below.

Individual air holes (trapped air), or spalled areas with a length of up to one-half the pipe radius, or 12 inches whichever is less, may be repaired by careful use of a hand-placed, stiff, pre-shrunk, 1-to-1 mortar of cement and fine sand, and with no additional preparation other than a thorough washing with water of the defect. Curing will be done either by moisture curing under wet burlap or by application of an approved membrane curing compound. Such repaired pipe which is sound, properly finished and cured, and which otherwise conforms to specification requirements will be acceptable.

Exposed reinforcing and minor spalling in the spigot groove may be accepted if repaired in the following manner: The spalled areas will be chipped back to solid concrete. Exposed reinforcing will be cleaned of all laitance and scale. The entire area is to be coated with an approved epoxy at a thickness of 5 to 10 mils. The coating must be smooth and conform to the shape of the groove. The epoxy must be a Type F-1 as specified in Section 926.

SECTION 450
PRECAST PRESTRESSED CONCRETE CONSTRUCTION

450-1 Description.

Fabricate, store, transport and erect precast/prestressed concrete members prestressed by the pretensioning method. Pretensioned precast prestressed concrete products are products prestressed by the pretensioning method. In this method, steel or fiber reinforced polymer (FRP) components are stressed and anchored; the concrete for the product is then cast and cured, and finally the stress in the steel or FRP components is released from the anchorages to the concrete through bond, after the concrete has attained its specified release strength.

A precast prestressed concrete plant, hereinafter called plant, is an independent operating facility capable of performing all the operations necessary to fabricate precast/prestressed concrete products.

Obtain precast/prestressed products from a plant that is currently on the Department's Production Facility Listing. Producers seeking inclusion on the list shall meet the requirements of Section 105.

When the Producer's Quality Control Program is suspended, accept responsibility of either obtaining precast/prestressed products from a precast/prestressed concrete plant with an accepted Quality Control Program, or await re-approval of the Producer Quality Control Program. The Engineer will not allow changes in Contract Time or completion dates as a result of the concrete plant's Quality Control Program suspension. Accept responsibility for all delay costs or other costs associated with the plant's Quality Control Program suspension.

450-2 Quality Control Program.

450-2.1 General: Develop a Producer Quality Control Program as specified in Section 105.

Meet the requirements of the accepted Quality Control Program, Contract Documents, and Precast/Prestressed Concrete Institute (PCI) Manual for Quality Control for Plants and Production of Structural Precast Concrete Products (MNL-116). The requirements of the Contract Documents will govern, when there is a discrepancy between the PCI Manual and the Contract Documents.

Accept responsibility for performing daily Quality Control (QC) inspections of all phases of work ensuring all materials and workmanship incorporated into the product meet the requirements of the Contract Documents. Also, maintain a daily activity report detailing the results of the daily Quality Control Program activities. Ensure these daily reports and minutes of the weekly meetings with the Engineer and the plant's production personnel are maintained at the plant. During the weekly meetings, discuss the results of the QC inspections.

Ensure a QC inspector is present during concrete placements and performs inspection during all fabrication of precast prestressed concrete products, including the inspection of the operations before, during and after the placement of concrete.

450-2.2 Plant: Ensure each plant has an onsite QC Manager or designee meeting the requirements of Section 105 at all times during fabrication.

450-2.3 Tolerances:

Inspect all prestressed concrete products within five working days of detensioning to ensure their dimensions (other than sweep and camber) conform to the specified tolerances and to determine if there are any deficiencies.

Inspect the product for conformance with the product dimension tolerances shown in Appendix B of PCI Manual MNL-116, except as modified herein.

Apply the tolerances with respect to the theoretical positions and dimensions shown in the Plans. Apply the same tolerances for U-Beams as those specified for I-Beams, when inspecting the product for conformance with dimension tolerances.

For Florida U-Beam diaphragms, the tolerances are:

1. Plus 1 inch and minus 1/2 inch for the thickness of intermediate diaphragms.

2. Plus or minus 3 inches for the location of intermediate diaphragms, relative to design plan positions.

3. Plus 3 inches and minus 1/2 inch for the thickness of the end diaphragms.

The tolerance for beam strand sheathing is plus or minus 2 inches.

Ensure the tolerance on all miscellaneous shaping including, but not limited to, chamfers, miters, bevels, keys, tapers, radii, holes, inserts, and block outs is within plus or minus 1/8 inch of the control dimension of the shape.

The tolerances represent the total allowable tolerance that will be accepted in the finished product. Do not apply tolerances shown for the overall dimensions of a member to violate the tolerances shown for positions of reinforcing and prestressing steel or FRP. Apply the tolerances during and after the fabrication of prestressed products. Do not reduce the concrete cover for reinforcing steel, FRP reinforcing, prestressing steel, FRP prestressing strands, or any other metallic or polymeric objects specified in the Plans more than 1/4 inch. Do not reduce the concrete cover for reinforcing steel, FRP reinforcing, prestressing steel, FRP prestressing strands, or any other metallic or polymeric objects when the cover specified in the Plans is minimum cover.

Limit sweep to 1/2 inch for U-Beams and Inverted T-Beams.

The maximum allowable sweep for I-Beams and piles is 1/8 inch for every 10 feet, and will be determined by the following equation:

Sweep (in) = (0.0125 in/ft) x Length (ft) of beam or pile

Measure and record the sweep and camber of the beams immediately after detensioning and monthly. Beyond 120 days after casting, monthly sweep and camber measurements may be reduced to quarterly if there are no identified issues with the beam, and if the sweep and camber measurements are in tolerance. Once the reduced frequency is applied, camber and sweep shall be measured no more than 7 calendar days prior to shipping. Keep the measurement records on file for review upon request by the Engineer.

Notify the Engineer immediately when the sweep or camber exceeds the specified tolerances.

If the actual camber is less than 50% of the predicted camber at release provided by the Plans, move the dunnage towards the center of the beam to a maximum of 5% of the total length at each end to induce camber.

If the camber is outside of the design camber shown in the Plans by plus or minus 1 inch, take appropriate actions to accommodate the product in the structure.

If the sweep exceeds the tolerance specified, immediately propose measures to the Engineer to bring the sweep of the product back to within tolerance. Special storage conditions for the purpose of removing excessive sweep will not be restricted by requirements of this Section.

450-2.4 Product Certification: Ensure the QC inspector inspects all completed products at the plant not less than 24 hours before shipment to verify that all Contract Documents requirements are met. Upon verification that all Contract Document requirements have been met and all necessary repairs have been satisfactorily completed, the product will be stamped with the approved QC Manager stamp identified in the Producer QC Plan.

With each monthly request submitted for payment, attach a certification stating that the listed precast prestressed products have been produced under the Producer QC Plan and meet the Contract Document requirements. Ensure the certification is signed by a legally responsible person of the plant and is submitted on the plant's letterhead.

450-2.5 Documentation: Ensure that a system of records is maintained in each plant which will provide all information regarding the certification and testing of prestressing steel, FRP prestressing strands, reinforcing steel, FRP reinforcing, concrete materials and concrete, curing materials, embedded items, tensioning, concrete proportioning, pre-placement, placement, post-placement inspections, curing, and disposition of products. Include in the record keeping all the deficiencies found as a result of the inspection and testing. Keep certified test reports for all materials incorporated into the production of precast prestressed concrete products.

Ensure that the record of tensioning operations is maintained and reflects the identification of the bed, type of fabricated products, the complete Financial Project Identification Number, jack identification number, date prestressing strands were stressed, temperature at the time of stressing, and signature of the qualified tensioning machine operator.

Ensure the proposed method and format for documenting required information is included in the Producer QC Plan.

Maintain records until all the precast prestressed products for a project have been fabricated then submit required records to the Engineer. Ensure records are available at all times for the Engineer's inspection.

450-2.6 Quality Assurance Inspection and Testing: The Engineer will perform periodic inspections, sampling, and testing to ensure of the quality and acceptability of the materials, methods, techniques, procedures and processes being utilized in the fabrication of precast prestressed concrete products.

450-3 Materials.

450-3.1 General: Meet the following requirements:

Concrete	Section 346
Steel Strands*	Section 933
Carbon Fiber Reinforcing Polymer (CFRP) Strands*	Section 933
Steel Prestressing Bars	Section 933
Steel Accessories	Section 933
Steel Spirals	Section 931
Reinforcing Steel and Metal Welded Wire Reinforcement	Sections 415 and 931
FRP Reinforcing	Sections 415 and 932
FRP Spirals**	Section 932
Embedded Ducts	Section 960
Membrane Curing compounds***	Section 925
Epoxy Resin Compounds	Section 926
Burlap	Section 925

Curing Blanket 400-16
Penetrant sealer*** .....Section 413
Methacrylate .....Section 413
Epoxy Injection of Cracks .....Section 411

* Do not use strands from more than one source in any individual prestressed element, with the exception of the partially tensioned strands (dormant strands).

** The FRP spirals cannot be used in combination with steel prestressing strand.

*** Use membrane curing compounds and sealers that are compatible with coating or other materials that are applied to concrete surface.

Use inserts in accordance with the recommendations of the manufacturers and within their certified capacities and application qualifications. Do not use aluminum inserts.

Use draped strand devices of sufficient rigidity having adequate support to retain the position of the strand unchanged under the induced load. Do not allow the devices to induce friction to the strands such that the required jacking force and elongation cannot be attained.

450-3.2 Strand Chucks and Splice Chucks: For pretensioning, use strand chucks that are capable of anchoring the strands without slippage after seating and ensure against strand failure within the grips at loads less than 95% of ultimate tensile strength of the prestressing strand.

Submit manufacturer's certification that splice chucks used to transmit the prestressing force from one prestressing strand to another are capable to hold at least 95% of the ultimate tensile strength of the prestressing strand.

Do not use wedges that become worn, cracked, deformed, or that allow dead end seating in excess of 3/8 inch. Use components from the same manufacturer to make up chucks and to provide proper wedge fit.

Use chucks as complete units. Clean, inspect, and lubricate the chucks between each use. Use wedges and housing that are compatible and made for the specific type and size of prestressing strand used. Ensure proper fit and proper seating of wedges on the strands.

The Engineer will allow one splice per strand subject to the following:

1. Splices are located outside the concrete products (except for precast piling where up to two splices are permitted to be used in each pile, so long as they are not located in the same vertical cross section, perpendicular to longitudinal axis of the pile).

2. Strands which are being spliced have the "lay" or "twist" in the same direction.

450-4 Material Acceptance and Testing.

450-4.1 Concrete: Perform the QC sampling and testing of concrete in accordance with the requirements of Section 346.

450-4.2 Reinforcing, Welded Wire Reinforcement and Prestressing Strand for Pretensioning:

450-4.2.1 General: Identify all reinforcing steel, welded wire reinforcement and prestressing strand for pretensioning by LOTs. A LOT of reinforcing steel or welded wire is a shipment of material from the same manufacturer and heat. A LOT of prestressing steel is a shipment of material of the same size, production grade and heat from the same manufacturer. A LOT of FRP reinforcing bars or prestressing strands is a shipment of material of the same size, fiber lot and resin batch from the same manufacturer.

Acceptance of reinforcing bars, welded wire reinforcement and prestressing steel for pretensioning is based on manufacturer's certification and the Department's

verification tests. The sampling for verification testing will be performed by the Department at each plant, on at least one LOT every six months. Additional samples may be taken at the manufacturing source of reinforcing bars, welded wire reinforcement and prestressing strands.

When products contain the material that has failed to meet the requirements of 450-3, reject the unused material of the failed LOT. The Engineer may require an engineering analysis of the products which contain the failed material, in accordance with Section 6.

450-4.2.2 Steel Reinforcing and Welded Wire Reinforcement: Obtain and maintain for each LOT a certified mill analysis, physical property test report and the manufacturer's assigned LOT number with the heat of the material represented. Verify that the report represents the steel received and that the steel meets the Contract Documents requirements. Reject all unidentified reinforcing steel or welded wire reinforcement received at the plant or job site.

Submit the manufacturer's certified mill analysis and provide three, 7 foot long, randomly selected samples from the designated LOT of reinforcing steel and three randomly selected samples from the designated LOT of welded wire reinforcement when requested by Engineer. Ensure each sample of welded wire reinforcement covers an area of four intersections of transverse and longitudinal bars. Ensure the transverse wires of each piece of welded wire reinforcement extend approximately 6 inches to both sides.

450-4.2.3 Fiber Reinforced Polymer (FRP) Reinforcing: Meet the requirements of 932-3.

450-4.2.4 Steel Prestressing Strand for Pretensioning: Obtain and maintain for each LOT of material received, the manufacturer's assigned LOT number, certified test values for specified material properties together with a representative load-elongation curve and the modulus of elasticity value based upon strand nominal area. Submit and support by records maintained by the strand manufacturer, production tolerances applied in selection of the reported strand modulus. Verify that documents submitted represent the shipment received and meets the Contract Documents requirements.

Reject all unidentified prestressing steel received at the plant or job site.

Submit the manufacturer's certified mill analysis and provide three, 5 foot long randomly selected samples from the designated LOT of material when requested by the Engineer.

450-4.2.5 Fiber Reinforced Polymer (FRP) Prestressing Strand for Pretensioning: Meet the requirements of 933-5.2.2.

450-4.2.6 Strand Chucks and Splice Chucks: Obtain and maintain certified test results certifying that the material meets the requirements of 450-3.

450-4.2.7 Steel Accessories: Use only steel accessories meeting the requirements of 450-3.

450-4.2.8 Ducts: Obtain and maintain certified test results certifying that the material meets the requirements of 450-3.

450-5 Shop Drawings.

Submit shop drawings for all pretensioned prestressed concrete products containing FRP bars, FRP strands, or stainless steel strands. Submit shop drawings for all other pretensioned prestressed concrete products when the Contract Documents do not contain all the detailed information necessary to fabricate and erect the pretensioned prestressed concrete product. Ensure the submitted shop drawings meet the requirements of the Contract Documents.

Obtain prior approval of any adjustments to the shop drawings which will result in a net change of prestressing force within the product. Shop drawings are not required to depict negligible, supplemental reinforcement used to facilitate fabrication of products if the additions do not affect the performance of the product.

In lieu of shop drawings, submit the following to the Engineer:

1. The Framing Plan with product designations for all superstructure components.
2. Strand detensioning schedule.
3. Tensioning and elongation calculations.
4. Details of supplemental reinforcement that remains as part of the finished product.
5. Drawings, details and spacing for embedded items associated with fall protection systems used on beams.
6. When proposing to use materials and/or methods that differ from the requirements of the Contract Documents, submit full plan details and Specifications for the alternate materials and methods. Ensure the alternate materials and methods meet the following requirements:

a. The provisions of the Contract Documents.

b. The AASHTO LRFD Bridge Design Specifications, edition with interims as referenced in Plans.

c. The recommendations of the material manufacturer.

d. Any materials change proposed by the Contractor and approved by the Engineer.

e. Net compressive stress in the concrete due to prestressing acting alone, after all losses, is not less than or 5% greater than that provided by the stranding shown in the Plans.

f. Ultimate strength of the structure with the proposed changes is not less than the ultimate strength of the original design.

g. The provisions of the Departments Structures Design Guidelines.

450-6 Forms.

450-6.1 General: Use metal side and bottom forms, unless otherwise specified in the Contract Documents. For members with special shapes such as corner sheet piles, wood forms are permitted. Slab beams, slab units and sheet piles may be cast on concrete surfaces meeting the profile dimensional tolerances of 450-6.3. Apply release agents in accordance with the manufacturer's recommendations. Liquid membrane curing compounds may be used to prevent bonding of slab products and sheet piles to the existing concrete surface, when applied in two or more coatings. Ensure the last application of liquid membrane is applied immediately before placement of the slab or sheet pile.

For all beam members, use side forms designed to be removed without damaging the top flange of the beam. Remove the forms horizontally away from the beam by a method that prevents any contact of the form with the top flange after release of the form. Do not subject the top flange to any vertical force at any time. Include the form details and method of removal in the Producer QC Plan.

For all Florida I-Beams, use forms that do not have more than two horizontal joints.

Use void forms of a type for which service adequacy has been demonstrated, having sufficient strength to provide stability during handling and placing and to withstand

hydrostatic pressures and other forces imposed upon them during concrete placement. Use form material that is neutral with respect to the generation of products harmful to the physical and structural properties of the concrete. Ensure that the presence of the form materials does not cause any detrimental effect to the concrete or other materials within the member. Positively vent all voids to the outside of the member. For end headers and inside forms, other materials capable of resisting the pressure from concrete are permitted, except that end headers used with CFRP strands must be either timber headers or steel headers with rubber grommets to protect the CFRP strands from damage.

Use end headers so designed that they can be placed and maintained in correct position between the side forms. Hold the headers in place with devices capable of being removed or loosened after the concrete has attained its initial set allowing free form expansion during curing methods that involve heat. Use end headers with openings conforming to the prestressing strand pattern to permit passage of the prestressing strand. Locate the openings accurately within 1/8 inch of planned location of prestressing strand elements.

Construct circular openings for strands a maximum of 1/4 inch larger than the nominal strand diameter. Construct square or rectangular openings a maximum of 1/4 inch larger, horizontally and vertically, than the nominal strand diameter. Ensure that all headers are mortar tight.

450-6.2 Supports: Use forms of sufficient thickness, with adequate external bracing and stiffeners, which are anchored to withstand the forces due to placement and vibration of concrete. Ensure that joints in forms are mortar tight. Support bottom forms on concrete pallets with metal stiffeners, wales or shims. Do not use timber elements between the bottom metal form and concrete pallets.

450-6.3 Alignment: Make and maintain during their use, forms and centering true to the shapes and dimensions for the product being produced. Plumb, align, and secure forms for each product in position before each reuse.

Apply the following tolerances to form alignment and pallets or beds used in prestressed construction:

1. Horizontal Alignment (horizontal deviation of side forms either side of a vertical plane within the length of a product) = 1/8 inch,
2. Vertical Alignment (vertical deviation of the bed or pallet from a horizontal plane within the length of a product) = 1/8 inch,
3. Vertical joints (offset between adjacent form sections) = 1/8 inch.
4. Horizontal joints (offset between adjacent form sections) = 1/16 inch.

450-6.4 End Header Locations:

450-6.4.1 General: Provide a minimum of 18 inches of exposed strands from the end header to the stressing anchorage for all products. Provide a minimum of 18 inches of exposed strands between adjacent ends of all products except 24-inch square and smaller piles. Provide a minimum of 6 inches of exposed strands between adjacent ends of 24-inch square and smaller piles.

450-6.4.2 Cold Weather: Provide a distance of at least 5 feet from the end header to the stressing anchorage, when the ambient temperature is expected to be below 55ºF between the time of tensioning and detensioning. When the ambient temperature is expected to be below 55ºF between the time of tensioning and detensioning and the product's exposed strands between the stressing anchorages are not protected, maintain a 25 foot minimum free length of stressed strands, between the end header and the stressing anchorage at each end of a bed line. When cold

weather concrete conditions as specified in 450-10.1 are in effect, protect all exposed strands between stressing anchorages regardless of length. When the products and strands between stressing anchorages are protected, provide protection adequate to maintain the ambient temperature of the air around the strands at or greater than 55ºF until the products are detensioned or 24 hours after placing concrete, whichever is less.

450-6.5 Surface Conditions: Use clean, rust free form surfaces against which concrete is to be cast. Inspect forms and, if necessary, recondition them.

450-6.6 Form Ties: Ensure that no form wires or metal pieces are left within 2 inches of the surface of the finished concrete.

450-6.7 Corners, Angles and Joints: Ensure corners and angles are chamfered, mitered, or rounded with a radius of 3/4 inch, unless otherwise specified or shown in the Plans. Provide smooth mortar tight joints between panel forms within the alignment tolerances.

450-6.8 Form Release Agent: Before placing concrete, treat the facing of all forms with a form release agent in accordance with the manufacturer's requirements. Ensure the application of form release agents does not contaminate prestressing strands and/or reinforcing steel.

450-7 Protection and Placement of Prestressing Strand.

450-7.1 Protection of Prestressing Strand: Maintain and store prestressing steel above the ground surface on platforms, skids, or other supports, to prevent contamination from below, and protect them from mechanical injury. Do not use any packaging or wrapping material that retains moisture at the bottom of the reel. Clean contaminated prestressing strand before use or otherwise reject it. Handle prestressing strand carefully to prevent nicks or kinks. Do not expose prestressing strand to temperatures greater than 165ºF at any time prior to concrete placement. Do not expose CFRP prestressing strand coupler assemblies to temperatures greater than 120°F at any time. Do not use arc welding equipment, including welding electrode lines, within 2 feet of prestressing strand. Do not perform welding on forms that have been set in place after the prestressing strand is placed in the bed. Reject prestressing strand that has sustained any physical damage at any time.

450-7.2 Placing Prestressing Strand: Use care during placement of prestressing strand to avoid physical damage and contamination. Reject damaged strands. Do not use prestressing strand containing nicks, kinks, or former chuck grip marks. Do not use prestressing strand showing evidence of scale formation or which has become pitted. Remove and replace any damaged prestressing strand in the bed.

450-7.3 Cleanliness of Prestressing Strand: Inspect the prestressing strand for any evidence of contamination. Use strand that is free of deleterious materials such as grease, oil, wax, dirt, paint (except that used for marking identification) or other similar contaminants. Remove any contaminants detected from the strand before proceeding with fabrication activities. Rust on prestressing steel that can be removed by light rubbing is acceptable. Streaks or spots which may remain after rust removal are acceptable if no pitting is present.

450-7.4 Debonded Strands: Install debonding material (sheathing) according to the prestressing strand locations and lengths shown in the Plans, and manufacturer's instructions, except as modified herein. Do not install sheathing over the full length of a product. Extend the sheathing through the header. Tape and tie the sheathing at the terminus located at the inside of the member. The tape must be strong enough to hold the sheathing closed.

Use non-slit tubular or two-part sheathing that is high-density plastic. The sheathing must have a minimum wall thickness of 0.025 inch, and an inside diameter exceeding the maximum outside diameter of the strand by 0.020 inch to 0.150 inch. Tape the entire length

of seams to ensure mortar tightness when using two-part sheathing. The sheathing and tape must not react with concrete, coating, steel, or FRP components.

Slit tubular sheathing may be used to repair minor defects such as breakages or punctures in non-slit tubular sheathing, rectifying an improperly debonded strand, or incorrect debonded length of a strand. Tape the entire length of the slit tubular sheathing seam and tie the ends to ensure mortar tightness.

450-8 Tensioning Equipment and Operations.

450-8.1 Equipment: Use a hydraulic jacking system that is adjustable to the automatic application and sustaining of a predetermined load, together with a pressure transducer or load cell built into the hydraulic system. Connect such pressure gage or transducer to a dial or digital readout and printer (manual recording of the tensioning operations is permitted) which will provide an instantaneous readout and record of the applied load in pounds. Use a jacking system with the capacity to induce the required load. Base the use of this system on demonstrated accuracy and repeatability of plus or minus 2% of anticipated load verified through comparison with loads indicated by an independent load cell.

Calibrate all jacking systems before using and repeat calibration at intervals not exceeding 12 months. Calibrate and recalibrate in accordance with the equipment manufacturer's recommendations, by qualified calibration agency or by plant personnel under the supervision of a Specialty Engineer.

Calibrate gages, jacks and pumps as a system in the same manner they are used in tensioning operations with the cylinder extension in the approximate position that it will be in actual use at final jacking force. In multi-strand tensioning systems, gages may be calibrated against a master gage of known accuracy, provided that the other units of the system are calibrated against the same master gage. Ensure calibrations cover the load ranges that will be used during production. Verify the accuracy setting of the automatic cutoff valves by running the desired cutoff load. Ensure a certified calibration curve accompanies each tensioning system. Load readings can be used directly if the calibration determines a reading is within plus or minus 2% tolerance of anticipated load. Ensure calibration of load cells or proving rings used to calibrate jacking systems are on compression force testing equipment that has been calibrated in accordance with ASTM E74.

When any jack or gage appears to be giving erratic results, or if the jack force and elongation do not compare within specified limits and differences cannot be justified while work is in progress, recalibrate the equipment. Also verify the accuracy of the equipment after internal jacking system repairs or when gage and jacking units are switched.

Calibrate or recalibrate in accordance with ASTM E4 using equipment that is calibrated in accordance with ASTM E74. After calibration or recalibration is completed, prepare a certificate and have it signed by the person responsible for the verifications as outlined in ASTM E4 and ASTM E74. Ensure that the calibration report includes, the serial number of the equipment that is calibrated, calibration chart in a graph or tabular form, calibration date, temperature, full range of readings before and after calibration, National Institute of Standards and Technology's (NIST's) traceable number of calibration device, method of calibration, calibration agency, and laboratory or Engineer supervising the calibration.

Verify the accuracy of the jacking and recording system a minimum of once each week during tensioning operations by either an independently calibrated load cell, or by comparison with calculated strand elongation. When weekly verification is to be performed by comparison with calculated strand elongation, check a minimum of ten strands and the difference

in the indicated load and the load determined from the elongation must agree within 5% of the computed theoretical load values. If the differences are greater than 5%, suspend the tensioning operation, evaluate the tensioning operation by qualified personnel, and correct any deficiencies before proceeding.

When weekly verification is done by load cell, perform a minimum of five spot checks to the maximum anticipated load. Use a load cell or proving ring calibrated in accordance with ASTM E74 and the accuracy of the force must be traceable to NIST. Maintain records of readings obtained from the force recording system and verifying standard. Ensure the weekly verification record includes the serial number of the equipment, verification date, verification agency, NIST traceable number of calibration standard, and name of the person making the spot checks. The load reading from the recording system must agree within plus or minus 2% of the anticipated load indicated by the load cell or proving ring that are calibrated annually.

450-8.2 Operations:

450-8.2.1 General: The tensioning operations consist of the application of the final force or load required by the Plans and with adjustments for abutment rotation, bed shortening, anchorage header movement, live end seating, dead end seating, splice chuck seating, friction in the jacking system and any other elements as applicable for the type of bed and anchorage used. Also, adjust the force when the temperature differential between the ambient temperature at time of stressing and the expected concrete temperature at time of placement is greater than 25ºF. Increase the force at the rate of 1% for each 10ºF increment that the ambient temperature at time of stressing is below the expected concrete temperature at time of placing. Decrease the force at the rate of 1% for each 10ºF that the ambient temperature at time of stressing is above the expected concrete temperature at the time of placing. Do not allow the stress in the steel prestressing strand to exceed 80% of the specified tensile strength of the strand, after seating. Do not allow the stress in the CFRP prestressing strand to exceed 70% of the specified tensile strength of the strand, after seating. During each tensioning operation, for the verification of the live and dead end seating, check the seating of at least 4 strands or a minimum of 10% of the total number of strands, whichever is greater. Maintain a record of the tensioning operation.

Compensation for temperature differential and abutment rotation are not required for self-stressing beds. However, adjust the final load for the effects of bed shortening due to the load from all the strands.

If the placement of concrete is delayed for more than seven calendar days after the completion of the stressing operation, check and adjust the final strand load as necessary before placement of concrete and maintain a record of the stressing operation.

Accomplish tensioning by either single strand tensioning or multiple strand tensioning, and ensure that it is symmetrical about the vertical axis of the product. Tensioning methods, in general, consist of tensioning to the required loads indicated by the jacking system, or tensioning to the required load while monitoring the elongation of the prestressing strand.

Production personnel will perform tensioning operations under supervision of a QC Inspector/Technician in accordance with Section 105 for prestressed concrete plant quality control personnel, or certified personnel may perform tensioning operations directly.

450-8.2.2 Single Straight Strand Tensioning: Apply an initial force of 5% to 25% of the final force to eliminate slack in the system. When single straight strand tensioning is

used, tension the prestressing strand until the required final force is attained. Measure and record the force and elongation.

450-8.2.3 Multiple Straight Strand Tensioning: Apply the initial uniform tensioning load to each individual strand before the application of full tensioning load to the group of strands. The amount of the initial load will be influenced by the length of the casting bed and the size of strands in the group to be tensioned. The minimum initial tensioning load will be 5% of the required final load. Increase the magnitude of this load if deemed necessary but do not allow it to exceed 25% of the required final load. Then tension the strands by multiple strand tensioning to final load by pulling to elongation and checking against the jack load. Allow the required elongation to control the tensioning. The actual jack load must agree within 5% of the required load.

For uniform application of load to strands, the face of anchorage at final load must be in a plane parallel to its position under initial load. Verify this by measurement of movement on opposite sides of the anchorage and check its plumb position before and after application of the final load. During tensioning, allow the anchorage to move without restraint.

450-8.2.4 Draped Strand Tensioning: Tension draped strands by either partial tensioning and subsequent strains or by final tensioning in draped position.

Partial stressing and subsequent strains applies when the strands are tensioned through a combination of applied jack loads and strand uplift. To verify the final force, place a load cell between the tensioning anchorage and anchor chucks at the dead end on at least two draped strands. Other methods as approved by the Engineer may be used to verify the final force in the dead end. Apply an initial force of 5% to 25% of the final force to eliminate slack in the system. After application of the initial force, establish reference marks for measuring elongation. Apply a pre-calculated jacking force and measure elongations on a minimum of four strands. The average measured elongation must agree within 5% of the theoretical elongation for strand force measured by jack load, or the factors contributing to the difference must be identified and corrected before proceeding. Allow the load indicated by the jacking system to control the tensioning for the pre-calculated load. Obtain the required final force by lifting or depressing the strand simultaneously at all pickup or hold down points or in an approved sequence as shown on the shop drawings. On each different bed setup, after lifting or depressing the strands to their final position, check the final force at the dead end of at least two strands on the bed. If the load is below the required tensioning force by more than 5%, adjust it to the final load.

When the final stressing is performed in the draped position, apply the tensioning load in two increments with the strands being held in their draped positions. To verify the final force, place a load cell between the tensioning anchorage and anchor chucks at the dead end on at least two draped strands. Other methods as approved by the Engineer may be used to verify the final force in the dead end. Bring each strand to an initial tension of 5% to 25% of the final load before the application of the required final load. After application of the initial load, establish reference marks for measuring elongation. Then tension the strands to final load and measure the elongation. Allow the load indicated by the jacking system to control the tensioning for the initial and final loads. The measured elongation must agree within 5% of the theoretical elongation for the strand force measured by jack load, or the factors contributing to the difference must be identified and corrected before proceeding. When the jacking is performed at one end of the bed, check the applied load on two draped strands at the other end of the bed. If

the load on the end opposite the jacking end is below the required value by more than 5%, adjust the load to the required final load.

450-8.2.5 Wire Breakage:

450-8.2.5.1 Steel Prestressing Strand: Limit wire breakage to 2% of the total area of the strands in any product and verify that breakage is not indicative of a more extensive distress condition, otherwise reject the defective strand. Replace individual strands with more than one wire failure.

450-8.2.5.2 Fiber Reinforced Polymer (FRP) Prestressing Strand: Replace individual strands with any wire failure.

450-8.2.6 Position of Prestressing Strand: Position prestressing strand as shown in the Plans within the tolerances allowed in 450-2.3. Fix the required vertical and horizontal position of each prestressing strand at the ends of each product and at intervals within each product not exceeding 30 feet. Use the method of fixing the prestressing strand shown in the Producer QC Plan. When blocks are to be used for supporting prestressing strand, use those cast from concrete of the same concrete class or higher as used in the prestressed product. When the product's mix design requires a highly reactive pozzolan, use blocks cast from concrete of the same mix design. Stagger the location of blocks with an offset of 12 inches or greater and do not stack them.

450-9 Placement of Reinforcing Bars and Other Embedded Materials.

450-9.1 Reinforcing Bars and Supports: Tie and/or support in position all reinforcing steel in each product with other reinforcing bars in a manner that will accurately position the reinforcing bars throughout the fabrication process. Use types of ties and methods of tying recommended by the CRSI, including lacing. Do not tie reinforcing bars to debonded prestressing strands within the limits of the sheathing material.

Tie or lace beam stirrup bars at a minimum of three points. Tie reinforcing bars, other than stirrup bars in beam ends, at a minimum of every other intersection. Either tie or lace spirals in piling at all four corners in the 1 inch pitch area, at the top corners and bottom center in the 3 inch pitch area, and at the top corners in the center area. Tie the bottom center in the pile center area as necessary to maintain concrete cover. Bend all ties away from the form surface to provide maximum concrete cover.

When shown in the Plans, weld reinforcing steel in accordance with the requirements of AWS Structural Welding Code D 1.4. Do not weld in the prestressing bed.

450-9.2 Other Embedded Materials:

450-9.2.1 Inserts and Lifting Devices:

450-9.2.1.1 Placement: Locate inserts and lifting devices in accordance with the tolerances listed in 450-2.3. For stainless-steel or FRP reinforced products, use only non-metallic or stainless-steel (Type 304 or 316) inserts and lifting devices.

450-9.2.1.2 Corrosion Protection: Provide corrosion protection for embedded metal lifting devices that would remain exposed after lifting operations are complete as indicated below:

1. For recessed lifting devices, backfill block-outs with a Type F epoxy compound meeting the requirements of Section 926 for a minimum distance of 2 inches beyond the perimeter of the device. If the block-out extends less than 2 inches beyond the perimeter of the device, extend the epoxy compound beyond the block-out along the concrete surface.

2. For flush or protruding lifting devices, cut the lifting devices back to a minimum depth of 1 inch below the concrete surface and patch with a Type F epoxy compound meeting the requirements of Section 926.

If Type 304 or 316 stainless steel lifting devices are used, non-shrink grout meeting the requirements of Section 934 may be used to backfill the block-out within its limits.

For all square prestressed piling, concrete sheet piling and concrete poles, cut and patch lifting devices before transporting from the casting yard.

450-9.2.2 Placement of Bearing Assemblies: Set bearing assemblies designed to transmit reaction forces to the concrete in the position shown in the Plans. Place bearing plate assemblies or shoes which are to be cast in a product within appropriate tolerances as provided in 450-2.3. Check the assemblies for position after stripping from the forms.

450-10 Concrete Operations.

450-10.1 Temperature Restrictions:

450-10.1.1 Cold Weather Concreting: When the temperature of the surrounding air is expected to be below 40ºF within 24 hours after placing concrete, the temperature of the plastic concrete as placed must be 55ºF or greater. Maintain the temperature of the concrete after placement at or above 55ºF for the first 24 hours or until detensioning, whichever occurs first. For piles and other members with a minimum section dimension of 12 inches or more, maintain the temperature of the concrete after placement at or above 50°F for the first 24 hours or until detensioning, whichever occurs first. Make arrangements for heating, covering, insulating or housing the concrete work in advance of placement and maintain the required temperature without adversely affecting the concrete due to concentration of heat. Do not use direct fired heaters during the first 24 hours after concrete placement, unless actions are taken to prevent exposure of the concrete to exhaust gases which contain carbon dioxide. Continuously monitor the temperature of the concrete or the ambient air around the product until the product is detensioned. Monitor by the use of thermocouples located in the product cross-section or temperature recording devices located under the enclosure. Provide one thermocouple or temperature recording device for each 200 feet of bed length or part thereof. Locate the thermocouples within the products cross-section as shown in the Producer QC Plan or as approved by the Engineer. Record the monitored temperatures determined by each thermocouple. Review the recorded temperatures to ensure that they are within the specified limits. Initially calibrate recording devices or thermocouples and recalibrate them at least annually in accordance with the manufacturer's recommendations.

450-10.1.2 Hot Weather Concreting: Meet the requirements of Section 346 for temperature requirements and special measures for mixing concrete in hot weather.

Apply mist of water to prestressing strands, steel reinforcing, FRP reinforcing, and steel forms just before placing the concrete when the hot weather concreting special measures are in effect and the temperature of steel forms or reinforcing steel is greater than 120ºF.

450-10.2 Protection of Concrete from Adverse Conditions or Weather: Have protection materials available before the concrete placement begins to cover the products in the event of rain or other adverse conditions during the placement of concrete. Protection materials may be tarps, curing blankets, or other impervious material that will not puncture when placed over protruding reinforcing and/or form elements. Include the method and materials for protection in the Producer QC Plan.

450-10.3 Concrete Placement:

450-10.3.1 General: Check forms, reinforcing bars, prestressing strand, vent pipes, anchorages and other embedded items for compliance with the Contract Documents before placing concrete. Place concrete in accordance with 400-7, except as modified herein.

For concrete operations conducted at night, provide enough lighting to allow visual inspection of the interior of the forms during the complete concrete placement operation.

Convey concrete by the use of buckets, conveyors, pumps, troughs, or other equipment specifically designed for concrete conveyance, provided the placement method consistently produces quality concrete with no segregation or separation of the mix. Locate the concrete conveyance equipment within 12 inches of the top of the forms or surface of the concrete to minimize the free fall of the concrete.

Multiple placements may be used within a bedline, provided compliance with 450-11.1 is maintained.

450-10.3.2 Requirements for Successive Layers: Except for self-consolidating concrete (SCC), place concrete as described in 450-10.3.2.1 through 450-10.3.2.5 as shown in the Producer QC Plan or as approved in writing by the Engineer.

In any progressive concrete placement operation, do not allow the time between successive placements onto previously placed concrete to exceed 20 minutes, unless the previously placed concrete has not yet stiffened, as evidenced by the continued effective use of vibration.

450-10.3.2.1 AASHTO Type II, Florida I-Beam 36 and Double T-Beams, Piling, Slab Beams and Precast Slab Units (Except Voided Piling and Slabs): Place concrete in one or more layers or lifts. If more than one layer is used for Double T-Beams, end the first layer such that the top of the concrete is slightly below the bottom of the flange.
end the first layer such that the top of the concrete is slightly below the bottom of the flange.

450-10.3.2.2 AASHTO Type III, Type IV and Florida I-Beams 45 and 54 and Voided Units (Slabs and Piling): Place concrete in a minimum of two horizontal layers. The thickness of the first layer will be such that the top of the concrete is just above the top of the bottom flange. In voided units, end the first layer slightly above the middle height of the void.

450-10.3.2.3 All Beams 63 Inches or Deeper: Place concrete in a minimum of three horizontal layers. The thickness of the first layer will be such that the top of the concrete is slightly above the top of the bottom flange. The thickness of the second layer will be such that the top of the concrete is slightly above the bottom of the top flange.

450-10.3.2.4 Pretensioned I-Beams Containing Longitudinal Post-Tensioning Ducts: Place concrete in one continuous lift beginning in the end block zone and progressing to the other end. Do not allow the progression of the concrete placement to proceed until previously placed concrete is properly consolidated, and the rate of advancement equals the ability to fill the forms. In progression of the placement, deposit concrete within the forms on the surface of previously placed concrete.

450-10.3.2.5 Florida U-Beams: Place the concrete in Florida U-Beams in a minimum of two horizontal layers. The thickness of the first layer shall be such that the top of the concrete is above the top of the bottom flange.

450-10.4 Vibration of Concrete: Except for SCC, consolidate concrete in steel reinforced products by internal or external vibration, or combination of these methods. For SCC,

meet the requirements of Section 8.4 of the Materials Manual for production batch verification. For CFRP strand reinforced products, use SCC without the use of vibration. If further consolidation is needed, manual rodding is permitted.

Design external form vibrators for the specific use. Design forms used in conjunction with external vibration and build them to effectively transmit vibration to the concrete mass. Mount and operate form vibrators in compliance with the vibrator manufacturer's recommendations, a copy of which must be on file at the plant. Secure vibrators to the form mounts by positive locking devices so that maximum vibration is transmitted into the form. Modify or replace external form vibrator systems that are demonstrated to be ineffective. Operate vibrators at each mount location for the time necessary for complete concrete consolidation. Do not allow progressive points of vibration to exceed twice the visually effective radius of vibration. Keep forms equipped with external vibrators clean, and free of any buildup of hardened concrete.

Ensure internal vibrators are available before concrete placement is started. Use an internal vibrator with a head of such size that proper vibration of the concrete will be secured without causing movement of the prestressing strand or reinforcing bars. The vibrating frequency range must be 8,000 to 15,000 impulses per minute. Have at least one standby vibrator available on-site. Insert the vibrator in the concrete at points spaced to ensure uniform vibration of the entire mass of the concrete. Do not allow points of insertions to be further apart than the radius over which the vibrator is visibly effective. Allow the vibrator to sink into the concrete by its own weight and penetrate into the underlying layers sufficiently so that the layers are thoroughly consolidated. After the concrete is thoroughly consolidated, slowly withdraw the vibrator to avoid formation of holes.

Revise the existing placement and consolidation procedure to improve the consolidation of the concrete, if the existing placement and consolidation procedure has produced unacceptable surface defects such as honeycombing, aggregate or mortar pockets, or excessive air bubbles.

450-10.5 Finishing:

450-10.5.1 General: When concrete incorporating silica fume is used, screed and finish with a continuous water fog mist maintained above the concrete. Do not apply the mist directly toward the concrete. A monomolecular finishing aid approved by the Engineer may be applied in accordance with the manufacturer's recommendation.

450-10.5.2 Beams: Rough float the top surface of the beam and then scrub it transversely with a coarse brush or metal tine to produce a roughened surface for bonding. For the other external surfaces of prestressed beams, unless otherwise specified, apply a General Surface Finish in accordance with 400-15.1. Remove mortar leakage and stains to produce beams with a uniform appearance.

450-10.5.3 Piling: Unless a Class 5 Applied Finish Coating is specified, apply a general surface finish as specified in Section 400 to pile surfaces, except that pointing with mortar will not be required for chips and bug holes with a depth less than 1/4 inch and a diameter of less than 3/4 inch. All other general surface finish requirements will apply, including the pointing of material form tie cavities with mortar. Surface finish deficiencies that meet the definition of noncomplying prestressed products must be corrected in accordance with 450-12. Miter or round the top corners similar to the corner radius of the pile forms. Surfaces exposed during casting must have a steel trowel finish.

450-10.5.4 Slabs and Double-T Beams: When the Plans show the top surface of prestress slab units, slab beams, or Double T-Beams units to be the riding surface, apply a Class 4 floor finish in accordance with Section 400. When the Plans show the surface to be overlaid with asphalt or concrete, rough float the top surface and then scrub it transversely with a coarse brush to remove all laitance and to produce a roughened surface for bonding. For the other external surfaces of slabs and Double T-beams, unless otherwise specified, apply a General Surface Finish in accordance with 400-15.1.

450-10.6 Curing: Cure prestressed concrete for a minimum duration of 72 hours. If forms are loosened upon setting of concrete and/or removed before the 72 hour curing period is complete, expand the curing to cover the newly exposed surfaces by either coating with curing compound or extending the continuous moist cure area. Maintain concrete surface moisture at all times until curing is begun. If a water sheen is not present, apply supplemental moisture by misting or prevent water sheen loss on flat work by use of an evaporation retarder.

After the finishing operations have been completed and as soon as the concrete has hardened sufficiently to permit the application of curing material without marring the exposed surface, cover the exposed surfaces of all prestressed concrete products by one of the following procedures or other alternate curing methods. Alternate curing methods must be approved by the Engineer. Base alternate curing methods upon a demonstrated ability to retain surface moisture of the concrete and to control curing temperatures within acceptable limits. Discontinue use of any alternate curing method other than those included herein upon any indication of noncompliance with this Specification.

450-10.6.1 Continuous Moisture: Place burlap on the surface and keep it continuously saturated for the curing period by means of soil soakers, leaking pipes, or automatic sprinklers. Do not apply moisture manually. If side forms are removed during the curing period, extend the burlap to completely shield the sides of the product. Water flow may be metered to cycle repetitively for five minutes on and five minutes off during the 72 hour curing period. When it is not practical to apply moisture or curing compound inside the voided piles, cover their ends with wet burlap to prevent moisture loss.

450-10.6.2 Membrane Curing Compound: Apply a Type 2 white pigmented curing compound to all surfaces in a single-coat, continuous operation, at a uniform coverage as recommended by the manufacturer but not less than 1 gallon per 150 square feet. Apply the curing compound on the concrete surfaces that are still damp but have no free standing water. Allow surfaces covered by the membrane curing compound to remain undisturbed for the curing period. Recoat any cracks or other defects in the membrane seal which are detected during the curing period upon discovery.

If side forms are loosened during the curing period, remove them at that time and immediately coat the formed surfaces with either a Type 1 clear, or Type 2 white pigmented membrane curing compound. Maintain the surface seal for the remainder of the curing period. Bottom surfaces must be similarly coated after removal of the forms. Remove membrane curing compound to applied surfaces of concrete products to which other concrete is to be bonded by sandblasting or water-blasting until all traces of membrane curing compound are removed.

When the curing compound is applied by spraying, use a compressor driven sprayer of sufficient size to provide uniform spray at the nozzle. Keep all nozzles clean to ensure a uniform application of compound. For compressor driven sprayers, provide a calibrated reservoir which will allow the quantity of applied materials to be accurately determined.

Maintain standby equipment in case of mechanical failure. If a mechanical failure occurs, a hand held pump-up sprayer may be used to apply curing compound to the remainder of the products cast in the day's production. Suspend additional concrete placements until the mechanical sprayer is functioning properly.

450-10.6.3 Curing Blankets: Curing blankets may be used for curing the top surfaces of products. Do not use curing blankets which are torn or punctured. Securely fasten edges to provide as tight a seal as practical. Allow curing blankets to remain in place for the curing period. Should the system fail to maintain a moist condition on the concrete surface, discontinue the use of curing blankets and take immediate corrective action to prevent further loss of concrete moisture.

450-10.7 Accelerated Curing:

450-10.7.1 General: Use low-pressure steam curing, radiant heat curing or continuous moisture and heat curing. Submit steam and/or radiant heat curing procedures for CFRP strand products for approval. If accelerated curing is completed before the curing period has elapsed, continue curing for the remaining part of the curing period in accordance with one of the curing methods above.

If accelerated curing is used, furnish and use temperature recording devices that will provide accurate, continuous, and permanent records of the time and temperature relationship of the enclosure and concrete throughout the entire curing period. Place the temperature recording sensors at a minimum of two locations, spaced approximately at or near the third point of bed length, to measure the temperatures of the enclosure and concrete. Initially calibrate recording thermometers and recalibrate them at least annually in accordance with manufacturer's recommendations. Place the sensors at the center of gravity of the bottom flanges for beams. Place the sensors at the center of gravity of the cross sections perpendicular to the length for solid piles or poles, and at the midpoint of the wall thickness for voided piles or poles.

When the ambient air temperature is equal to or higher than 50ºF, start the accelerated curing by supplying or retaining moisture and the application of the heat, following the initial set period of concrete. Determine the initial set time in accordance with ASTM C403. During the application of heat, do not allow the temperature rise in the concrete product to exceed 36ºF per hour. The maximum curing temperature of the enclosure or concrete must not exceed 150ºF. Maintain the maximum curing temperature uniform throughout the enclosure, with variation of not more than 20ºF from the maximum peak temperature until concrete reaches the required release strength. Allow the concrete element to cool gradually at the maximum cooling rate of 50ºF per hour and continue the cooling at this rate until the concrete temperature is 40ºF or less above the ambient temperature outside the curing enclosure.

When the ambient air temperature is below 50ºF cure the concrete in two stages. Start the accelerated curing of the first stage during the preset period by applying heat to increase the temperature of concrete at the maximum rate of 10ºF per hour. The total temperature gain of concrete during the initial set period cannot exceed 40ºF higher than the placement temperature, or 104ºF, whichever is less. Upon obtaining the initial set, continue curing as stated above for ambient temperature of 50ºF or higher. To prevent moisture loss on exposed surfaces during the preheating period, cover products as soon as possible after casting or keep the exposed surfaces wet by misting or wet blankets. Use enclosures for heat curing that allow free circulation of heat about the product and that are constructed to contain the heat with minimum moisture loss. The use of tarpaulins or similar flexible covers may be used provided they are kept

in good repair and secured in such a manner to prevent the loss of heat and moisture. Use enclosures that cover the entire bed from stressing abutment to stressing abutment, including all exposed stranding, except when using CFRP strands. When using CFRP strands, follow the manufacturer's instructions.

450-10.7.2 Low-Pressure Steam: The steam must be in a saturated condition. Do not allow steam jets to impinge directly on the concrete, test cylinders, or forms. Cover control cylinders to prevent moisture loss and place them in a location where the temperature is representative of the average temperature of the enclosure.

450-10.7.3 Curing with Radiant Heat: Apply radiant heat by means of pipe circulating steam, hot oil or hot water, or by electric heating elements. To prevent moisture loss during curing, keep the exposed surfaces wet by misting or wet blankets.

450-10.7.4 Continuous Moisture and Heat: This method consists of heating the casting beds in combination with the continuous moisture method described above. Do not allow the heating elements to come in direct contact with the concrete or the forms. The initial covering of burlap and the continuous application of moisture will be as described in 450-10.6.1. An auxiliary cover in addition to the burlap for retention of the heat will be required over the entire casting bed. Support this cover a sufficient distance above the product being cured to allow circulation of the heat.

450-10.8 Curing Requirements for Silica Fume Concrete: Use either a 72 hour continuous moisture curing or a (12-24) hour low-pressure steam curing in accordance with 450-10.7. Upon completion of the low-pressure steam curing, continue curing for the remaining part of the 72 hour curing period by application of the curing compound, continuous moisture curing, or use of the curing blankets.

If 72 hour continuous moisture is used, begin curing silica fume concrete immediately after the finishing operation is complete and keep a film of water on the surface by misting until the curing blankets are in place. No substitution of alternative methods nor reduction in the time period is allowed. After completion of the 72 hour curing period, apply a membrane curing compound to all concrete surfaces. Apply curing compound according to 450-10.6.

450-10.9 Form Removal: Do not remove forms sooner than six hours after casting and not until the concrete strength is sufficient to avoid structural damage. For AASHTO Type V, Type VI, Florida I-Beams, and Bulb I-Beams, do not remove the forms supporting the top flange concrete sooner than 12 hours after casting unless the release strength has been reached.

450-11 Detensioning.

450-11.1 General: The required concrete strength at which the prestressing force may be transferred to the concrete in a product will be a minimum of 4,000 psi, unless specified otherwise in the Plans. Verify the release strength by compressive strength cylinder tests or other approved means, no later than 24 hours after casting and every 24 hours thereafter until release strength is developed.

In lieu of every 24 hour testing, estimate the strength development of concrete using the maturity method in accordance with ASTM C1074, the pulse velocity method in accordance with ASTM C597, or any other nondestructive test method acceptable to the Engineer, until the time of the detensioning.

Before detensioning, verify the concrete release strength by testing the compressive strength test cylinders. Make a minimum of two compressive strength release test cylinders daily for each individual mix or for each LOT, or fraction thereof, of a given concrete

mix design where the daily consumption exceeds this volume or when non-continuous batching or dissimilar curing is used. The release strength test, representing the LOT, is the average compressive strength of two test cylinders, cured under conditions similar to the product or match-cured test specimens, which are match cured until the time of release.

For products cured using accelerated curing, release the prestressing force immediately after terminating the accelerated curing process. After the detensioning operation is completed, continue to 72 hour curing period using one of the methods listed in 450-10.6. For products cured using methods other than accelerated curing, release the prestressing force within a detensioning time limit, not to exceed five calendar days after the verification of release strength by compressive strength cylinder test or other approved strength gain monitoring system.

For all products in a casting line, use the same test method for determining their release strengths. Ensure the detensioning time limit is included in the Producer QC Plan. Cure concrete cylinders used for detensioning strength tests in the same manner and location as the prestressed concrete products they represent.

For I-Beams, when side forms are loosened upon setting of concrete or removed before the 72 hour curing period is complete, the top flange dormant strands may be released after the concrete reaches a compressive strength of 2,000 psi.

Production personnel will perform detensioning operations under the supervision of a QC Inspector/Technician in accordance with Section 105 for prestressed plant quality control personnel, or certified personnel may perform detensioning operations directly.

450-11.2 Method of Stress Transfer: In all detensioning operations, keep the prestressing forces nearly symmetrical about the vertical axis of the product and apply them in a manner that will minimize sudden shock or loading. Remove or loosen forms, ties, inserts, or other devices that would restrict longitudinal movement of the products along the bed. Release hold-downs for products with draped strands in a sequence as shown in the Plans or Producer QC Plan. Cut dormant strands (partially tensioned strands) before releasing any fully tensioned strands. Release fully bonded strands next, beginning with the lowest row and moving upwards, followed progressively by strands having the minimum length of tubular sheathing through to those strands having the maximum length of tubular sheathing.

Transfer prestressing forces to the concrete by either single strand release or multiple strand release.

450-11.3 Single Strand Detensioning: Detension the strand by using a low-oxygen flame in accordance with a pattern and schedule provided in the approved shop drawings, or Producer QC Plan, or described in 450-5. Heat with a low-oxygen flame played along the strand for a minimum of 5 inches. Heat strands in such a manner that the failure of the first wire in each strand will occur after the torch has been applied for a minimum of five seconds.

Release strands in all prestressed products simultaneously and symmetrically about the vertical axis at both ends of the bed and at all intermediate points between products to minimize sliding of products. Strands in piles, sheet piles, slabs, and AASHTO Type II Beams may be detensioned at the intermediate areas after detensioning both ends.

For CFRP strands coupled with steel strands, detension the steel strands first using the flame cutting process described above. At intermediate locations where CFRP strands are continuous between adjacent precast components, flame or shear cutting of the strands is not allowed.

450-11.4 Multiple Strand Detensioning: In this method, detension all strands simultaneously by hydraulic dejacking. The total force is taken from the header by the jack, then released gradually. Do not allow the overstress required to loosen the anchoring devices at the header to exceed the force in the strand by 5%. After detensioning, strands at all points may be cut progressively from one end of the bed to the other using equipment and methods described above.

450-11.5 Cutting Strands and Bars: Upon completion of the detensioning operation, cut steel strands to required length, using an oxygen flame or mechanical cutting device. Do not use electric arc welders to cut bars or steel strands. Upon completion of the detensioning operation, cut CFRP strands to the required length using a mechanical cutting device. Do not use flame or shear cutting to cut CFRP strands.

450-11.5.1 Beams: For beam ends that will be permanently encased in concrete diaphragms, cut strands to 2.5 inches plus or minus 0.5 inch beyond the end of the product or as specified in the Plans. For beams with ends that will not be encased in permanent concrete diaphragms, mechanically cut strands a minimum of 1/8 inch below the concrete surface.

450-11.5.2 Piles: Mechanically cut strands flush with the concrete surface. For top (head) of fender piles and pile ends not embedded under final conditions, burn the strands a minimum of 1 inch below the concrete surface and clearly mark the pile to identify the top (head) end.

450-11.5.3 Poles: Mechanically cut strands to a minimum of 1/8 inch below the concrete surface.

450-11.6 Protecting Ends of Strands: Prepare the concrete surfaces and apply Type F-1 epoxy in accordance with the manufacturer's recommendations.

450-11.6.1 Beam Ends that will not be Permanently Encased in Concrete Diaphragms:

1. Remove any corrosion product from all accessible surfaces at the cut end of the strands.

2. Apply two layers of epoxy to the exposed beam ends (including clipped and chamfered surfaces) at the applicable time frame below:

a. For beams without debonded strands, at least 3 calendar days prior to shipping but no later than 50 calendar days after detensioning.

b. For beams with debonded strands, at least 3 calendar days prior to shipping, or between 42 and 50 calendar days after detensioning, whichever occurs first.

3. As an option to item 2b, the epoxy may be applied in two steps as follows:

a. To the upper area of the beam end within 4 inches of the outer stands of the bottom strand group any time after detensioning.

b. To the remaining area that includes the bottom strand group between 42 and 50 calendar days after detensioning. Ensure that the entire beam end is fully coated at least 3 calendar days prior to shipping.

Ensure that the first epoxy layer is cured before applying the second layer. The finished thickness of the epoxy coating must be a minimum of 1/16 inch and form a vertical flat plane without deviations or localized depressions from recessed strands or other defects.

Ensure that the epoxy coating is cured per the manufacturer's recommendations prior to shipping the products.

Any modifications to the time limits above must be approved by the Engineer.

450-11.6.2 Beam Ends that will be Permanently Encased in Concrete Diaphragms:

1. Cut the strands in accordance with 450-11.5.1.
2. Seal openings between strand and sheathing for debonded strands with 100% silicone sealant within fourteen calendar days of detensioning, and cure per the manufacturer's recommendations.

450-11.6. 3 Piles: Apply epoxy patches to all recessed strands.

450-11.6. 4 Poles: Coat entire face of tip (top) and butt (bottom) ends with epoxy.

450-12 Noncomplying Prestressed Products.

450-12.1 General: When a precast prestressed concrete product does not comply with the requirements of this Section or is damaged, use the following provisions for evaluating and dispositioning of deficiencies. However, when precast prestressed concrete products have been installed, the disposition of concrete cracks shall be in accordance with Section 400. Apply these provisions in all cases that clearly fall under the circumstances described in Section 400. Consider situations not covered by these specific circumstances on their individual merits. Consider and apply the following where practical.

Make all major repairs that require a repair proposal under the observation and the satisfaction of the QC Manager or designee.

450-12.2 Identification of Defects: The QC Manager, or QC inspectors under direction of the QC Manager, will examine all deficiencies within the time limit specified in 450-2.3 and 450-2.4, to determine the applicable provisions and requirements of this Article and which course of action is appropriate.

1. If the QC Manager or designee determines that a deficiency is a cosmetic or minor defect, as stated 450-12.3, appropriate repairs may be executed in accordance with 450-13.
2. If the deficiency is major as defined in this Section, and is repairable for acceptance, submit a completed Noncomplying Prestressed/Precast Concrete Component Data Sheet (Form No. 700-030-10) to the Engineer within 30 days of the defect identification.

Submit an Engineering Analysis Scope in accordance with 6-4 for approval, to address the deficiency. A previously approved Engineering Analysis Report (EAR) may not be applied to a current major repair without the approval from the original engineer who signed and sealed the previously approved EAR.

Make major repairs under the observation of and to the satisfaction of the QC Manager. The Engineer reserves the right to witness the repairs.

The disposition of deficiencies and repair methods provided herein must at no time, and under no circumstances, be used as an excuse for or applied in such a manner so as to relieve the Contractor of his responsibility for QC. The number and type of deficiencies evaluated under this Specification will, however, be used in evaluating the Contractor's QC.

The Engineer may require a credit on any products with deficiencies that require an EAR and are accepted for use in the structure. Bear the costs of repairs and any actions taken to rectify deficiencies at no expense to the Department.

450-12.3 Common Defects in Precast Prestressed Concrete Products:

450-12.3.1 Surface Deficiencies: Surface deficiencies are defined below and include spalls, chips, bug holes, surface porosities, honeycombs, and shallow surface cracks.

Regardless of the types of deficiencies, when the total surface area of all deficiencies within a single product exceeds 1.0% of the product's area that will be exposed to the environment, the deficiencies are considered major.

450-12.3.1.1 Bug Hole: A bug hole is a void caused by air that is entrapped against the form and that has an area up to 3.0 square inches and a depth up to 1.5 inches. Treat any bug hole with a dimension exceeding either of these dimensions as a honeycomb. The Engineer will not require repair of any bug hole with a depth less than 0.25 inch and less than 0.75 inch in diameter, unless otherwise indicated in the Plans or Specifications.

450-12.3.1.2 Spall: A spall is a depression resulting when a fragment is detached from a larger mass by impact, action of weather, by pressure or by expansion within the larger mass.

A cosmetic spall is a circular or oval depression not greater than 1.0 inch in depth nor greater than 3.0 square inches in area, and must be repaired in accordance with 450-13.2.

With the exception of spalls in the bearing areas and edges of the top flange, a minor spall is defined as a spall not larger than 2.0 square feet and no deeper than one inch plus the sum of the concrete cover and the diameter of the bar in the first layer of reinforcing. Repair minor spalls in accordance with 450-13.4.

Repair cosmetic and minor spalls as described above, except for spalls with visually exposed reinforcing steel, prestressing strand, inserts, or weldment surfaces, which require repair in accordance with 450-13.5

Spalls located at the edges of the top flange are considered minor spalls as follows:

1. A spall on one edge of the top flange, without a coincident spall on the other edge of the top flange, is considered a minor spall if the total longitudinal length of the defect does not exceed 10 feet and any lateral dimensions of the spall measured perpendicular to the longitudinal axis of the beam are not greater than 25% of the width of the top flange.

2. Coincident spalls on opposite edges of the top flange are considered minor spalls if the total length of the defects within both spalls does not exceed 10 feet and any lateral dimensions of the spalls at a given location measured perpendicular to the longitudinal axis of the beam are not greater than 25% of the width of the top flange.

Spalls are considered major when they are located in the extended bearing area of the beams as defined in 450-12.3.5, or if any depression exceeds the dimensions that are described for minor spalls.

450-12.3.1.3 Chip: A chip is the local breaking of the corners or edges of the concrete with the resulting void containing angular surfaces. Repair chips in accordance with 450-12.3.1.2.

450-12.3.1.4 Surface Porosity: Surface porosity is considered a minor defect and is the localized porosity of a formed surface due to medium scaling. Medium scaling is defined as the loss of surface mortar up to 3/8 inch in depth and exposure of concrete aggregate. Repair surface porosity in accordance with 450-13.3.

450-12.3.1.5 Honeycombing: Honeycombing is voids in the concrete, loss of fines or other material from between the aggregate particles, the inclusion of air pockets

between aggregate particles, or larger volumes of lost material. Remove honeycombing in its entirety to sound concrete before establishing the classification of the defect.

Minor honeycombing is a void no deeper than concrete cover and no larger than 2.0 square feet in area after the removal of unsound material. Repair minor honeycombing in accordance with 450-13.6.

Major honeycombing is a void deeper than concrete cover regardless of the surface area, or shallower but with a surface area greater than 2.0 square feet that results after the removal of unsound material.

450-12.3.1.6 Shallow Surface Cracks: Shallow surface cracks are considered a minor defect, and are defined as the separation of the formed or finished surface up to 0.25 inch in depth.

Remove the affected material and repair the surface in accordance with 450-13.3.

450-12.3.2 Segregated Appearance in Hardened Concrete: Segregation of hardened concrete is considered a major defect. When hardened concrete segregation is evident, evaluate in accordance with FM 5-617.

450-12.3.3 Cold Joints: A cold joint is a plane of weakness in concrete caused by a batch of concrete setting before the next batch is added, so that the two batches fail to bond. A cold joint is considered a major defect and requires an EAR.

450-12.3.4 Formed Surface Misshaping: Formed surface misshaping is the visual and measurable deficiency or excess of material from the specified tolerance on any surface of a product.

1. Pile Ends: Make square pile ends which are outside this Section's tolerances by grinding in accordance with 450-13.7, or any other means of removal as approved by the Engineer. Reshape the chamfer if more than 0.25 inch from the cast pile end is removed and such removal affects the chamfer dimension.

2. Pile Chamfers**:** Reshape chamfers outside of this Section's tolerances to within the tolerances in accordance with 450-13.7.

3. Other Surfaces: Any deficiency exceeding the plan dimensions for size, length, squareness, designated skew, plumbness, and the like by up to twice the specified plus (+) tolerance may be corrected by grinding to within the allowable tolerance in accordance with 450-13.7. Any deficiency exceeding the specified minus (-) tolerance or twice the specified plus (+) tolerance will be considered major.

450-12.3.5 Bearing Area Flaws: Consider the bearing area to extend from the end of the product to 3 inches beyond the edge of the bearing contact area for the full product width.

Do not allow the bearing plate or bearing area plane of precast prestressed concrete beam and slab units to deviate from a true plane by more than 1/8 inch when tested in all directions with a steel straightedge. In the event that a 100% true plane is not achieved, the Engineer will accept a surface having not less than 80% of its area in a true plane provided the deviations are evenly distributed. Remove minor convex projections by grinding with an abrasive stone. The Engineer will accept minor depressions, provided that they amount to not more than 20% of the bearing area, are evenly distributed over the entire bearing area, and are not deeper than 1/8 inch.

450-12.3.6 Cracks: A crack may appear before or after detensioning and may or may not cause separation throughout the product thickness or depth. Identify cracks by the

classifications and locations described below and subject them to the disposition required by the identified crack.

If the total surface length of all cracks within a single product, regardless of their width and depth, located between the end zones exceeds one-quarter of the product's length, the cracks are considered major. Establish crack sizes subsequent to release of all pretensioning forces.

The Engineer will reject any pile that is cracked to the point that a transverse or longitudinal crack extends through the pile, shows failure of the concrete as indicated by spalling of concrete on the main body of the pile adjacent to the crack, or which in the opinion of the Engineer will not withstand driving stresses. Occasional hairline surface cracking caused by shrinkage or tensile stress in the concrete from handling will not be cause for rejection.

450-12.3.6.1 Locations of Cracks: Regardless of cause and for the purposes of this Specification, cracks will be identified as occurring in either critical or non-critical locations of the product in accordance with the following criteria and conditions:

450-12.3.6.1.1 Critical Location Cracks: Critical locations of cracks are any locations in which a crack would tend to open under stresses occurring at any time during the service life of the structure, or which may reduce the ultimate capacity or fatigue life of the product. Specifically, critical locations of cracks are any locations in a product not defined and not included in 450-12.3.6.1.2 as non-critical. Cracks in critical locations require engineering evaluation and disposition in accordance with 450-12.

450-12.3.6.1.2 Non-Critical Location Cracks: Non-critical locations of cracks are defined by the position within a product's length, the position within a product's depth, and the orientation of the crack.

1. Piles**:** Surface cracks in any direction and of a length not exceeding twice the width of the pile.

2. Simple Span Pretensioned Concrete Beams: End zones (within a distance of three times the depth of the product from the end):

a. Horizontal or diagonal cracks at either or both ends in the top flange and web of the product, not in the plane of nor intersecting any row of prestressing strands, and extending from the end of the product for a length not to exceed the product's depth.

b. Vertical cracks extending through the top flange not to exceed one-half of the product's depth after detensioning.

c. Mid-span region (between end zones): Vertical cracks extending through the top flange and web of the product.

d. Any Location: Horizontal crack at the interface of the web and top flange which is not longer than the product's depth.

e. Intermediate diaphragms of Florida U-Beams: cracks at any location.

3. Simple Span Double T-Beams:

a. End zones (within a distance of twice the depth of the product from the end): One horizontal crack at either or both ends and in the top flange of the product, not in the plane of nor intersecting any row of prestressing strands, and extending from the end of the product for a length not to exceed half the product's depth.

b. Mid-span Region (between end zones): Vertical cracks extending through the top flange and not exceeding half the web depth of the product.

c. Any Location: Horizontal crack at the interface of the web and top flange which is not longer than the product's depth.

4. Pretensioned I-Beams Containing Longitudinal Post-Tensioning Ducts:

a. End zones (within a distance of twice the depth of the beam from the end): Vertical cracks in the bottom half of the beam within an end zone with no post-tensioning anchorages and where the post-tensioning ducts are located in the top of the beam at the location of a permanent substructure support. Horizontal or diagonal cracks at either or both ends in the top flange and web of the product where no post-tensioning anchorage zone is present.

b. Mid-span Region (between quarter points): Vertical cracks in the web and top flange of the beam provided the beam is to be supported at each end in its final position in the structure.

c. Any Location: Horizontal cracks not longer than the beam's depth and only at the interface of the web and top flange provided the beam is to be supported at each end in its final position in the structure.

5. Post-Tensioned Beams for Drop-In Spans:

a. Pier Sections: Horizontal or diagonal cracks at either or both ends in the top flange and web of the product.

b. Drop-In Sections: Same as simple span pretensioned concrete beams.

c. End Sections: At end of beam with post-tensioning anchorages: same as pretensioned I-Beams containing longitudinal post-tensioning ducts. At end of beam adjacent to pier sections: same as for simple span pretensioned concrete beams.

6. Simple Span Prestressed Slab Beams and Slab Units:

a. End Zones (within a distance of twice the depth of the product from the end): One horizontal crack at either or both ends in the top half of the product, which is not in the plane of nor intersecting any row of prestressing strands, and extending from the end of the product for a length not to exceed half the product's depth.

b. Any Location (after detensioning): Vertical cracks in the top half of the product's depth.

7. Pretensioned Concrete Poles:

a. Longitudinal cracks - Any location: The length of each crack must be less than twice the base width of the pole, or transverse or diagonal cracks perpendicular to or at an inclined angle to the longitudinal direction of the pole.

b. Edge cracks: Cracks exhibiting at the edge and extending across one or two adjacent planes of a square pole, less than 2.0 inches of total length across all planes.

450-12.3.6.2 Classification and Treatment of Cracks: Cracks in precast prestressed components, excluding piling, will be identified according to their width, and surface appearance, and classified as follows:

450-12.3.6.2.1 Cosmetic Cracks: Cracks located in non-critical locations on product which are less than 0.006 inch wide. Based on the environmental classification of the site where the product will be located, treat cosmetic cracks as follows:

1. Slightly or moderately aggressive environment: Do not treat cracks.

2. Extremely aggressive environment: After detensioning, apply penetrant sealer in accordance with Section 413.

450-12.3.6.2.2 Minor Cracks: Cracks located in non-critical locations on products which are between 0.006 and 0.012 inch wide, inclusive. Based on the environmental classification of the site where the product will be located and the final elevation of the product on the site, treat minor cracks as follows:

1. Slightly aggressive environment: Do not treat the cracks.

2. Moderately aggressive environment:

a. For products that will be located at an elevation of more than 12 feet above the existing ground level or above mean high water elevation: Do not treat cracks.

b. For products that will be located at an elevation within 12 feet above the existing ground level or above mean high water elevation: Apply a penetrant sealer on the cracks after detensioning in accordance with Section 413.

3. Extremely aggressive environment:

a. For products that will be located at an elevation of more than 12 feet above the existing ground level or above mean high water elevation: Apply a penetrant sealer on the cracks after detensioning in accordance with Section 413.

b. For products that will be located at an elevation within 12 feet above the existing ground level or above mean high water elevation: Inject epoxy into the cracks after detensioning in accordance with Section 411.

450-12.3.6.2.3 Major Cracks: Cracks, regardless of environmental classification, located in critical locations on products or cracks in non-critical locations of the product that are greater than 0.012 inch wide. Major cracks are considered major defects and require an EAR in accordance with Section 6 to determine the disposition of the affected product

450-12.3.6.2.4 Cracks in the Riding Surface: Repair cosmetic and minor cracks in the top surface of components which will become the riding surface (with no overlays), once in service, regardless of the environmental classification as follows:

1. Epoxy inject cracks wider than 0.006 inch in accordance with Section 411, unless the Engineer approves the sealing of cracks with high molecular weight methacrylate in accordance with Section 413.

2. Seal cracks that are 0.006 inch wide or less by applying a penetrant sealer in accordance with Section 413.

450-13 Repair Methods and Materials.

450-13.1 General: Before beginning the repairs of bug holes, spalls, chips, surface porosity, and honeycomb, remove all laitance, loose material, form oil, curing compound and any other deleterious matter from the repair area. Repair cosmetic or minor deficiencies by methods specified herein. Submit alternative repair methods as needed.

For each project, maintain the record of deficiencies and their repair methods. Ensure the record includes information about product description, unit serial number, date cast,

defect description including dimensions, repair method and materials, defect discovery date, and signature of producer's QC Manager indicating concurrence with the information.

Use materials for concrete repair that will meet or exceed the strength requirement of the concrete class used. Cure repaired surfaces for the full 72 hour curing time or for the curing time as recommended by the manufacturer of the repair material. Ensure the repaired surfaces have a surface texture, finish and color which matches the appearance of the unaffected surrounding area of the product.

450-13.1.1 Product Acceptance on the Project: Use only materials listed on the Approved Product List (APL), in accordance with the following Sections:

Epoxy Compounds (Type F) …….. Section 926
Materials for Concrete Repair……. Section 930
Non-shrink Grout…… Section 934

450-13.2 Cosmetic Surface Filling: Repair areas to be filled with an approved non-shrink grout or material for concrete repair. Mix, apply, and cure the material in accordance with the manufacturer's recommendations. Coating of the prepared surface with epoxy compound before placement is not required.

450-13.3 Surface Restoration: Maintain the surface continuously wet for a minimum of three hours before application of repair material. Repair areas to be restored with a mortar mix consisting by volume of one part cement, 2.5 parts sand that will pass a No. 16 sieve, and sufficient water to produce a viscous slurry mix or repair areas to be restored with an approved non-shrink grout or material for concrete repair. Mix, apply, and cure the material in accordance with the manufacturer's recommendations. Cure areas repaired with a mortar mix in accordance with 450-10.6. Coating of the prepared surface with epoxy compound before placement is not required.

450-13.4 Cutting and Filling: Carefully cut all feathered edges of the area to be repaired back perpendicular to (or slightly undercut from) the surface and to the depth of sound concrete or to a minimum depth of 1/2 inch, whichever is deeper. Coat the prepared surface with an approved epoxy bonding compound applied in accordance with the manufacturer's recommendations. Fill the cutout area with an approved non-shrink grout, material for concrete repair, or epoxy mortar. Mix, apply, and cure in accordance with the manufacturer's recommendations. Firmly consolidate the material in the cutout area.

450-13.5 Restoration of Surfaces and Edges: When reinforcement is exposed, remove concrete from around the items to provide a 1-inch clearance all around. When less than one-half the reinforcement diameter is exposed, a positive connection utilizing anchor screws may be proposed in lieu of 1-inch clearance all around. Do not damage the reinforcement. Form surfaces and edges to the original dimensions and shape of the product. Coat the prepared surface with an approved epoxy bonding compound applied in accordance with the manufacturer's recommendations. Restore surfaces and edges with an approved non-shrink grout, material for concrete repair, or epoxy mortar. Mix, apply, and cure in accordance with the manufacturer's recommendations. Firmly consolidate the material in the area to be repaired. Restore surfaces and edges to the original dimensions and shape of the product.

450-13.6 Removal and Restoration of Unsound Concrete: Carefully cut the area of unsound concrete to be repaired back perpendicular to (or slightly undercut from) the surface and to the depth of sound concrete or to a minimum depth of 1 inch, whichever is deeper. When reinforcement is exposed, remove the concrete from around the items to provide a 1-inch clearance all around. When less than one-half the reinforcement diameter is exposed, a positive

connection utilizing anchor screws may be proposed in lieu of 1-inch clearance all around. Do not damage the reinforcement. Coat the prepared surface with an approved epoxy bonding compound applied in accordance with the manufacturer's recommendations. Fill the area to be repaired with an approved non-shrink grout, concrete repair material, or epoxy mortar. Mix, apply, and cure in accordance with the manufacturer's recommendations. Firmly consolidate the material in the area to be repaired. Restore surfaces and edges to the original dimensions and shape of the product.

450-13.7 Surface Grinding: Grind off misshaped formed surfaces with an abrasive stone. Apply two coats of penetrant sealer in accordance with the requirements of Section 413, to any surfaces which are not subsequently encased in concrete, immediately after grinding has been accepted. Do not apply a penetrant sealer to any surfaces to be subsequently encased in concrete.

450-13.8 Treatment of Cracks: Treat cracks in accordance with 450-12.3.6.

450-14 Handling, Storage, Shipping and Erection.

450-14.1 Handling: All products which are pretensioned may only be handled after transfer of the prestressing force. For products that are prestressed by a combination of pretensioning and post-tensioning do not handle before sufficient prestress has been applied to sustain all forces and bending moments due to handling. Exercise care in handling to prevent damage to products. Lift and move products so as to minimize stresses due to sudden changes in momentum.

Calculate pick up and dunnage points. Pick up products only at points designated as pickup points as shown on the Plans or shop drawings. Maintain all beams in an upright position at all times.

Evaluate the temporary stresses and stability of beams during their handling. The temporary stresses induced into the products during handling must be within the acceptable stresses at release listed in the Department's Structures Design Guidelines. Take appropriate action to increase the stability of products during handling when the factor of safety against lateral buckling instability is below 2.0. Include the expected fabrication tolerance for sweep in the analysis. The analysis procedure provided by the PCI or similar procedures may be used for the stability evaluation.

Verify lifting devices for capacity in lifting and handling products, taking into account various positions during handling. Keep multiple component lifting devices matched to avoid non-compatible use. When a product has multiple lifting devices, use lifting equipment capable of distributing the load at each device uniformly to maintain the stability of the product. When the lifting devices are grouped in multiples at one location, align them for equal lifting.

Take appropriate steps to prevent the occurrence of cracking. When cracking occurs during handling and transportation, revise handling and transporting equipment and procedures as necessary to prevent cracking for subsequent products.

450-14.2 Storage: Store precast prestressed beams, Double T-Beams, slab beams and slab units on only two points of support located within 18 inches of the end of the product or as calculated. Support skewed beams, Double T-Beams, slab beams or slab units within 18 inches of the end of the full product section or as calculated. Do not support slab beams on the outer 6 inches of the product width. Support other products on an adequate number of supports so as to keep stresses in the products within the allowable stresses at release listed in the Department's Structures Design Guidelines. Locate multiple supports (more than two) within 1/2 inch of a

horizontal plane through the top surface of the supports. Adequately brace beams as necessary to maintain stability.

All supports must be level and on adequate foundation material that will prevent shifting or differential settlement which may cause twisting or rotation of products. Immediately pick up products in storage that have rotated or twisted and adjust the supports to provide level and uniform support for the product.

Support prestressed products that are stacked by dunnage placed across the full width of each bearing point and aligned vertically over lower supports. Move dunnage points in accordance with 450-2.3 with the approval of the QC Manager. Do not use stored products as a storage area for either shorter or longer products or heavy equipment.

Where feasible, base the selection of storage sites, storage conditions and orientation upon consideration of minimizing the thermal and time-dependent creep and shrinkage effects on the camber and/or sweep of the precast pretensioned products.

Continuous application of water during the initial 72 hour moist curing period may be interrupted for a maximum of one hour to allow relocation of precast prestressed concrete elements within the manufacturing facility. Keep the moist burlap in place during relocation of the element.

450-14.3 Shipping: Do not ship precast prestressed concrete products to the project site prior to the completion of the 72 hour curing period and attainment of the required 28-day strength. Verification of the shipping strength test, before 28 days, is permitted by testing compressive strength cylinders that are cured under the conditions similar to the product or by testing temperature match cured cylinders.

The use of maturity method, ASTM C1074, pulse velocity method in accordance with ASTM C597, or any other nondestructive test method acceptable to Engineer, is permitted to estimate the strength before its verification by test cylinders. The shipping strength test is the average compressive strength of two test cylinders. Do not ship products until accepted and stamped by the QC Manager or the inspectors under the direct observation of the QC Manager or designee.

In the case of elements repaired due to major defects, notify the Engineer at least 72 hours in advance of shipping to verify compliance with the Specification.

At the beginning of each project, provide a notarized statement to the Engineer from a responsible company representative certifying that the plant will manufacture the products in accordance with the requirements set forth in the Contract Documents and Producer QC Plan.

The QC Manager’s stamp on each product indicates certification that the product was fabricated in conformance with the Producer QC Plan, the Contract, and the Specifications. Ensure that each shipment of prestressed concrete products to the project site is accompanied with a signed or stamped delivery ticket providing the description and the list of the products.

Evaluate the temporary stresses and stability of all products during shipping and locate supports, generally within 18 inches from the beam end, in such a manner as to maintain stresses within acceptable levels. Include impact loadings in the evaluation. Do not support slab beams on the outer 6 inches of the product width.

450-14.4 Erection: Erect precast prestressed products without damage. Meet the handling and storage requirements of 450-14.1 and 450-14.2 for field operations. Before casting diaphragms and the deck slab, do not allow the horizontal alignment of prestressed concrete beams to deviate from a straight line connecting similar points of beam ends by more than the

sweep tolerances specified in 450-2.3. Adequately brace beams as necessary to maintain stability.

450-15 Measurement and Payment.

450-15.1 General: The work specified in this Section will be measured and paid for as shown below for the particular item involved. Precast prestressed concrete members are acceptable to the Department for full payment when all requirements of the Contract Documents have been met. No partial payments will be made for precast prestressed concrete members until the 28-day strength requirement, along with other applicable Specification requirements, have been met.

450-15.2 Prestressed Concrete Piling: Payment will be made at the Contract unit price per foot for the particular type of piling, measured and paid for as specified in Section 455, including the provisions for cutoffs and splices.

450-15.3 Prestressed Concrete Beams: Payment will be made at the Contract unit price per foot for Prestressed Beams, complete in place and accepted. Final pay lengths will be plan quantity based on casting lengths, as detailed in the Plans, subject to the provisions of 9-3.2.

450-15.4 Prestressed Concrete Slab Units and Slab Beams: Payment will be made at the Contract unit price per foot for the units, complete in place and accepted. Final pay lengths will be plan quantity based on casting lengths, as detailed in the Plans, subject to the provisions of 9-3.2.

450-16 Basis of Payment.

Price and payment will be full compensation for all work and materials specified in this Section, including reinforcement, pretensioning strand, embedded ducts, hardware, inserts and other materials as required, to fabricate, transport and place the product into its permanent position in the structure.

Payment for the items will be made under the following:

Item No. 450- 1-	Prestressed Beams - per foot.
Item No. 450- 2-	Prestressed Beams: Florida I-Beams - per foot.
Item No. 450- 3-	Prestressed Slab Units - per foot.
Item No. 450- 4-	Prestressed Beam U-Beams - per foot.
Item No. 450- 8	Prestressed Beams: Florida Slab Beam – per foot.
Item No. 450- 88-	Prestressed Slab Units Transversely Post-Tensioned - per square foot.

SECTION 451
PRESTRESSED SOIL ANCHORS

451-1 Description.

Construct prestressed soil anchors consisting of a high strength steel tendon anchored to the retaining wall on one end and to the soil on the other end through a bulb of pressure injected portland cement concrete grout. Test each anchor by prestressing to the load indicated in the Contract Documents before locking off to the retaining wall.

Select the prestressed soil anchor type and the installation method, and determine the bond length and anchor diameter. Assume responsibility for installing prestressed soil anchors that develop the load-carrying capacity indicated in the Plans in accordance with 451-7.

Provide corrosion protection for permanent prestressed soil anchors. The Engineer will not require corrosion protection for temporary prestressed soil anchors. Protect anchor tendons from corrosion as shown in the Plans in accordance with 451-8.

451-2 Definitions.

1. Anchorage Devices: The anchor head wedges or nuts which grip the prestressing steel.

2. Bearing Plate: The steel plate which distributes the prestressed soil anchor force to the structure.

3. Bond Length: The length of the prestressed soil anchor which is bonded to the ground and transmits the tensile force to the soil or rock. For a compression prestressed soil anchor, the bond length will be different from the tendon bond length.

4. Factored Design Load: The maximum anticipated load that will be applied to the prestressed soil anchor during its service life after completing stressing and testing. The factored design load includes appropriate load factors to ensure that the overall structure has adequate strength for its intended use.

5. Fine-grained Soils: Soils with at least 50% of the material smaller than the No. 200 sieve size.

6. Tendon: The complete anchor assembly, excluding grout, consisting of anchorage and prestressing steel with sheathing and coating when required.

7. Coupling: The means by which the prestressing force may be transmitted from one partial-length of prestressing tendon to another.

8. Sheathing: Enclosure around the prestressing steel to avoid temporary or permanent bond between the prestressing steel and the surrounding grout or to provide corrosion protection.

9. Coating: Material used to protect against corrosion or lubricate the prestressing steel.

10. Anchor Grout: Portland cement grout that is injected into the anchor hole to provide anchorage at the bond length of the tendon.

11. Proof Load: Temporary loading of an anchor to its factored design load for testing purposes.

12. Transfer (Lock-Off) Load: Prestressing force in an anchor after proof loading immediately after the force has been transferred from the jack to the stressing anchorage.

13. Stressing Anchorage: That portion of assembly not within the earth fill.

14. Alignment Load: A small load maintained on an anchor during testing sufficient to keep the testing equipment positioned.

15. Performance Test: Incremental test loading and unloading of a prestressed anchor recording the movement of the tendon at each increment.

16. Proof Test: Incremental loading of a prestressed anchor recording the movement of the tendon at each increment.

17. Creep Test: A test to determine the movement of the tendon at constant load during a certain period of time.

18. Lift-Off Reading: A check made to determine that the actual transfer load is within 10% of the desired transfer load. This check is made immediately after transferring the load to the stressing anchorage.

19. Residual Movement: The non-elastic (non-recoverable) movement of an anchor measured during soil anchor testing.

20. Elastic Movement: The recoverable movement of an anchor measured during soil anchor testing.

21. Prestressed Soil Anchor: A system, referred to as a tieback or a ground anchor, used to transfer tensile loads to soil or rock. A prestressed soil anchor includes all prestressing steel, anchorage devices, bearing plates, grout, coatings, corrosion protection, sheathings and couplers if used.

22. Minimum Specified Ultimate Tensile Strength: The minimum breaking strength of the prestressing steel as defined by the specified standard.

23. Tendon Bond Length: The length of the tendon which is bonded to the anchor grout.

24. Total Anchor Length: The unbonded length plus the tendon bond length.

25. Unbonded Length: The length of the tendon which is not bonded to the grout. The grout surrounding the unbonded length is a void filler and provides corrosion protection.

26. Service Load: The load anticipated to be applied to the prestressed soil anchor during its service life after completing stressing and testing in order to limit deflection. The service load does not include load factors.

27. Test Stressing Length: The unbonded length plus the length extending through the jack up to the anchorage devices during any anchor acceptance test (i.e. Performance Test, Proof Test or Creep Test).

451-3 Qualifications.

The Contractor or subcontractor performing the work described in this Section shall have installed prestressed soil anchors for a minimum of five years. At the preconstruction conference, the Contractor shall submit a list containing at least five projects, completed within the last five years, where the Contractor has installed prestressed soil anchors. Include a brief description of each project and a reference for each project listed. As a minimum, include with the reference an individual's name and current phone number.

Prior to the start of work, the Contractor shall submit a list identifying his engineer, drill operators, and on-site supervisors who will be assigned to the project. Include in the list a summary of each individual’s experience.

Assign a Specialty Engineer to supervise the work with at least five years of experience in the design and construction of permanently-anchored structures. Do not use manufacturers' representatives in order to meet the requirements of this Section. Provide drill operators and on-site supervisors that have a minimum of one year experience installing permanent prestressed soil anchors with the Contractor’s organization.

The Engineer will approve or reject the Contractor’s qualifications and staff within 15 working days after receipt of the submission. Do not start work on any prestressed soil anchor wall system or order materials until receiving approval of the qualifications. The Engineer may suspend the prestressed soil anchor work if the Contractor or subcontractor substitutes

unqualified personnel for approved personnel during construction. If work is suspended due to the substitution of unqualified personnel, the Contractor is fully liable for additional costs resulting from the suspension of work and the Department will not allow any adjustment in Contract Time resulting from the suspension of work.

451-4 Materials.

451-4.1 General: Meet the following requirements:

Concrete .....Section 346
Prestressed Construction.....Section 450
Structural Steel and Miscellaneous Metals .....Section 460

451-4.2 Prestressing Steel: Use prestressed soil anchor tendons fabricated from single or multiple elements of one of the following prestressing steels, unless otherwise shown in the Plans:

1. Steel bars meeting the requirements of AASHTO M 275.
2. 7-wire, low-relaxation strands meeting the requirements of AASHTO M 203.
3. “Compact” 7-wire, low-relaxation strands meeting the requirements of ASTM A779.

451-4.3 Anchorage Covers (include for temporary anchors only when shown in the Plans): Use exposed anchorage covers fabricated from steel or ductile cast iron with a minimum thickness of 0.10 inches. Ensure that the cover is securely attached to the anchorage device or bearing plate. If the cover is to be grease filled, ensure the cover forms a permanent watertight enclosure for the anchorage device.

451-4.4 Anchorage Devices: Use anchorage devices capable of developing 95% of the minimum specified ultimate tensile strength of the prestressing steel tendon. Use anchorage devices that meet the static strength requirements of Section 3.1.6(1) and Section 3.1.8(1) of the Post Tensioning Institute “Guide Specification for Post-tensioning Materials”. Use couplers for tendon sections capable of developing 95% of the minimum specified ultimate tensile strength.

451-4.5 Cement Grout: Use grout for anchorage consisting of a pumpable mixture of portland cement meeting the requirements of Section 921, sand, water, and admixtures. The Contractor may use admixtures which control bleed, improve flowability, reduce water content, and retard set in the grout subject to the approval of the Engineer. The Contractor may only add expansive admixtures to the grout used for filling sealed encapsulations, trumpets, and anchorage covers. Do not use accelerators. Use admixtures compatible with the prestressing steels and mixed in accordance with the manufacturer's recommendations.

Do not perform strength testing as system performance will be measured by proof-testing each anchor. The Department may require cylinder testing if the Contractor uses admixtures or irregularities occur in anchor testing. Cast a set of three 4 inches x 8 inches grout cylinders for each LOT in accordance with ASTM C31, except fill the cylinder molds in one layer without rodding. Use grout that attains a minimum compressive strength of 3,400 psi within seven days, when tested in accordance with ASTM C39.

451-4.6 Bearing Plate: Use bearing plates fabricated from steel meeting the requirements of AASHTO M 270 or ASTM A709.

451-4.7 Bondbreaker: Use bondbreaker fabricated from a smooth plastic tube or pipe having the following properties:

1. Resistant to chemical attack from aggressive environments, grout, or grease
2. Resistant to aging by ultra-violet light
3. Fabricated from material non-detrimental to the tendon

4. Capable of withstanding abrasion, impact, and bending during handling and installation

5. Enable the tendon to elongate during testing and stressing

6. Allow the tendon to remain unbonded after lock-off.

451-4.8 Centralizers: Use centralizers fabricated from plastic, steel, or material that is nondetrimental to the prestressing steel. Do not use wood. Ensure that the centralizer is able to support the tendon in the drill hole, and position the tendon so a minimum of 0.5 inches of grout cover is provided over the tendon bond length. In addition, locate the upper centralizer a maximum of 5 feet from the top of the tendon bond length, and locate the lower centralizer a maximum of 12 inches from the bottom of the tendon bond length. The Engineer will not require centralizers on pressure injected tendons if the Contractor installs the anchor in coarse grained soils using grouting pressures greater than 150 psi. The Engineer will not require centralizers if the Contractor installs the anchors and grouts them through a hollow stem auger and maintains the hole full of stiff grout (slump less than 9 inches) during extraction of the auger.

451-4.9 Corrosion Inhibiting Grease (include for temporary anchors only when shown in the Plans): For corrosion inhibiting grease, meet the requirements of Section 3.2.5 of the Post Tensioning Institute Specification for Unbonded Single Strand Tendons.

451-4.10 Heat Shrinkable Tubes: Use heat shrinkable tubes fabricated from a radiation cross-linked polyolefin tube internally coated with an adhesive sealant. Prior to shrinking, ensure that the tube has a nominal wall thickness of 24 mils. Ensure that the adhesive sealant inside the tube has a nominal thickness of 20 mils.

451-4.11 Sheath (include for temporary anchors only when shown in the Plans): Use a sheath as part of the corrosion protection system for the unbonded length portion of the tendon fabricated from one of the following:

1. A polyethylene tube pulled or pushed over the prestressing steel. Use polyethylene Type II, III, or IV as defined by ASTM D1248 or approved equal, with a minimum wall thickness of 60 mils, plus or minus 10 mils.

2. A hot-melt extruded polypropylene tube. Use polypropylene cell classification PP 210 B5554211 as defined by ASTM D4101 or approved equal, with a minimum wall thickness of 60 mils, plus or minus 10 mils.

3. A hot-melt extruded polyethylene tube. Use polyethylene high density Type III as defined by ASTM D3350 and ASTM D1248 (or approved equal), with a minimum wall thickness of 60 mils, plus or minus 10 mils.

4. Steel tubing meeting the requirements of ASTM A500, with a minimum wall thickness of 0.20 inches.

5. Steel pipe meeting the requirements of ASTM A53, Schedule 40 minimum.

6. Plastic pipe meeting the requirements of ASTM D1785, Schedule 40 minimum.

7. A corrugated tube meeting the requirement of the tendon bond length encapsulation.

451-4.12 Spacers: Use spacers to separate elements of a multi-element tendon and which permit grout to flow freely up the drill hole. Use spacers fabricated from plastic, steel, or material which is nondetrimental to the prestressing steel. Do not use wood. The Contractor may use a combination centralizer-spacer.

451-4.13 Tendon Bond Length Encapsulations (include for temporary anchors only when shown in the Plans): When the Contract drawings require the tendon bond length to be

encapsulated to provide additional corrosion protection, use encapsulation fabricated from one of the following:

1. High density corrugated polyethylene tubing meeting the requirements of AASHTO M 252, with a minimum wall thickness of 30 mils
2. Deformed steel tubing or pipes with a minimum wall thickness of 25 mils
3. Corrugated, PVC tubes manufactured from rigid PVC compounds meeting the requirements of ASTM D1784, Class 13464-B.

451-4.14 Trumpet (include for temporary anchors only when shown in the Plans): Use a trumpet to provide a transition from the anchorage to the unbonded length corrosion protection fabricated from a steel pipe or tube meeting the requirements of ASTM A53 for pipe or ASTM A500 for tubing. Use a trumpet that has a minimum wall thickness of 0.125 inches for diameters up to 4 inches and 0.20 inches for larger diameters.

451-4.15 Water: Use potable water for mixing grout.

451-4.16 Grout Tube: Use a grout tube fabricated from a high density polyethylene tube, or a PVC pipe, or a steel pipe with a 0.5 inches minimum inside diameter.

451-5 Tendon Fabrication.

Provide tendons that are either shop or field fabricated. Fabricate the tendon as shown on the approved shop drawings.

Ensure that tendons are free of dirt, rust, or any other deleterious substance. Degrease the bond length.

Handle and protect tendons, prior to installation, in a manner to avoid corrosion and physical damage. The Engineer will consider damage such as abrasion kinks, welds and weld splatters, cuts, and nicks which impair the proper performance of the tendon cause for rejection.

Sheath tendons in the stressing length to prevent contact of the anchor tendon with the drill hole wall. The Contractor may use sheathing that consists of tubes surrounding individual tendon elements or a single tube surrounding the elements altogether.

The Contractor may use sheathing material of either steel, plastic, or any other material nondetrimental to the high strength prestressing steel. The Contractor may use tape to prevent grout from entering under the sheath on individually sheathed elements.

Select the type of tendon to be used. Unless otherwise shown in the Plans, size the tendon so the factored design load does not exceed 80% of the minimum specified ultimate tensile strength of the tendon. Increase the tendon size by the sacrificial steel thickness shown in the Plans. In addition, size the tendon so the maximum test load does not exceed 90% of the minimum yield strength of the tendon.

Assume responsibility for determining the bond length necessary to develop the design load indicated in the Plans or the shop drawings. Use a minimum bond length of 10 feet in rock and 15 feet in soil. Ensure that the minimum tendon bond length is 10 feet.

451-6 Installation.

451-6.1 General:

451-6.1.1 Drilling: Core drilling, rotary drilling, percussion drilling, auger drilling, or driven casing may be used. At the ground surface, locate the drill hole within 12 inches of the location shown in the Plans or the approved shop drawings. Locate the drill hole so that the longitudinal axis of the drill hole and the longitudinal axis of the tendon are parallel. In particular, do not drill the prestressed soil anchor hole in a location that requires the tendon to be bent in order to connect the bearing plate to the supported structure. At the point of entry,

install the prestressed soil anchor within plus or minus 3 degrees of the inclination from horizontal shown in the Plans or the approved shop drawings. At the point of entry, make the horizontal angle formed by the prestressed soil anchor and the structure to within plus or minus 3 degrees of a line drawn perpendicular to the plane of the structure unless otherwise shown in the Plans or approved shop drawings. Do not allow the prestressed soil anchors to extend beyond the right-of-way or easement limits shown in the Plans.

451-6.1.2 Tendon Insertion: Insert the tendon into the drill hole to the desired depth. When the tendon cannot be completely inserted, remove the tendon from the drill hole, and then clean or redrill the hole to permit insertion. Do not drive or force partially inserted tendons into the hole.

451-6.1.3 Installation of Trumpet and Anchorage: When corrosion protection is required, extend that portion of the corrosion protection surrounding the unbonded length of the tendon, up beyond the bottom seal of the trumpet or 12 inches into the trumpet if no trumpet seal is provided. If the protection does not extend beyond the seal or sufficiently far enough into the trumpet, extend the corrosion protection, or lengthen the trumpet.

When required, ensure that the corrosion protection surrounding the unbonded length of the tendon does not contact the bearing plate or the anchor head during testing and stressing. If the protection is too long, trim the corrosion protection to prevent contact.

Place the bearing plate and anchor head so the axis of the tendon is perpendicular to the bearing plate within plus or minus 3 degrees and the axis of the tendon passes through the center of the bearing plate.

If using grout protected tendons, electrically isolate the bearing plate, anchor head, and trumpet from the surrounding concrete, soldier pile, or any metallic element embedded in the structure.

Completely fill the trumpet with corrosion inhibiting grease or grout. Trumpet grease may be placed any time during construction. Place trumpet grout after the prestressed soil anchor has been tested and stressed. Demonstrate to the Engineer that the procedures selected for placement of either grease or grout will produce a completely filled trumpet.

For permanent soil anchors, cover all anchorages permanently exposed to the atmosphere with a corrosion inhibiting grease-filled or grout-filled cover. Demonstrate to the Engineer that the procedures selected for placement of either grease or grout will produce a completely filled cover. If the Plans require restressable anchorages, use corrosion inhibiting grease to fill the anchorage cover.

451-6.2 Anchor Grouting: Provide grouting equipment that produces a grout free of lumps and undispersed cement. Use a positive displacement grout pump equipped with a pressure gauge to monitor grout pressures. Ensure that the pressure gauge is capable of measuring pressures of at least 150 psi or twice the actual grout pressures used, whichever is greater. Size the grouting equipment to enable the grout to be pumped in one continuous operation. Ensure that the mixer is capable of continuously agitating the grout.

Inject the grout from the lowest point of the drill hole. Grout may be pumped through grout tubes, casing, hollow-stem-augers, or drill rods. The grout may be placed before or after insertion of the tendon. Record the quantity of the grout and the grout pressures. Control the grout pressures and grout takes to prevent excessive heave or fracturing.

Except where indicated below, the grout may be placed above the top of the bond length at the same time as the bond length grout but may not be placed under pressure. Ensure that the grout at the top of the drill hole does not contact the back of the structure or the bottom of the trumpet.

If the prestressed soil anchor is installed in a fine-grained soil using drill holes larger than 6 inches in diameter, place the grout above the top of the bond length after testing and stressing the prestressed soil anchor. The Engineer will allow the entire drill hole to be grouted at the same time if it can be demonstrated that the particular prestressed soil anchor system does not derive a significant portion of its load-carrying capacity from the soil above the bond length portion of the prestressed soil anchor.

If using grout protected tendons for prestressed soil anchors anchored in rock, use pressure grouting techniques. For pressure grouting, seal the drill hole, and inject grout until a 50 psi grout pressure (measured at the top of the drill hole) can be maintained on the grout for five minutes.

Upon completion of grouting, the grout tube may remain in the hole, but it must be filled with grout.

After grouting, do not load the tendon for at least three days.

Record the following data concerning the grouting operation:

1. Type of mixer
2. Water/cement ratio
3. Types of additives (if any)
4. Grout pressure
5. Type of cement
6. Strength test samples (if any)
7. Volume of first and second stage grout

451-7 Prestressed Soil Anchor Testing and Stressing.

451-7.1 General: Test each prestressed soil anchor. The Engineer will select the prestressed soil anchors to be performance tested and those to be creep tested, and at his discretion, may increase or decrease the number of tests.

Perform creep testing and performance testing at the beginning of the anchor installation, prior to installation of the remaining soil anchors, unless directed otherwise by the Engineer. In projects with multiple anchor row levels, the Engineer may request performance and creep testing at the beginning of the installation of soil anchors for subsequent levels. The purpose of these initial tests is to verify the Contractor's installation procedures, the performance of the bond length, and the calibration of testing equipment.

Perform creep testing as follows:

1. as shown in the Plans
2. on 5% of the prestressed soil anchors.

Perform performance testing as follows:

1. as shown in the Plans
2. on 10% of the prestressed soil anchors or a minimum of three, whichever is greater.

Perform proof tests on all prestressed soil anchors, not subjected to a performance test or a creep test. Record the results of each test on form 700-020-04 Soil Anchor Forms. Submit a separate form for each test. Submit the test results to the Engineer on a weekly basis within one week of testing. Do not apply a load greater than 10% of the factored design load to

the prestressed soil anchor prior to testing. For the maximum test load, do not exceed 90% of the minimum yield strength of the tendon. Simultaneously apply the test load to the entire tendon. Do not perform stressing of single elements of multi-element tendons.

Provide testing equipment that consists of:

1. a dial gauge or vernier scale capable of measuring to 0.001 inch to measure the ground anchor movement. Use a movement-measuring device that has a minimum travel equal to the theoretical elastic elongation of the total anchor length at the maximum test load and that has adequate travel so the prestressed soil anchor movement can be measured without resetting the device.

2. a hydraulic jack and pump to apply the test load. Use the jack, with a minimum ram travel of not less than the theoretical elastic elongation of the total anchor length at the maximum test load, and a calibrated pressure gauge, graduated in 100 psi increments or less, or calibrated load cell with readout box, to measure the applied load. Ensure that the jack and pressure gauge are calibrated by an independent firm as a unit, and that the calibration is performed within 60 calendar days of the date submitted.

3. Provide an electrical resistance load cell and readout to be used when performing a creep test. Load cell may also be used in performance and proof tests, at the Contractor's discretion. Ensure that the load cell is calibrated by an independent firm and that the calibration is performed within 60 calendar days of the date submitted. Obtain the Engineer's approval of the calibration before testing commences.

4. Keep a calibrated reference pressure gauge at the site in possession of the Engineer. Ensure that the reference gauge is calibrated with the test jack and pressure gauge.

5. Place the reference pressure gauge in series with the pressure gauge during each performance test and creep test.

6. Place the stressing equipment over the prestressed soil anchor tendon in such a manner that the jack, bearing plates, load cells and stressing anchorage are axially aligned with the tendon and the tendon is centered within the equipment.

If, during the performance of any load test (proof, performance, or creep), the load determined by the load cell or the load determined by the reference gauge differs by more than 10% from the load determined by the pressure gauge when the pressure gauge measures 80% of the Factored Design Load (0.80 DL), suspend the test, unload the anchor being tested, recalibrate the load cell, jack, pressure gauge, and reference pressure gauge, and repeat the test at no expense to the Department. Obtain the Engineer's approval of the recalibration data prior to resuming testing.

If, at any time, a pressure gauge, reference pressure gauge, or load cell is repaired or replaced, obtain the Engineer's written approval of calibration data of the repaired or the new measuring device (load cell or pressure gauge, or reference gauge) prior to resuming testing. Perform additional performance tests, at no expense to the Department, on the first two soil anchors using the repaired or new measuring device to verify the calibration of the equipment.

451-7.2 Criteria for Performing a Performance Test and a Proof Test: Raise the load from one increment to another immediately after recording the prestressed soil anchor movement. Measure and record the prestressed soil anchor movement to the nearest 0.001 inch with respect to an independent fixed reference point at the alignment load and at each increment of load. Monitor the load with a pressure gauge or load cell. At load increments other than the maximum test load, hold the load just long enough to obtain the movement reading.

Hold the maximum test load for at least 10 minutes. Pump the jack as necessary in order to maintain a constant load. Start the load-hold period as soon as the maximum test load is applied, and measure and record the prestressed soil anchor movement, with respect to an independent fixed reference, at 1, 2, 3, 4, 5, 6, and 10 minutes. If the prestressed soil anchor movement between 1 minute and 10 minutes exceeds 0.04 inches, hold the maximum test load for an additional 50 minutes. If extending the load-hold, record the prestressed soil anchor movements at 15 minutes, 20, 25, 30, 40, 50 and 60 minutes.

451-7.2.1 Performance Test: Perform the performance test by incrementally loading and unloading the prestressed soil anchor in accordance with the following schedule:

Performance Test Schedule	
Load	Load
AL	AL
0.20 DL*	0.20 DL
AL	0.40 DL
0.20 DL	0.60 DL
0.40 DL*	0.80 DL
AL	0.90 DL*
0.20 DL	AL
0.40 DL	0.20 DL
0.60 DL*	0.40 DL
AL	0.60 DL
0.20 DL	0.80 DL
0.40 DL	0.90 DL
0.60 DL	1.00 DL*
0.80 DL*	Reduce to lock-off load
AL - is the alignment load. DL - is the prestressed soil anchor factored design load.	

Plot the prestressed soil anchor movement versus load for each load increment marked with an asterisk (*) in the performance test schedule, and plot the residual movement of the tendon at each alignment load versus the highest previously applied load.

451-7.2.2 Proof Test: Perform the proof test by incrementally loading the prestressed soil anchor in accordance with the following schedule:

Proof Test Schedule	
Load	Load
AL	0.80 DL
0.20 DL	0.90 DL
0.40 DL	1.00 DL
0.60 DL	Reduce to lock-off load

Compare the proof test results to the performance test results. If there is any significant variation from the performance test results, perform a performance test on the next anchor.

Plot the prestressed soil anchor movement versus load for each load increment in the proof test.

451-7.3 Criteria for Performing a Creep Test: Perform the creep test by incrementally loading and unloading the prestressed soil anchor in accordance with the performance test schedule given above. At the end of each loading cycle, hold the load constant for the observation period indicated in the creep test schedule below. Use the following times for reading and recording the prestressed soil anchor movement during each observation period: 1, 2, 3, 4, 5, 6, 10, 15, 20, 25, 30, 40, 50, 60, 75, 90, 100, 120, 150, 180, 210, 240, 270, and 300 minutes as appropriate. Start each load-hold period as soon as applying the test load. Pump the jack as necessary in order to maintain a constant load.

Plot the prestressed soil anchor movement and the residual movement measured in a creep test as described for the performance test above, and plot the creep movement for each load-hold as a function of the logarithm of time.

Creep Test Schedule	
Load	Observation Period (minutes.)
AL	
0.20 DL	10
0.40 DL	30
0.60 DL	30
0.80 DL	40
0.90 DL	60
1.00 DL	300

451-7.4 Lock-Off: Upon satisfactory completion of all testing, reduce the load to the lock-off load, and transfer the load to the anchorage device. Use a lock-off load that is 80% of the prestressed soil anchor service load. The Contractor may completely unload the prestressed soil anchor prior to lock-off. After transferring the load and prior to removing the jack, take a lift-off reading. Use a lift-off reading that is within 10% of the specified lock-off load. If the load is not within 10% of the specified lock-off load, reset the anchorage, and take another lift-off reading. Repeat this process until obtaining the desired lock-off load.

451-7.5 Cutting of Tendon Protrusions: After an anchor has been accepted by the Engineer, saw cut the portion of the anchor tendon extending beyond the anchorage. Take care not to damage the tendon or the tendon anchorage.

451-7.6 Prestressed Soil Anchor Load Test Acceptance Criteria: The Engineer will accept a performance or proof-tested prestressed soil anchor with a 10 minute load hold if the:

1. Prestressed soil anchor carries the maximum test load with less than 0.04 inches of movement between 1 minute and 10 minutes; and

2. For performance tests, net movement at the maximum test load cycle (movement between alignment load after 0.90 DL and the final movement reading at 1.00 DL) exceeds 80% of the theoretical elastic elongation of the test stressing length. For proof tests, net movement at the maximum test load (movement between alignment load and the final movement reading at 1.00 DL) exceeds 80% of the theoretical elastic elongation of the test stressing length.

The Engineer will accept a performance or proof-tested prestressed soil anchor with a 60 minute load hold if the:

1. Prestressed soil anchor carries the maximum test load with a deformation rate that does not exceed 0.08 inches in the last log cycle of time; and

2. For performance tests, net movement at the maximum test load cycle (movement between alignment load after 0.90 DL and the final movement reading at 1.00 DL) exceeds 80% of the theoretical elastic elongation of the test stressing length. For proof tests, net movement at the maximum test load (movement between alignment load and the final movement reading at 1.00 DL) exceeds 80% of the theoretical elastic elongation of the test stressing length.

The Engineer will accept a creep tested prestressed soil anchor if the:

1. Prestressed soil anchor carries the maximum test load with a creep rate that does not exceed 0.08 inches/log cycle of time; and

2. Net movement at the maximum test load cycle (movement between alignment load after 0.90 DL and the final movement reading at 1.00 DL) exceeds 80% of the theoretical elastic elongation of the test stressing length.

If the total movement of the prestressed soil anchors at the maximum test load does not exceed 80% of the theoretical elastic elongation of the test stressing length, replace the prestressed soil anchor at no cost to the Department.

Stop the creep test as soon as the creep rate exceeds 0.08 inches/log cycle of time. Incorporate prestressed soil anchors which have a creep rate greater than 0.08 inches/log cycle of time in the finished work at a load equal to one-half its failure load. The failure load is the load carried by the prestressed soil anchor after the load has been allowed to stabilize for 10 minutes without exceeding 0.04 inches of movement between 1 and 10 minutes.

When a prestressed soil anchor does not satisfy the load test acceptance criteria, the Contractor may modify the design and/or the construction procedures. These modifications may include, but are not limited to, installing replacement prestressed soil anchors, reducing the factored design load by increasing the number of prestressed soil anchors, modifying the installation methods, increasing the bond length or changing the prestressed soil anchor type. Obtain the Engineer's approval prior to making any modification which requires changes to the structure. Perform any modifications at no additional cost to the Department. The Department will not allow additional Contract Time for modifications. The Engineer will not allow retesting of the failed prestressed soil anchor except to determine the anchor failure load.

451-8 Corrosion Protection (include for temporary anchors only when shown in the Plans).

451-8.1 General: Protect prestressed soil anchors against corrosion using materials and procedures described herein. The following materials may be used independently or in various combinations:

1. Portland cement grout
2. Plastic pipe or tubing
3. Steel pipe or tubing
4. Greases specially compounded for post-tensioning
5. Bitumens
6. Heat shrinkable polyethylene tubing

Use corrosion protection materials with properties that are not detrimental to the prestressing steel and that prevent the intrusion of corrosive environments. Use coating materials that also have the following properties:

1. Free from cracks and not brittle or fluid over the entire anticipated range of temperature

2. Chemically stable for the life of the tendon

3. Nonreactive with the surrounding materials such as concrete, tendons, or sheathing

4. Corrosion-inhibiting

5. Impervious to moisture

When acidic water can enter the bore hole during the period subsequent to the drilling and flushing operation and prior to tendon insertion and grouting, introduce chemical additives for neutralizing purposes. Maintain a minimum pH of 9.0 when the prestressing steel is in contact with this water. During prolonged periods, monitor the pH at regular intervals, and add additional neutralization as required. Concentrated sodium hydroxide and calcium hydroxide have proven effective for this purpose.

451-8.2 Protection Systems:

451-8.2.1 Bond Length:

1. When the Plans require grout protected prestressed soil anchor tendons, meet the following requirements:

a. Provide corrosion protection of the tendon bond length by the cement grout cover.

b. Use spacers along the tendon bond length of multi-element tendons to separate each of the individual elements of the tendon so the prestressing steel will bond to the grout. Position spacers so their center to center spacing does not exceed 10 feet. In addition, locate the upper spacer a maximum of 5 feet from the top of the tendon bond length, and locate the lower spacer a maximum of 5 feet from the bottom of the tendon bond length.

c. Use centralizers to ensure a minimum of 0.5 inches of grout cover over the tendon bond length. Position centralizers so their center to center spacing does not exceed 10 feet. In addition, locate the upper centralizer a maximum of 5 feet from the top of the tendon bond length, and locate the lower centralizer a maximum of 12 inches from the bottom of the tendon bond length.

d. The Engineer will not require centralizers on pressure-injected prestressed soil anchor tendons if the prestressed soil anchor is installed in coarse-grained soils using grouting pressures greater than 150 psi.

e. The Engineer will not require centralizers on hollow-stem-augured prestressed soil anchor tendons if the prestressed soil anchor is grouted through the auger and the hole is maintained full of a stiff grout, (9 inches slump or less) during extraction of the auger.

2. When the Plans require the tendon bond length to be encapsulated:

a. Protect the tendon bond length portion of the tendon against corrosion by encapsulating the tendon in a grout-filled corrugated plastic or deformed steel tube. Grout the tendon inside the encapsulation prior to inserting the tendon in the drill hole or after the tendon has been placed in the drill hole. Mix expansive admixtures with the encapsulation grout if the tendon is grouted inside the encapsulation prior to inserting it in the drill hole. Centralize the tendon within the tendon bond length encapsulation with a minimum of 0.10 inches of grout cover. Use spacers along the tendon bond length of multi-element tendons to separate the elements of the tendon so the prestressing steel will bond to the encapsulation grout.

b. Use centralizers to provide a minimum of 0.5 inches of grout cover over the tendon bond length encapsulation. Position centralizers so their center to center spacing does not exceed 10 feet. In addition, locate the upper centralizer a maximum of 5 feet

from the top of the tendon bond length, and locate the lower centralizer a maximum of 12 inches from the bottom of the tendon bond length.

c. The Engineer will not require centralizers on encapsulated, pressure-injected prestressed soil anchor tendons if the prestressed soil anchor is installed in coarse-grained soils using grouting pressures greater than 150 psi.

d. The Engineer will not require centralizers on encapsulated, hollow-stem-augured prestressed soil anchor tendons if the prestressed soil anchor is grouted through the auger and the hole is maintained full of a stiff grout (9 inches slump or less) during extraction of the auger.

451-8.2.2 Unbonded Length: For the minimum unbonded length of the tendon, use 15 feet or as indicated in the Plans or the approved shop drawings, whichever is greater.

If grouting the entire drill hole (tendon bond length and unbonded length) in one operation, provide the corrosion protection of the unbonded length by a sheath completely filled with corrosion inhibiting grease or grout, or a heat shrinkable tube internally coated with an elastic adhesive. If using grease under the sheath, make provisions to prevent the grease from escaping at the ends of the sheath. With grease, completely coat the tendon, fill the void between the tendon and the sheath, and fill the interstices between the wires of the 7-wire strands. Ensure that the shop drawings show how to provide a transition between the bond length and the unbonded length corrosion protection. If the sheath is grout filled, provide a separate bondbreaker that prevents the tendon from bonding to the grout surrounding the unbonded length.

If providing grease-filled sheath corrosion protection and the drill hole above the bond length is grouted after locking off the prestressed soil anchor, grout the tendon inside a second sheath.

451-8.2.3 Anchorage and Trumpet: Use non-restressable anchorage devices except where indicated in the Plans. Provide restressable anchorages on those prestressed soil anchors designated as restressable in the Plans. Ensure that the post-tensioning supplier provides a restressable anchorage compatible with the post-tensioning system provided along with written recommendations concerning the restressing of the tendons.

If using strand tendons, submit written recommendations from the post-tensioning supplier for seating the wedges. Include with the recommendations the minimum load required to properly seat the wedges in the anchor head.

Size the bearing plates so that:

1. the bending stresses in the plate do not exceed the yield strength of the steel when applying a load equal to 95% of the minimum specified ultimate tensile strength of the tendon; and

2. the average bearing stress on the concrete does not exceed that recommended in Section 3.1.7 of the Post Tensioning Institute Guide Specification for Post-Tensioning Materials.

Weld the trumpet to the bearing plate. Provide a trumpet that has an inside diameter equal to or larger than the hole in the bearing plate. Ensure that the trumpet is long enough to accommodate movements of the structure during testing and stressing. For strand tendons with encapsulation over the unbonded length, provide a trumpet that is long enough to enable the tendon to make a transition from the diameter of the tendon in the unbonded length to the diameter of the tendon at the anchor head without damaging the encapsulation. Ensure that trumpets filled with corrosion-inhibiting grease have a permanent Buna-N synthetic rubber or

approved equal seal provided between the trumpet and the unbonded length corrosion protection. Ensure that trumpets filled with grout have a temporary seal provided between the trumpet and the unbonded length corrosion protection or that the trumpet overlaps the unbonded length corrosion protection by a minimum of 12 inches and fits tightly over the unbonded length corrosion protection.

451-9 Submittals.

Prepare and submit Shop drawings and a design submission describing the prestressed soil anchor system or systems intended for use to the Engineer for review and approval 30 working days prior to the commencement of the prestressed soil anchor work. Include the following in the shop drawings and design submission:

1. A prestressed soil anchor schedule providing the following:
    a. Prestressed soil anchor number
    b. Prestressed soil anchor factored design load
    c. Type and size of tendon
    d. Minimum total anchor length
    e. Minimum bond length
    f. Minimum tendon bond length
    g. Minimum unbonded length
2. A drawing of the prestressed soil anchor tendon and the corrosion protection system. Include details for the following:
    a. Spacers and their location
    b. Centralizers and their location
    c. Unbonded length corrosion protection system
    d. Bond length corrosion protection system
    e. Anchorage and trumpet
    f. Anchorage corrosion protection system
3. Certificates of Compliance for the following materials, if used, stating that the material or assemblies to be provided will fully comply with the requirements of the Contract.
    a. Prestressing steel, strand or bar
    b. Portland cement
    c. Prestressing hardware
    d. Bearing plates
    e. Corrosion protection system

The Engineer will approve or reject the shop drawings and design submission within 30 working days after receipt of the submission.

Submit to the Engineer for review and approval or rejection mill test reports for the prestressing steel and the bearing plate steel. The Engineer may require the Contractor to provide samples of any prestressed soil anchor material intended for use on the project. The Engineer will approve or reject the prestressing steel and bearing plate steel within five working days after receipt of the test reports. Do not incorporate the prestressing steel and bearing plates in the work without the Engineer's approval.

Submit to the Engineer for review and approval or rejection calibration data for each test jack, pressure gauge, and reference pressure gauge to be used. The Engineer will approve or reject the calibration data within five working days after receipt of the data. Do not commence testing until the Engineer has approved the jack, pressure gauge, and reference pressure gauge calibrations.

Submit to the Engineer within 20 calendar days after completion of the prestressed soil anchor work a report containing:

1. prestressing steel manufacturer's mill test reports for the tendons incorporated in the installation
2. grouting records indicating the cement type, quantity injected, and the grout pressures
3. prestressed soil anchors test results and graphs.

451-10 Tendon Storage and Handling.

Handle and store tendons in a manner to avoid damage or corrosion. The Engineer will consider damage to the prestressing steel as a result of abrasions, cuts, nicks, welds and weld splatter cause for rejection. Protect the prestressing steel if performing welding in the vicinity. Do not ground welding leads to the prestressing steel. Protect prestressing steel from dirt, rust, or deleterious substances.

The Engineer will allow a light coating of rust on the steel. If heavy corrosion or pitting is noted, the Engineer will reject the affected tendons.

Use care in handling and storing the tendons at the site. Prior to inserting a tendon in the drill hole, examine the tendon for damage to the encapsulation and the sheathing. If, in the opinion of the Engineer, the encapsulation is damaged, repair the encapsulation in accordance with the tendon supplier's recommendations. If, in the opinion of the Engineer, the smooth sheathing has been damaged, repair it with ultra high molecular weight polyethylene tape. Spiral wind the tape around the tendon to completely seal the damaged area at a pitch that ensures a double thickness at all points.

451-11 Method of Measurement.

Unless otherwise shown in the Plans, the quantity to be paid for will be the number of prestressed soil anchors, based on the maximum anchor spacing shown in the Plans, installed and accepted. For prestressed soil anchors that do not meet the acceptance criteria, the original prestressed soil anchor and any required additional work or prestressed soil anchors will be, in sum, considered to be one prestressed soil anchor for payment purposes.

451-12 Basis of Payment.

Prices and payments will be full compensation for all work specified in this Section, including furnishing the materials necessary to complete the anchors in place and accepted. The quantity of performance and creep tests to be paid for will be the number of tests performed on accepted anchors.

The cost of proof testing will be included in Item No. 451-70.

No payment will be made for tests performed on unaccepted anchors.

Payment will be made under:

Item No. 451- 70-	Prestressed Soil Anchors - each.
Item No. 451- 70- 1	Prestressed Soil Anchor (Performance Tests) - each.
Item No. 451- 70- 2	Prestressed Soil Anchors (Creep Tests) - each.

SECTION 452
PRECAST SEGMENTAL BRIDGE CONSTRUCTION

452-1 Description.

Fabricate, store, transport and erect precast structural concrete superstructure and/or substructure segments on a prepared foundation, to the established lines and grades, in accordance with the design, dimensions and details shown on the Plans and in accordance with this Section.

Reinforcing steel, embedded items and all appurtenant items are included.

Base the bid on the design shown in the Plans.

The work in this Section does not include longitudinally post-tensioned beams upon which a concrete slab is cast-in-place.

452-2 Qualification of Contractor's Personnel.

Meet the requirements of Section 105.

When mixing, handling and applying an epoxy bonding agent, provide direct supervision by a person with knowledge and experience, or trained by a technical representative of the manufacturer in the use of this material. Arrange for a technical representative of the manufacturer to be at the site as an advisor at the beginning of this work.

Ensure that all personnel who will be working with an epoxy bonding agent are thoroughly familiar with the safety precautions necessary for use of this material.

452-3 Definitions.

The following definitions apply to segmental bridge construction:

452-3.1 Segment: A modular section of the superstructure and/or substructure consisting of a certain cross-section shape and length as detailed in the Plans.

452-3.2 Match Cast: A precast concrete fabrication process whereby a segment is cast against the preceding segment producing a matching interface which permits the re-establishment of the cast geometry at erection time. Match casting is accomplished by either the short line or long line casting method.

452-3.3 Short Line Casting: Casting segments one at a time in a casting cell between a bulkhead at one end and a previously cast segment at the other. The first segment is cast between the bulkhead and another, temporary bulkhead.

452-3.4 Long Line Casting: Casting segments on a casting bed of sufficient length to permit the cumulative casting of segments for the entire length of a span or cantilever between field closure pours without repositioning the segments on the casting bed. With this method, the first segment is cast between bulkheads and successive segments are cast between a movable bulkhead on one end and the previously cast segment on the other.

452-3.5 Casting Cell: A special formwork arrangement usually consisting of a fixed vertical bulkhead of the cross section shape at one end and adjustable soffit, side and core forms all designed and assembled into a machine for making a single superstructure segment. A casting cell for a substructure pier shaft segment consists of exterior and interior side forms and a soffit form of the cross section shape.

452-3.6 Wet Joint System: Where segments are made in a casting cell between two bulkheads and are not match cast. The segments are then erected in the superstructure with a narrow cast-in-place joint between each segment. (During erection, all the segments of a span or

multiple spans are supported by falsework, truss or other technique until the joints have gained strength and the longitudinal post-tensioning installed to make them self supporting.)

452-3.7 Span by Span (Erection): Placing a specified number of segments on a temporary support system, aligned and post-tensioned longitudinally forming a completed span of the superstructure.

452-3.8 Balanced Cantilever (Erection): The segments are sequentially erected alternately on either side of the pier in cantilever to a point where a closure is cast-in-place.

452-3.9 Progressive Cantilever: (Erection): The segments are erected progressively in cantilever, in one direction, from one pier to the next, using temporary intermediate piers, or other systems as required to support the advancing cantilever between piers.

452-3.10 Casting Curve: The curve of casting geometry that has to be followed in the casting cell or bed for achieving the theoretical bridge profile and alignment after all the final structural and time dependent (creep and shrinkage) deformations have taken place. The casting curve is a combination of the theoretical bridge geometrical profile grade, alignment and the camber.

452-3.11 Camber: The amount by which the concrete profile at casting time must differ from the theoretical geometric profile grade to compensate for all structural dead load, post-tensioning, all long term and time dependent deformations (creep and shrinkage) including all the intermediate erection stages and effects. (The opposite of deflections).

452-3.12 Erection Elevation: The elevation at which a segment is set in the structure at the time it is erected. (This is profile grade corrected by the amount of deflection calculated to occur from that stage onwards.)

452-4 Shop Drawings, Calculations and Manuals.

452-4.1 General: Use methods and procedures providing adequate safety to the general public from construction/erection activities and/or falsework placed over or adjacent to traveled roadways, navigational or recreational waterways or any existing commercial, industrial or other facility.

452-4.2 Information Required: Submit integrated detailed shop drawings, calculations, manuals and other information, including, but not limited to, the following:

452-4.2.1 Segment Shop Drawings:

1. A schedule of materials for segment fabrication including concrete, reinforcing steel, prestressing steel, duct filler, and other similar items.
2. Each segment number and the direction of erection.
3. Segment dimensions including widths, lengths, thicknesses, tapers, fillets, radii, working points, post-tensioning, clearances, rebar dimensions and spacing, embedded items, holes, anchorage positions, and other similar items.
4. Post-tensioning hardware components meeting the requirements as outlined in Section 462.
5. The volume of concrete, weight of reinforcement and weight of post-tensioning in each precast segment and the total weight for reinforcement and post-tensioning for both the superstructure and substructure summarized and tabulated on the shop drawings.
6. Details and calculations for any localized strengthening for concentrated supports and loads or reactions from any special erection equipment placed in locations not already allowed for in the Plans.

7. Details and supporting calculations for any modifications to segment geometry, cross section dimensions, or segment length including any required changes to reinforcing and post-tensioning.

8. Details of permanent and temporary embedded items including inserts, blockouts, temporary openings, holes, and other similar items; and any localized required strengthening and the materials and methods to fill and finish the holes.

452-4.2.2 Casting Yard:

1. Procedures for segment fabrication including layout of the casting yard, set up and operation of the casting cells, movable rain and sun shades, geometry control stations, the storage and handling of rebar cages. the preparation of as built geometry data, placing and finishing concrete, curing of concrete, form stripping, bond breaking, and other similar items.

2. Calculations and details for lifting, storage and stacking of segments. Additional strengthening of the segments to accommodate stacking will be at no expense to the Department.

3. Equipment for segments fabrication, including details of the forms and casting cells for the manufacture of the segments, surveying the segment, lifting and transportation of the segment in the yard, and other similar items.

4. Segment storage including layout of the storage area, method of supporting the segments, single or double stacking, placing erection marks and segment identification, and other similar items.

5. Segment transportation from the casting yard to the site.

452-4.2.3 Erection Manual: Meet the requirements in 452-8.

452-4.2.4 Manual for Geometry Control and Casting Curves: Meet the requirements in 452-6.3.

452-5 Materials.

452-5.1 General: Use materials which conform to this Section and the requirements prescribed in Division III, Materials, for the particular kind and type of material specified.

452-5.2 Concrete: Use concrete as specified in Section 346 except as specifically modified herein. Use No. 67 coarse aggregate in the concrete for segments.

Screenings are not allowed as a substitute for silica sand for use in concrete for Precast Superstructure Segments.

452-5.3 Reinforcing Steel: Use ASTM A615, Grade 60 reinforcing steel which meets the requirements of Section 415. When welding reinforcing steel, meet the requirements of the American Welding Society's Structural Welding Code D1.4. The Engineer may allow shop prepared welded reinforcing grillages. Field welding of reinforcing steel is not allowed.

452-5.4 Post-Tensioning Systems: Use post-tensioning hardware components meeting the requirements of Section 462 and used in field mock-up testing. Components are not interchangeable and must comply with the details of the approved shop drawings.

452-5.5 Epoxy Bonding Systems: Use only epoxy systems comprised of two components, a resin and a hardener, with each component distinctly pigmented so that mixing produces a third color similar to the color of the precast segments and are listed on the Department's Approved Product List (APL). Manufacturers seeking evaluation of their products must submit an application conforming to the requirements of Section 6.

In its workable state, or open time, the epoxy bonding agent must function as a lubricant for joining the segments. In its hardened state, the epoxy bonding agent must provide a watertight seal between the precast concrete segments. The hardened epoxy bonding agent must

provide intimate contact for stress transfer by completely filling all interstitial space between the match cast segment faces.

Do not use resin or hardeners from containers which are damaged or have been previously opened. Combining of resin and hardener from bulk containers will not be permitted; use only pre-proportioned, full containers of components.

Submit instructions, from the manufacturer, for the safe storage, handling, mixing, and application of the materials.

452-6 Casting Requirements.

452-6.1 General: Ensure that all materials, details, and procedures are as specified herein, as noted in the Plans, or as directed by the Engineer.

Do not begin casting segments until the Engineer approves the relevant shop drawings, calculations, casting manuals, concrete forms and concreting operations and the post-tensioning system components and layout if different from that on the Plans. (Approval of post-tensioning stressing elongations and forces for field erection operations is not required at this stage but is required prior to erection.)

To use wet joints to join cantilevers or for corrective measures, obtain the Engineer's written approval.

Give each segment an erection mark indicating its location, orientation and order in the erection sequence. Match mark abutting edges of adjacent segments. Show erection marks on the erection plans or in the erection manual.

452-6.2 Forms: Take responsibility for the design and engineering of the forms as well as their construction. Form all exposed formed surfaces of each element of the structure with the same material to produce similar concrete surface textures, color, and appearance. Obtain the Engineer's approval of forms prior to initiating casting operations. Build the details shown on the Plans or as amended by approved shop drawings into the forms.

Repair worn, damaged, or otherwise unacceptable forms and obtain the Engineer's approval before casting any segment.

Where sections of forms are joined, ensure that offsets in flat surfaces do not exceed 1/16 inches and that offsets with corners and bends do not exceed 1/8 inches.

Ensure that all joints in the forms and contact points with bulkheads and existing segments have good fitting seals to prevent loss of fine material and cement grout.

Check and inspect forms on a regular weekly basis to ensure proper alignment and geometric accuracy. Do not use forms which fail to meet the specified casting tolerances until such corrections are made to produce segments within the specified tolerances.

Use a small blockout at all locations where an external tendon enters or exits the face of the concrete at deviation blocks and diaphragms except at anchorage locations. The blockout will be approximately 2 inches larger in diameter or overall dimensions than the tendon duct and have a depth equal to at least the minimum prescribed concrete cover dimension shown in the Plans.

452-6.3 Casting Control (Geometry): Before commencing the casting operation, submit the proposed method of geometry control for all segment casting operations to the Engineer for approval. This submittal must be in the form of a "Casting Manual" and include but not necessarily be limited to:

1. All measuring equipment, procedures and the location of control points to be established on each segment.

2. The location and values of all permanent benchmarks and reference points in the precasting yard.

3. A geometry control procedure for the vertical and horizontal alignment control for the precasting of segments; including survey controls and procedures, observations, checks, computational and/or graphical methods and correction techniques.

4. The casting curves which include the theoretical geometric horizontal alignment, profile grade and superelevation appropriately combined with the camber.

Ensure that the casting manual covers all geometry control operations necessary and is compatible with the chosen methods of casting and erection, including erection survey, elevation and alignment control. Prepare the manual in accordance with submittal requirements of this Section.

Do not begin casting without the Engineer's approval of the geometry control method.

In the precasting yard, use instruments for the geometry control which are mounted on a permanent platform of sufficient height to sight on all control points. In addition, establish and maintain permanent benchmarks and reference points throughout the casting operations.

During casting, make all corrections required in the geometry of the segments from the control points established on each segment.

With a match cast system, after casting and before bond breaking to separate the segments, check the position of the new cast and match cast segments again. If positions are not as desired, make corrections in the next segment. In general, and unless otherwise approved by the Engineer, make observations on the geometry control reference hardware cast into the segments (i.e. elevation bolts, alignment offsets and lengths) to a precision of plus or minus 0.001 foot.

During casting operations, produce and maintain on a daily basis a graphical plot of the vertical and horizontal "as cast" alignments along each vertical and horizontal control line to an exaggerated scale in order to clearly highlight variations. Depict these against both the theoretical geometric vertical and horizontal alignment casting curves on a continuous layout of an entire unit of the bridge between expansion joints. Maintain this plot in good condition so that it may be used and referenced during erection.

Keep all geometry control hardware cast into any segments, such as elevation bolts and alignment hairpins, in place during erection for reference and checking purposes. Remove the hardware after completion of erection of the unit in the bridge between expansion joints.

Use experienced personnel to operate the instruments and supervise the casting operation. Prior to the commencement of casting, obtain the Engineer's approval of the experience and/or qualifications of the supervisory and instrument operating personnel, particularly with regard to the observational precision required.

452-6.4 Preparation for Match Casting: When match casting is used, take great care in positioning of the match cast (previously cast) segment in relation to the segment to be cast. Ensure that the match cast segment is not twisted.

Ensure that all materials to be embedded in the concrete of the new cast segment are properly positioned and supported in order to maintain their position and withstand concrete placement and consolidation without damage. Make provisions for all projections, recesses,

notches, openings, blockouts and the like in accordance with the Plans and approved shop drawings.

Cover the abutting surface of the match cast segment with a thin film of a bond breaker consisting of flax soap and talc, or other material approved by the Engineer. Use a soap and talc mixture consisting of five parts flax soap to one part talc. The Engineer will base acceptance of a material other than soap and talc prior to casting any segments by demonstration on a large specimen consisting of a precast piece and a new cast piece with a contact facial area of at least 4 square feet.

452-6.5 Embedded Items:

452-6.5.1 General: Embedded items must be in accordance with specifications for prestressed and post-tensioned construction and the requirements herein.

452-6.5.2 Embedded Post-Tensioning Ducts: Ensure that embedded ducts for post-tensioning tendons and bars are positioned accurately to their required alignment. Properly fabricate and identify all ducts so that proper positioning is assured and can be verified after casting.

Utilize positive methods to ensure that ducts will not be displaced or damaged during concrete placement and consolidation. Adequately secure all embedded post-tensioning ducts to the reinforcement cage at intervals not exceeding 30 inches for steel pipes and 24 inches for plastic ducts, (Small ducts and very flexible ducts may require closer supports). Any auxiliary ties and support bars needed for these purposes will be considered incidental and at no extra cost to the project. Prevent the concrete cover requirements from being violated by any auxiliary ties and support bars.

After installation in the forms, ensure that the ends of the ducts are sealed at all times to prevent entry of water, debris and fine material. Following each pour of concrete, demonstrate that all empty ducts are free of water and are unobstructed and undamaged.

Immediately prior to installation of the prestressing steel, again demonstrate to the satisfaction of the Engineer that all ducts are unobstructed and free of water and debris.

452-6.5.3 Anchorage Plates and Castings: Prior to placing concrete in the forms, fix all tendon anchorage plates and anchorage castings in their respective position in the forms, connected to their duct and sealed to prevent mortar intrusion. Ensure that anchorage plates and castings are rigidly fixed in the forms to maintain their correct alignment and position during concrete placement and consolidation.

452-6.5.4 Reinforcing Steel: Fabricate and place reinforcing steel in accordance with the Plans or as superseded by the approved shop drawings and as required herein.

Do not cut out or remove reinforcing steel to permit proper alignment of post-tensioning ducts. Replace any bar that cannot be fabricated to clear the ducts by additional bars with adequate lap lengths and submit the details to the Engineer for approval.

In the plane of the reinforcement parallel to the nearest surface of the concrete, ensure that bars do not vary from plan placement by more than 1 inch, nor by more than one-eighth of the spacing between bars, whichever is less. In the direction perpendicular to this plane of reinforcement, ensure that bars do not vary from plan placement by more than 1/4 inches. The top and bottom cover of reinforcing steel must be within 1/4 inches of the cover dimensioned in the Plans. The edge cover of the reinforcing steel must be within 1 inch of the cover dimensioned in the Plans.

452-6.6 Concrete Placement, Consolidation and Finishing:

452-6.6.1 General: Do not deposit concrete into the forms until the entire set-up of the forms, reinforcement, ducts, anchorages and embedded items have been thoroughly inspected and checked. Do not place concrete until the Engineer is satisfied that all the above items have been properly inspected and checked, and the rate of producing and placing the concrete will be sufficient to complete the casting and finishing operations within the scheduled time, that experienced concrete finishers are available where required for finish work and that all necessary finishing tools and equipment are on hand at the site of the work and are in satisfactory condition for use.

During conveying and placement, protect concrete against undue drying or rise in temperature and inclement weather.

452-6.6.2 Concrete Placement Equipment: Use concrete placement equipment of a size and design which permits placing concrete within the specified time. Clean all equipment at the end of each operation or workday and, just prior to reuse, check the equipment again and clean off hardened concrete and foreign materials.

Place concrete by belt conveyors and by pumping in accordance with 400-7.6 and 400-7.7, respectively.

452-6.6.3 Concrete Placement Sequence:

1. Superstructure box segments: First place concrete in the central portion of the bottom slab between the inside edges of the internal web forms, leaving a narrow gap of 6 inches to 12 inches for inspection and consolidation of the bottom corners when the next load is placed in the webs. Then place the concrete in the bottom corners of each web to connect and consolidate with that already placed in the bottom slab. Then place concrete in the remainder of the webs in lifts not exceeding 24 inches at a time up to the top of the webs but not into the slab over the webs. Place concrete in the top slab in the outer wing and mid slab regions between webs before placing, completing and consolidating zones over the top of the webs.

2. Substructure and Pier Shaft Segments: Cast precast pier shaft segments vertically. Place the concrete in uniform lifts of approximately 24 inches to 36 inches and consolidate well.

3. Obtain the Engineer’s approval on any alternative sequences to the above, or for any other precast components.

452-6.6.4 Concrete Placement and Consolidation: Discharge individual loads of concrete into the forms, and place and consolidate in the required locations. After discharge into the forms, do not bodily move concrete from place to place within the forms by mechanical vibrators or other similar equipment.

Place and consolidate concrete with care so that post-tensioning ducts, anchorages and any other embedded items are maintained in their proper positions and are not damaged.

Consolidate all concrete using approved vibrators together with any other equipment necessary to perform the work as specified. Use internal vibrators having a minimum frequency of 8,000 vibrations per minute and sufficient amplitude to consolidate the concrete effectively. Provide at least two stand-by vibrators in working condition for emergency use in case of malfunction.

Use of external vibrators for consolidating concrete when the concrete is inaccessible for adequate consolidation by internal means. When external vibration is used, construct the forms sufficiently rigid to resist displacement or damage.

Vibrate concrete in a manner which avoids displacement or damage to reinforcement, post-tensioning ducts, anchorages and other embedded items.

No construction joints are allowed within a segment, except as detailed in the Plans.

452-6.6.5 Finishing: Strike off the roadway surface of the segment with an approved mechanical screed operated by a self contained power source.

Furnish and use a straightedge at least 24 inches longer than the segment while finishing the concrete deck surface of superstructure box girder segments. Use the straightedge approximately parallel to the centerline of the segment to strike an accurate surface between the bulkhead and the top of the match cast segment at all positions across the segment width.

Give all other surfaces of segments and precast components a Class 3 Finish at the precast site in accordance with 400-15.

452-6.7 Curing:

452-6.7.1 General: Where casting cells are intended to operate on a short (daily) cycle and it can be demonstrated to the satisfaction of the Engineer that the required initial concrete strengths for the removal of the forms, application of prestress, moving and handling of the segments and that the final concrete strength can be achieved in a timely and consistent manner, then steam curing will not be required. However, take precautions to promote proper curing by methods approved by the Engineer and in accordance with Section 400. Such precautions must meet or exceed the following:

1. To prevent moisture loss, cover all exposed surfaces (those not in contact with a form or match cast segment) as soon as possible after casting with a moisture tight covering (wet curing blankets or other approved equal systems). Avoid spoiling the deck surface finish. Keep the cover on or within 12 inches of the deck surface.

2. Keep the moisture-tight covering substantially in place throughout succeeding operations such as geometry control survey, stripping of internal forms, wing forms and shifting of and working with a segment in a match cast position. Keep the concrete surface wet throughout these operations.

3. After stripping of the side and core forms, continue curing of the precast concrete by the application of a Type 2 (white pigmented) membrane curing compound as specified in 925-2 to all exposed surfaces (including segment exterior once exposed by removal from the form). Apply an approved debonding compound to match cast surfaces to serve both as a bond breaker and seal for curing.

4. Maintain the moisture tight covering for at least 72 hours.

As an alternative, steam curing may be used.

5. While the new cast segment is in contact with the match cast segment, cover the match cast segment with curing blankets, or other approved equal system, to minimize the effects of differential temperature between the segments.

452-6.7.2 Steam Curing: Meet the requirements of Section 400 modified by the following requirements when steam curing is used.

1. Provide a device or devices for simultaneously recording the temperature of three widely separated locations per casting cell. Locate the three temperature sensors near the top, middle and bottom of the enclosure or as otherwise approved by the Engineer. Identify the charts with the hours, dates and segment number and submit to the Engineer immediately after steam curing is completed unless otherwise approved.

2. Apply an approved debonding compound to match cast surfaces to serve both as a bond breaker and seal for curing.

3. Expose match cast segments to the same curing environment (temperature and humidity) as the new cast segment until the new segment reaches the required strength to allow the removal of the forms.

452-6.8 Removal of Forms: Prior to removing the forms, protect the plastic concrete from adverse weather effects.

Keep supporting forms in place until the concrete has reached the required strength for form removal as specified in the Plans, in this Section, or as approved by the Engineer.

Test cylinders, made and cured in the same manner as the segment, to confirm the form release strength prior to removing form. With the Engineer's approval, a strength curve chart may be established to determine the time necessary for achieving the required form release strength, in accordance with the specifications for form removal.

Avoid cracking or damaging the segment when removing the forms, especially match cast surfaces and shear keys. Notify the Engineer of any damage which occurs and repair in an approved manner.

452-6.9 Test Samples: Provide additional test samples and testing for compressive strength on precast segments and field closure joints to control the construction activities and to ensure adequate strength of these components at various stages of their manufacture and assembly.

Make test cylinders, in accordance with Section 346, cured in the same manner as the structural components to ensure adequate compressive strength has been achieved in accordance with the plan requirements for the following conditions:

1. Prior to release of prestressing for components which are to be pretensioned.

2. Prior to form release and/or moving the components to storage.

3. Prior to post-tensioning transverse tendons if the component is less than 28 days old.

4. Prior to placing a component into position in the structure and/or stressing of longitudinal post-tensioning tendons if the component is less than 28 days old.

Determine the number of cylinders in accordance with the proposed method for casting, transporting and erecting the various components.

Submit the results of the compression testing of one or more test cylinders for controlling the time of execution of the various construction operations. Obtain the Engineer's approval for meeting the Specification requirements on casting, curing and testing of concrete test cylinders.

No direct payment will be made for the concrete testing. All costs for such testing will be included in the bid items for the various precast structural components.

452-6.10 Age at Erection: Unless otherwise approved by the Engineer, precast components must be at least 14 days old prior to incorporating into the structure.

452-6.11 Tolerances:

452-6.11.1 General: The following tolerances apply to the fabrication of precast components:

Table 452-1	
(1) Superstructure Box Segments	
Width of Web	±1/4 inch
Depth of bottom slab	±3/16 inch
Depth of top slab	±3/16 inch
Overall depth of segment	±3/16 inch
Overall width of segment	±1/4 inch
Length of segment	±3/8 inch
Diaphragm dimensions	±3/8 inch
(2) Precast Box Pier Segments	
Height (Individual Element)	±1/4 inch
Width and Breadth (Individual Element)	±1/4 inch
Thickness (wall)	±1/4 inch
(3) All Fabricated Segments	
Ends (deviation from a plane per 20 ft width or depth	±1/4 inch per 20 ft not to exceed 1/2 inch.
Flat Surface (deviation from a plane at any location)	±0.025 in/ft not to exceed a total of 1/4 in.

452-6.11.2 Corrections: Control dimensions from segment to segment, including cast-in-place segments, and compensate for any deviations within a single segment or series of segments so that the overall dimensions of the completed structure meet the dimensions and overall erection tolerances shown in the Plans and allowed by this Section.

452-6.11.3 Repairs: Repair minor breakage, spalling, or honeycomb (not over 1 inch deep) by a method approved by the Engineer. Major breakage, spalling, or honeycomb in excess of 1 inch deep is subject to the Engineer's structural review. If found to be satisfactory, repair these areas using a method approved by the Engineer. Do not perform surface finishing or repairs on the matching joint surfaces of precast segments until after final erection of the segment, except as herein noted. If more than 20%, but less than 40% of the total contact surface of all shear keys in any single web is broken, spalled or honeycombed, grind the damaged areas to produce a cylindrical depression into sound concrete to a depth and width approximately equal to the shear key dimensions. Complete necessary repairs to shear keys damaged at the casting site prior to shipping the segment to the erection site. After erection of the segments adjacent to the damaged keys and prior to erection of additional segments, carefully pack the voids left by the depressions with an epoxy mortar as approved by the Engineer. With the Engineer's approval, an alternate method of repair may be used. The Engineer will consider the segment unsatisfactory for use if more than 40% of the total contact surface of all shear keys in any single web is broken, spalled or honeycombed. Use an Engineer approved method for repairing damaged alignment keys located in the top and bottom slabs. The Engineer will consider a segment unsatisfactory for use if more than 50% of the total contact surface of all alignment keys in any element of the slab (wing overhang, central portion between webs, etc.) is broken, spalled or honeycombed. Remove and dispose segments found to be unsatisfactory and not repairable after structural review and cast a new segment at no expense to the Department.

452-7 Precast Segment Handling, Storage and Shipment.

Handle segments with care to prevent damage. Handle segments using only the devices shown on the shop drawings for this purpose. Store all precast segments level in the upright position. Firmly support all precast segments for storage and shipment on an approved three point bearing system which does not introduce a twist under self weight. Do not stack superstructure segments one upon another unless approved by the Engineer.

Prior to shipment the Engineer will thoroughly inspect each segment for damage. Thoroughly clean the faces of all joints of laitance, bond breaking compound and any other foreign material by light sand blasting prior to shipment. Make no repairs of minor spalls or chipped areas on the joint surfaces until after erection of the segment. Upon arrival at the bridge site the Engineer will inspect each segment again. If in the Engineer's opinion, any damage has occurred during shipment that will impair the function of the segment (structurally, aesthetically, etc.), the segment will be rejected. Replace any rejected segment with an approved segment at no cost to the Department. Provide firm support at bearing locations noted above. Fully secure the segments against shifting during transport. Provide a storage area of suitable stability for the segments to prevent differential settlement of the segment supports during the entire period of storage.

452-8 Erection.

452-8.1 Erection Manual: Before commencing erection operations, submit proposals for all segment erection operations to the Engineer for approval. This submittal must be in the form of an "Erection Manual" and include but not necessarily be limited to:

1. A detailed step-by-step sequence for the erection of each segment including all intermediate procedures relating to erection equipment, temporary and permanent post-tensioning and making of closures between spans and/or cantilevers and other required sequencing.
2. Positioning, use and sequencing of falsework, jacking and/or releasing of falsework, temporary towers, supports, tie-downs, counterweights, closure devices and the like.
3. Positioning, use and sequencing of erection equipment such as cranes, beam and winch devices, gantries, trusses and the like, both on and off the structure, including the movement, introduction and/or removal of any supports onto or connections with the structure. Include drawings and calculations for the structural effects of erection equipment on the structure.
4. Detailed scheduling of all temporary and permanent post-tensioning operations and sequences in accordance with the segment erection and closure operations and other required scheduling.
5. Stressing forces and elongations for post-tensioning.
6. Sequencing of filler injection operations.
7. A method for the field survey control for establishing and checking the erected geometry (elevations and alignments) with particular attention to the setting of critical segments such as, for example, pier segments for balanced cantilever erection. This information may be included in the Erection Manual or may be submitted later as a supplementary or separate document.
8. Any other relevant operations as required and applicable to the structure type and construction method.

Do not start erection without the Engineer's approval of the erection manual.

452-8.2 Erection Geometry Control:

452-8.2.1 General: Numerical or graphical methods may be used for alignment control and checking during erection. Establish the key stages for checking of the erection in the erection manual and obtain the Engineer's review and approval. Key stages would include, for example, setting a pier segment during cantilever erection and various intermediate points during subsequent segment erection, at span closure and upon completion.

Prepare a table of elevations and alignments required at each key stage of erection in accordance with the Plans, as cast geometry, camber and erection elevations for establishing erection controls and submit to the Engineer for approval.

Carefully check elevations and alignments at each stage of erection and correct as required to avoid any possible accumulation of errors.

If geometric corrective measures are necessary, the Engineer will require the Specialty Engineer to develop the means and methods to ensure the epoxy joint remains watertight and free from localized stress concentrations. The Specialty Engineer will be required to submit the corrective measures to the Engineer for approval. Use shims made of ASTM A240 Type 304 wire cloth (roving) with a maximum of 1/8 inch thickness.

452-8.2.2 Span-by-Span and Wet Joint Erection: Position each span segment according to the final longitudinal alignment, grade, camber and cross-slope. Keep the horizontal and vertical alignment of the pier segment within 1/16 inches of that required by the approved erection plans.

Correct any deviation more than the tolerance allowed above using a method approved by the Engineer.

452-8.2.3 Balanced Cantilever and Progressive Cantilever Erection: Check the alignment and elevations of the cantilevers, using two independent surveys, within one hour of sunrise on each day that segments are to be erected. Check the measurements made by each survey and ensure they agree to within 1/4 inches. When measurements do not agree, discontinue erection of segments until discrepancies in measurements are resolved to the satisfaction of the Engineer.

Accurate positioning of the pier segments is very important as it will establish the line and grade for cantilevers in each direction. Position each pier segment according to the final longitudinal alignment, grade and cross-slope and ensure no further erection continues until and unless these segments are properly located on the piers by the means provided. Keep the horizontal and vertical alignments of the pier segment within 1/16 inch of the alignment values required to control points as established by the approved erection plans.

Check at each key stage of erection, in accordance with approved erection procedures, the ends of cantilevers for required elevations and alignment. Correct any deviation from the required alignment by a method approved by the Engineer.

452-8.3 Erection Tolerances:

1. Ensure that maximum differential between outside faces of adjacent segments in the erected position does not exceed 3/16 inches.

2. Ensure that transversely, the angular deviation from the theoretical slope difference between two successive segment joints not exceed 0.001 rad.

3. Ensure that longitudinally, the angular deviation from the theoretical slope change between two successive segments does not exceed 0.003 rad.

4. Dimensions from segment to segment will compensate for any deviations within a single segment so that the overall dimensions of the completed structure meets the

dimensions shown in the Plans such that the accumulated maximum error does not exceed 1/1000 of the span length for either vertical profile and/or horizontal alignment.

Carefully check elevations and alignments at each stage of erection and correct as required to avoid any possible accumulation of errors.

452-8.4 Other Miscellaneous Erection Requirements:

452-8.4.1 Span-by-Span and Wet Joint Erection:

452-8 .4.1.1 Closure Joints: Use concrete meeting the same specifications and criteria as the concrete in the segments. Ensure that concrete reaches the minimum required strength as shown in the Plans or in the Specifications prior to stressing the continuity post-tensioning. Ensure that the closure joint forms provide tolerances as specified under 452-6.11 Tolerances.

452-8.4.1.2 Wet Joints: Where forming joints between segments using cast-in-place concrete, the above conditions for closure joints also apply to wet joints. In addition, the cast-in-place "Wet Joints" cannot be less than 3 inches wide, nor greater than 9 inches wide unless otherwise approved by the Engineer.

452-8.4.1.3 Formwork: Adequately support formwork at all wet joints and closure joints to take all loads applied and do not remove them until the concrete in the joints has reached its required strength and the longitudinal tendons have been tensioned.

452-8.4.2 Balanced Cantilever and Progressive Cantilever Erection:

452-8.4.2.1 Deformations: For computing deformations due to time dependent stress variations, the erection time assumptions are shown in the Plans.

Deformations due to creep and shrinkage and the concrete modulus of elasticity have been computed using the FDOT's Structures Manual edition noted in the Plans. Obtain the Engineer's approval for method of calculating the above parameters.

452-8.4.2.2 Temperature Restrictions: Meet the requirements of Section 926 for substrate temperatures, epoxy formulation and thermal controls where precast segments are jointed with epoxy. Measure the substrate temperature at the mid-depth of the top slab for box girder sections or 4 inches from the top surface for slabs and other sections.

452-8.4.2.3 Permissible Loads on Cantilever: During balanced cantilever erection, unbalance the cantilever by only one segment at any time. In addition to the unbalanced load due to one segment, the cantilevers are designed for loads applied by the erection equipment as listed in the Plans. Use alternate erection methods which comply with the assumptions in the Plans or otherwise approved by the Engineer.

452-8.4.2.4 Span Closure Joints: Use concrete for closure joints which comply with the same specifications and criteria as the concrete in the segments. Ensure that concrete reaches the minimum required strength as shown in the Plans or in the Specifications prior to stressing the transverse or continuity post-tensioning. Ensure that the closure joint forms provide tolerances as specified for precast segments.

452-8.4.2.5 Falsework and Formwork: Support falsework and formwork at closure pours by the cantilever ends or terminating segments of each series of segments to be joined. Secure cantilever together vertically, longitudinally, and transversely so that the applied loads will yield equal deflections to both cantilevers. Do not remove securing devices until the closure pour concrete has reached its required strength and longitudinal continuity tendons are tensioned. Submit calculations and details to verify that the devices and methods have adequate rigidity and do not impose excessive loads and stresses on the structure.

452-8.4.3 Precast Box Pier Construction - Erection Tolerances:

1. Ensure that maximum differential between outside faces of adjacent segments in the erected position does not exceed 3/16 inches.

2. Ensure that the rotational angular deviation, measured about a vertical line, between two successive segment joints does not exceed 0.001 rad.

3. Ensure that the maximum angular deviation of a segment from a vertical line does not exceed 0.003 rad. and that the maximum overall deviation from the vertical, measured in any direction, does not exceed 0.01 inches per foot of height.

4. Ensure the base precast segment is within 1/2 inch of the Plan location.

452-8.5 Epoxy Jointing of Precast Segments: Furnish, mix and apply a two-component epoxy bonding system, meeting the requirements of this Section, to the match cast faces of joints between precast concrete superstructure and/or substructure segments in accordance with the Contract Documents

Prior to the use of epoxy on the project, conduct a site meeting with the Engineer and epoxy manufacturer to determine the proper formulations, storage and handling, mixing and application of the epoxy.

Have the necessary materials immediately available at the location of the segment joining, in the event that the segments must be separated and cleaned or epoxy reapplied.

Include in the erection manual required by this Section, details of erection and post-tensioning operations which assure that the time elapsing between mixing components of the first batch of epoxy bonding agent applied to the joining surfaces of precast concrete segments and the application of a compressive contact pressure across the joint do not exceed 70% of the open time for the particular formulation of epoxy bonding agent used. Also, include details of how the minimum, closing, contact pressure of approximately 40 psi will be applied uniformly to each joint to which epoxy is applied during the epoxy curing period. Contact pressure may be attained through combinations of weight and temporary and/or permanent post-tensioning.

452-8.5.1 Cleanliness of Surfaces to be Joined: Ensure that the application surfaces are free from oil, form release agent, laitance or any other deleterious material that would prevent the epoxy bonding agent from bonding to the concrete surface. Remove laitance by light sandblasting, wire brushing. Do not destroy the surface shape and profile of the mating surfaces.

Ensure that the surfaces have no free moisture on them at the time the epoxy bonding agent is applied. Free moisture will be considered present if a dry rag, after being wiped over the surface, becomes damp.

452-8.5.2 Substrate Temperatures and Epoxy Formulation: Apply the epoxy bonding agent only when the substrate temperature of both surfaces to be joined is between 40°F and 115°F. The formulation of the epoxy bonding agent must have an application temperature range that conforms to the substrate temperature of the surfaces being joined. If the mating surfaces have different substrate temperatures, then use the formulation for the higher temperature in hot weather periods. In cold weather periods, use the formulation for the lower temperature. Thermal control precautions may be taken in accordance with 452-8.5.5.

452-8.5.3 Mixing of Epoxy Bonding Agent: Mix the two components of the epoxy bonding agent in strict accordance with the manufacturer's instructions, using only full and undamaged containers. Only open the containers immediately before being combined and do not use any which have an expired shelf life. Thoroughly stir each container of component before combining the components. Combine the two components and thoroughly mix until a uniform

color is achieved. Mix with a properly sized mechanical mixer operating at no more than 600 rpm or in accordance with the recommendations of the epoxy manufacturer.

Do not mix until the segments to be joined are within approximately 18 inches of their final position. Schedule mixing of the epoxy bonding agent so that the material in a batch is applied to the face of a joint within a maximum of 20 minutes after combining the components.

The Engineer, at his discretion, may require a dry run to check the fit of two surfaces before applying the epoxy.

452-8.5.4 Mating of Segments: Immediately after each mating surface is covered with epoxy bonding agent, bring the segments together and apply the specified compressive contact pressure in accordance with the approved erection procedures. The contact pressure may be increased at any time after the epoxy has taken an initial set. Do not reduce the contact pressure until the epoxy in the joint has properly hardened and cured. If the contact pressure is reduced, do not subject the joint to tensile stress.

A discernable bead line of extruded epoxy bonding agent must be apparent along the exposed edges of the joint. Fill all areas of the joint which do not show a bead of epoxy by dispensing additional epoxy, meeting the requirements of this specification, into the joint using a pneumatic gun with epoxy cartridges. Inject epoxy to a minimum depth of 1 inch.

Catch and retain epoxy which is squeezed out of the joint in areas over waterways, roadways, buildings, etc.

Clean all extruded epoxy bonding agent from external visible surfaces in a way not to damage or stain the concrete surface. Do not smear surplus extruded epoxy bonding agent over large areas (areas more than 1 inch from each side of the joint), visible surfaces or surfaces to which a cover coat, Class 5 applied finish coat or similar or texturing is to be applied later.

Immediately after the segments are joined, swab all embedded (internal) post-tensioning ducts or conduits passing through the joints to smooth out any extruded epoxy bonding agent.

If the time between combining the components of the epoxy bonding agent and applying the compressive contact pressure exceeds 70% of the minimum open time, immediately separate the segments and clean in accordance with 452-8.5.6.

452-8.5.5 Thermal Controls:

452-8.5.5.1 Cooling in Hot Weather: If the substrate temperature exceeds 115°F, do not proceed with epoxy jointing. The Contractor may take precautions to keep the mating substrate surfaces cool by shading or wetting with clean water, except that the above requirements for no moisture at the time of application must be strictly adhered to.

452-8.5.5.2 Artificial Heating in Cold Weather: If electing to erect segments in cold weather when the substrate temperature of the mating concrete surfaces is below 40°F, an artificial environment may be used to increase the substrate temperature subject to the following:

1. Make the artificial environment by an enclosure surrounding the joint through which warm air is circulated, or heating is provided by radiant heaters.
2. Raise the temperature of the concrete substrate across the entire joint surface to at least 40°F.
3. Prevent localized heating and the temperature of the substrate exceeding 95°F at any point on the surface. Direct flame heating of the concrete is not allowed.

4. Maintain the temperature of the substrate surfaces between 40°F and 95°F for at least 24 hours after joining the surfaces.

5. The Contractor may propose, for review by the Engineer, an optional method of raising and maintaining the substrate temperature of the mating surfaces. Any optional method must meet the thermal restrictions above.

Epoxy jointing operations may proceed if the air temperature is above 45°F and rising and the limitations above are met.

452-8.5.6 Failure to Comply with Time Limits or Incomplete Jointing: If the time limit between mixing of the epoxy-bonding agent and the application of the contact pressure is exceeded, or if the joint is incompletely filled and sealed, separate the segments and remove all epoxy from the faces using spatulas and approved solvent. Do not re-apply epoxy until the faces have been properly cleaned and solvents dispersed, for a period of 24 hours.

452-8.5.7 Removal of Support to Segments:

452-8.5.7.1 Span-by-Span Erection: Ensure that precast concrete segments remain fully supported by the erection truss or system until at least 20 hours after mixing of the last batch of epoxy bonding agent applied to any joint in the span.

452-8.5.7.2 Cantilever Erection: Independent support to a newly erected cantilever segment may be removed when the epoxy bonding agent in the third previous mating joint has set. It is not necessary for the epoxy bonding agent in the new joint or the immediately previous joint to be set prior to removing the independent support of the new segment provided that the temporary and/or permanent post-tensioning has been installed to carry the load of the new and previous segment along with any applied construction loading as per the requirements of the erection system.

452-8.5.8 Record of Jointing: Record and submit to the Engineer on a weekly basis the following information:

1. General:
    a. Date and time of jointing,
    b. Segment numbers or spans jointed,
    c. Weather conditions
2. For each joint (identified by location or segment numbers):
    a. manufacturer's LOT number of epoxy bonding agent components.
    b. Temperature of the concrete on the joint surface at the middle of each segment when application of the epoxy bonding agent began.
    c. Time of mixing first batch of epoxy bonding agent applied to the joint and completion of application.
    d. Time of applying the required compressive contact pressure.
3. Details of any repairs performed including reason for repair, joint location, volume of epoxy used, method of application, etc.

452-8.6 Packed Mortar Joints for Joints or Bearings: Where designated on the Plans, place packed mortar after the joint or bearing has been set at the proper final elevation.

Pressure grouting may be allowed with the Engineer's approval of the materials and method to be used.

Mortar for packing consists of one part cement and one part fine aggregate, by volume, mixed with a non-shrink admixture as recommended by the manufacturer. Mix the dry

elements thoroughly to a uniform mixture. Add water to produce a mealy, slightly adhesive mixture. Pack the mortar until a water sheen is produced on the surface of the mortar.

Build a form around the joint leaving one side open. Secure the form to withstand the required packing forces. Insert a small amount of mortar into the open joint to form a 2 inches thick bead on the opposite side of the form. Pack this bead by striking a special tool made of 1/2 inch by 2 inch steel having a length approximately 10 inches longer than the largest dimension of the joint being packed with a 2 pound hammer. Continue compaction until water begins to bleed out of the mortar. When bleeding has occurred, insert another bead of mortar and pack as described above. Continue this process until the joint is filled to the limits shown in the Plans.

452-9 Traffic Railing and Median Setting.

Prior to forming the concrete traffic railings, accurately establish the as-constructed gutter line elevations at intervals not exceeding 10 feet. Then form the base of the traffic railing and median to provide an inside vertical face which extends from the surface of the concrete structure to an elevation located 3 inches (or as shown in the Plans) above the theoretical gutter line elevations. Maintain the plan vertical height of the traffic railings as a minimum when variations exist between the plan profile and the actual profile of the gutter.

452-10 Bridge Deck Surface.

Provide a Class 4 Floor Finish in accordance with Section 400 for Long Bridges upon completion of superstructure segment erection and prior to opening to traffic. Install expansion joints in accordance with Section 400.

452-11 Watertight Decks.

Check all segment joints, closure joints and deck hole repairs to assure every location is watertight, upon completion of all milling and grinding activities on the riding surface. Repair all locations showing evidence of leaks by cutting a 3/8 inches wide x 5/8 inches deep groove along the leak interface. Clean and completely fill the groove with epoxy meeting the requirements of Section 926. Dispense the epoxy into the groove using a pneumatic gun and epoxy cartridges. Clean all excess epoxy bonding agent from external visible surfaces in a way not to damage or stain the concrete surface. Do not smear epoxy over areas located more than 1 inch from each side of the groove.

452-12 Method of Measurement.

Precast superstructure and substructure segment concrete, including cast-in-place concrete for closure and wet joint pours, will be measured by volume according to the quantities represented by the dimensions of the segments and cast-in-place pours on the Plans or approved shop drawings; whichever is the lesser.

All reinforcement in precast superstructure and substructure segments, cast-in-place closures and wet-joints will be measured by weight according to the quantities represented by the reinforcement details in the Plans or approved shop drawings; whichever is the lesser.

All permanent post-tensioning in the superstructure and substructure will be measured by weight according to the quantities represented by the details in the Plans or approved shop drawings; whichever is the lesser.

452-13 Basis of Payment.

452-13.1 General: Payment will be in accordance with the following:

452-13.2 Precast Segments-Concrete: Payment for precast superstructure and substructure segment concrete will be at the Contract bid prices per cubic yard for the various classes of concrete called for.

Such prices and payments will be full compensation for manufacture, storage, transport, assembly and erection of the segments complete and in place, including filling all concrete blockouts and similar miscellaneous details. These prices and payments will also include the furnishing and the application of epoxy bonding agent and Class 5 applied finish coating when specified in the Plans, providing temporary and permanent segment access details, material testing, special erection equipment, temporary post-tensioning, tools, labor and incidental items necessary for completing the work in accordance with the Plans, Specifications and approved shop drawings.

Cast-in-place concrete for closure and wet joint pours will be paid for under these items which also include the cost of all formwork, closure devices and other temporary construction needed to make these closures and joints and cast-in-place segments or portions thereof as designated in the Plans.

Include the cost of providing a Class 4 floor finish on the bridge deck and approach slab surfaces in the cost of superstructure and approach slab concrete.

The Bridge floor grooving will be measured and paid for separately.

No additional payment will be made for extra concrete necessitated by approved modifications to the segments or structure needed to accommodate the Contractor's construction methods.

452-13.3 Precast Segments-Reinforcement: Payment for reinforcement in precast segments, closure pours, wet joints and other cast-in-place concrete joints and details will be at the Contract bid price per pound for reinforcing steel (superstructure) and for reinforcing steel (substructure).

No additional payment will be made for extra reinforcement necessitated by approved modifications to the segments or structure for the purposes of the Contractor's construction methods.

452-13.4 Precast Segments-Post-Tensioning: Payment for permanent post-tensioning will be in accordance with Section 462.

No additional payment will be made for extra permanent or temporary post-tensioning necessitated by approved modifications to the segments or structure for the purposes of the Contractor's construction methods, nor will payment be made for temporary tendons which are approved to be left in the structure, either stressed or unstressed, for the convenience of the Contractor's operations.

452-13.5 Precast Segments-Partial Payment: Partial payment for precast segments will be made at 65% of the bid price per cubic yard of concrete and per pound of reinforcement when the segment has been cast and accepted. Remaining payment will be made when the segment has been erected and accepted for incorporation into the structure. Payment for post-tensioning will be in accordance with Section 462.

452-13.6 Precast Segment-Non-Compliance: Any penalties or deductions for non-compliance with regard to concrete, reinforcement or post-tensioning will be applied to the work affected in accordance with the requirements of the respective specifications.

452-13.7 Precast Segment Production: Preparatory operations for superstructure segment casting will be paid for separately at the Contract Lump Sum price for precast segment production. This item consists of the work necessary for establishing and putting into operation segment casting facilities. It includes preparatory work, operations, acquisition or lease of real property, acquisition or lease of segment manufacturing equipment, acquisition or lease of equipment for the handling, transport and storage of the segments, and all other work or operations which must be performed or costs incurred prior to the manufacture of the concrete segments, including engineering services such as shop drawings.

Partial payments will be made as indicated below:

1. Upon production of documentary evidence, such as paid invoices, canceled checks or similar executed financial instruments, the cost for the acquisition of the casting forms for the precast segments by purchase, lease or manufacture will be paid up to a limit of 25% of the Lump Sum Price bid.

2. When the first precast superstructure segment has been cast out of the first operable casting form and the segment is approved and accepted by the Engineer, 25% of the Lump Sum Price bid will be paid.

3. Thereafter, when each succeeding superstructure segment has been cast out of any operable casting form and approved and accepted by the Engineer, 5% of the Lump Sum Price bid will be paid for each segment up to a limit of 50% of the Lump Sum Price bid (i.e., 5% for each of the next ten acceptable segments).

The total Lump Sum Price bid under this item will not exceed the least of:

1. 12% of the sum of the amounts paid for the concrete in the precast segments only (i.e., excluding any cast-in-place concrete in joints, closures or designated cast-in-place segments) or

2. 5% of the Contract amount excluding mobilization and this item.

The balance of the Lump Sum Price not paid after completion of casting the first eleven satisfactory superstructure segments will be paid after completion of the erection of the first span or closure of the first pair of cantilevers, whichever occurs first.

452-13.8 Epoxy Jointing: No separate payment will be made for the work of epoxy jointing of precast concrete segments. The cost of this work will be included in payment for the various precast concrete items.

452-13.9 Payment Items:

Payment will be made under:

Item No. 400- 4- 39-	Class IV Concrete (Precast Superstructure Segments) - per cubic yard.
Item No. 400- 4- 40-	Class IV Concrete (Precast Substructure Segments) - per cubic yard.
Item No. 400- 8- 40-	Class V Concrete (Precast Substructure Segments) - per cubic yard.
Item No. 415- 1- 4-	Reinforcing Steel (Superstructure) - per pound.
Item No. 415- 1- 5-	Reinforcing steel (Substructure) - per pound.
Item No. 452- 70-	Precast Segment Production - lump sum.

SECTION 455
STRUCTURES FOUNDATIONS

Index

A. GENERAL

455-1 General.

The Contractor may examine available soil samples and rock cores obtained during the soil boring operations at the appropriate District Materials Office.

455-1.1 Monitor Existing Structures: Monitor existing structures in accordance with Section 108.

455-1.2 Excavation: Complete all excavation of the foundations prior to installing piles or shafts unless otherwise authorized by the Engineer. After completing pile/shaft installation, remove all loose and displaced materials from around the piles/shafts, leaving a clean, solid surface. Compact the soil surface on which concrete is to be placed or which will support the forming system for the concrete to support the load of the plastic concrete without settling or causing the concrete to crack, or as shown in the Contract Documents.

455-1.2.1 Abutment (End Bent) Fill: Place and compact the fill before installing end-bent piling/shafts, except when driving specified test piling in end bents or the Plans show uncased piles through proprietary retaining wall fills.

When installing piles/shafts or casing prior to placing fill, take necessary precautions to prevent displacement of piles/shafts during placing and compacting fill materials within 15 feet of the piles/shafts or casing. Reference and check the position of the piles/shafts or casing at three approximately equal intervals during construction of the embankment.

Place embankment material in 6 inch compacted lifts in the 15 foot area around the piles/shafts or casing. Compact embankment material within the 15 foot area adjacent to the piles/shafts or casing to the required density with compaction equipment weighing less than 1,000 pounds. When installing piles/shafts prior to the completion of the surrounding fills, do not cap them until placing the fills as near to final grade as possible, leaving only the necessary working room for construction of the caps.

When shown in the Plans, provide permanent casings installed prior to placement of the fill, for all drilled shafts through mechanically stabilized fills (for example, behind proprietary retaining walls) for shafts installed after fill placement. Install temporary casings through the completed conventional fill when permanent casings are not required.

Provide permanent casings, if required, before the fill is placed extending a sufficient distance into the existing ground to provide stability to the casings during construction of the abutment fill.

455-1.3 Cofferdams: Construct cofferdams as detailed in the Plans. When cofferdams are not detailed in the Plans, employ a qualified Specialty Engineer to design cofferdams, and to sign and seal the plans and specification requirements. Submit the designs to the Engineer for their records before beginning construction.

Provide a qualified diver and a safety diver to inspect the conditions of the foundation enclosure or cofferdam when the Contract Documents require a seal for construction. Equip these divers with suitable voice communications, and have them inspect the foundation enclosure and cofferdam periphery including each sheeting indentation and around each piling or drilled shaft to ensure that no layers of mud or other undesirable materials were left above the bottom of seal elevation during the excavation process. Also have the divers check to make sure the surfaces of the piles or drilled shafts are sufficiently clean to allow bond of the concrete down to the minimum bottom of seal elevation. Ensure that there are no mounds of stone, shell, or unapproved backfill material left after placement and grading. Assist the Engineer as required to ensure that the seal is placed as specified and evaluate the adequacy of the foundation soils or rock. Correct any deficiencies found by the divers. Upon completion of inspection by the divers, the Department may also elect to inspect the work before authorizing the Contractor to proceed with subsequent construction operations. Submit a written report by the divers to the Engineer indicating the results of their underwater inspection before requesting authorization to place the seal concrete.

455-1.4 Vibrations on Freshly Placed Concrete (Drilled Shafts and Piers): Ensure that freshly placed concrete is not subjected to peak particle velocities greater than 1.5 inches per second from vibration sources located within 30 feet (from the nearest outside edge of freshly placed concrete to the vibration source) until that concrete has attained its final set as defined by ASTM C403 except as required to remove temporary casings before the drilled shaft elapsed time has expired.

455-2 Static Compression Load Tests.

455-2.1 General: Employ a professional testing laboratory, or Specialty Engineer with prior load test experience on at least three projects, to conduct the load test in compliance with these Specifications, to record all data, and to submit reports of the test results to the Engineer except when the Contract Documents show that the Department will supply a Geotechnical Engineer to provide these services.

Perform the load test by applying a load up to the load required in the Contract Documents or to the failure load, whichever occurs first.

Do not apply test loads to piles sooner than 48 hours (or the time interval shown in the Plans) after driving of the test pile or reaction piles, whichever occurs last.

Do not begin static load testing of drilled shafts until the concrete has attained a compressive strength of 3,400 psi. The Contractor may use high early strength concrete to obtain this strength at an earlier time to prevent testing delays.

Load test piles/shafts in the order directed by the Engineer. Unless shown otherwise in the Contract Documents, provide all equipment, materials, labor, and technical personnel required to conduct the load tests, including determination of anchor reaction member depths. In this case, provide a loading apparatus designed to accommodate the maximum load plus an adequate safety factor.

While performing the load test, provide safety equipment, and employ safety procedures consistent with the latest approved practices for this work. Include with these safety

procedures, adequate support for the load test plates and jack to prevent them from falling in the event of a release of load due to hydraulic failure, test pile/shaft failure, or any other cause.

Include in the bid the cost of transporting load test equipment and instrumentation supplied by the Department from their storage location to the job site and back. Handle these items with care. The Contractor is responsible for the safe return of these items. After completion of the static load tests, return all Department furnished equipment in satisfactory operating condition. Repair all damage to the test equipment furnished by the Department to the satisfaction of the Engineer. Clean all areas of rust on structural steel items, and recoat those areas in accordance with Section 560. Return all load test equipment supplied by the Department within 30 days after completing the load tests.

The Contractor is responsible for the equipment from the time it leaves its storage area until the time it is returned. During this time, insure the equipment against loss or damage for the replacement cost thereof (the greater of $150,000 or the amount shown in the Plans) or for the full insurable value if replacement cost insurance is not available.

Notify the Engineer at the preconstruction conference, or no later than 30 days before beginning test pile installation, of the proposed testing schedule so that items supplied by the Department may be reserved. Notify the Department at least ten working days before pick-up or return of the equipment. During pick-up, the Department will complete a checklist of all equipment placed in the Contractor's possession. The Department will later use this checklist to verify that the Contractor has returned all equipment. Provide personnel and equipment to load or unload the equipment at the Department's storage location. Provide lifting tongs or nylon slings to handle Department owned test girders. Do not perform cutting, welding, or drilling on Department owned girders, jacks, load cells, or other equipment.

455-2.2 Loading Apparatus: Provide an apparatus for applying the vertical loads as described in one of the following:

1. As shown and described in the Contract Documents.

2. As supplied by the Contractor, one of the following devices designed to accommodate a load at least 20% higher than the test load shown in the Plans or described herein for test loads:

a. Load Applied by Hydraulic Jack Acting Against Weighted Box or Platform: Construct a test box or test platform, resting on a suitable support, over the pile, and load it with material with a total weight greater than the anticipated maximum test load. Locate supports for the weighted box or platform at least 6 feet or three pile/shaft diameters, whichever is greater, measured from the edge of the pile or shaft to the edge of the supports. Insert a hydraulic jack with pressure gauge between the test pile or shaft and the underside of the reaction beam, and apply the load to the pile or shaft by operating the jack between the reaction beam and the top of the pile or shaft.

b. Load Applied to the Test Pile or Shaft by Hydraulic Jack Acting Against Anchored Reaction Member: Construct reaction member anchorages in accordance with article 6.3 of ASTM D1143. Attach a girder(s) of sufficient strength to act as a reaction beam to the upper ends of the anchor piles or shafts. Insert a hydraulic jack with pressure gauges between the head of the test pile/shaft and the underside of the reaction beam, and apply the test load to the pile/shaft by operating the jack between the reaction beam and the pile/shaft head.

If using drilled shafts with bells as reaction member anchorages, locate the top of the bell of any reaction shaft anchorage at least three shaft diameters below the bottom of the test shaft.

c. Combination Devices: The Contractor may use a combination of devices (a) and (b), as described above, to apply the test load to the pile or shaft.

d. Other systems proposed by the Contractor and approved by the Engineer: When necessary, provide horizontal supports for loading the pile/shaft, and space them so that the ratio of the unsupported length to the minimum radius of gyration of the pile does not exceed 120 for steel piles, and the unsupported length to the least cross-section dimension does not exceed 20 for concrete piles or drilled shafts. Ensure that horizontal supports provide full support without restraining the vertical movement of the pile in any way.

When required by the Contract Documents, apply a horizontal load to the shaft either separately or in conjunction with the vertical load. Apply the load to the test shaft by hydraulic jacks, jacking against Contractor provided reaction devices. After receiving the Engineer's approval of the proposed method of load application, apply the horizontal load in increments, and relieve it in decrements as required by the Contract Documents.

455-2.2.1 Modified Quick Test:

1. Loading Procedure: Apply vertical loads concentric with the longitudinal axis of the tested pile/shaft to accurately determine and control the load acting on the pile/shaft at any time. Place the load on the pile/shaft continuously, in increments equal to approximately 5% of the maximum test load specified until approaching the failure load, as indicated by the measuring apparatus and/or instruments. Then, apply increments of approximately 2.5% until the pile/shaft "plunges" or attains the limiting load. The Engineer may elect to stop the loading increments when he determines the Contractor has met the failure criteria or when a settlement equal to 10% of the pile/shaft width or diameter is reached. Apply each load increment immediately after taking and verifying the complete set of readings from all gauges and instruments. Apply each increment of load within the minimum length of time practical, and immediately take the readings. Complete the addition of a load increment and the completion of the readings within 5 to 15 minutes. The Engineer may elect to hold the maximum applied load up to one hour.

Remove the load in decrements of about 10% of the maximum test load. Remove each decrement of load within the minimum length of time practical, and immediately take the readings. Complete the removal of a load decrement and the taking of the readings within 5 to 15 minutes. The Engineer may also require up to two reloading cycles with five loading increments and three unloading decrements. Record the final recovery of the pile/shaft until movement is essentially complete for a period up to one hour after the last unload interval.

2. Failure Criteria and Nominal Resistance: Use the criteria described herein to establish the failure load. The failure load is defined as the load that causes a pile/shaft top deflection equal to the calculated elastic compression plus 0.15 inches plus 1/120 of the pile/shaft minimum width or the diameter in inches for piles/shafts 24 inches or less in width, and equal to the calculated elastic compression plus 1/30 of the pile/shaft minimum width or diameter for piles/shafts greater than 24 inches in width. Consider the nominal resistance of any pile/shaft so tested as either the maximum applied load or the failure load, whichever is smaller.

455-2.3 Measuring Apparatus: Provide an apparatus for measuring movement of the test piles/shafts that consists of all of the following devices:

1. Wire Line and Scale: Stretch a wire as directed by the Engineer between two supports located at a distance at least:

a. 10 feet from the center of the test pile but not less than 3.5 times the pile diameter or width.

b. 12 feet from the centerline of the shaft to be tested but not less than three shaft diameters.

Locate the wire supports as far as practical from reaction beam anchorages. At over-water test sites, the Contractor may attach the wire line as directed by the Engineer to the sides of the service platform. Mount the wire with a pulley on one support and a weight at the end of the wire to provide constant tension on the wire. Ensure that the wire passes across the face of a scale mounted on a mirror attached to the test pile/shaft so that readings can be made directly from the scale. Use the scale readings as a check on an average of the dial readings. When measuring both horizontal and vertical movement, mount separate wires to indicate each movement, horizontal or vertical. Measure horizontal movements from two reference wires set normal to each other in a horizontal.

2. Wooden Reference Beams and Dial Gauges: Attach wooden reference beams as detailed in the Plans or approved by the Engineer to independent supports. For piles, install the greater of 3.5 times the pile diameter or width or 10 feet from the centerline of the test pile. For drilled shafts, install at the greater of three shaft diameters or 12 feet from the centerline of the shaft to be tested. Locate the reference beam supports as far as practical from reaction beam anchorages. For over-water test sites, the Contractor may attach the reference beams as directed by the Engineer between two diagonal platform supports. Attach dial gauges, with their stems resting either on the top of the pile/shaft or on lugs or similar reference points on the pile/shaft, to the fixed beams to record the movement of the pile/shaft head. Ensure that the area on the pile/shaft or lug on which the stem bears is a smooth surface which will not cause irregularities in the dial readings.

Provide a minimum of four dial gauges, each with 0.001 inch divisions and with 2 inch minimum travel, placed at 90 degree intervals for measuring vertical or horizontal movement.

3. Survey Level: As a check on the dial gauges, determine the elevation of a point near the top of the test pile/shaft (on plan datum) by survey level at each load and unload interval during the load test. Unless approved otherwise by the Engineer, level survey precision is 0.001 foot. Alternately, the surveyor may read an engineer's 50 scale attached near the pile/shaft head. Determine the first elevation before applying the first load increment; make intermediate readings immediately before a load increment or an unload decrement, and after the final unload decrement that completely removes the load. Make a final reading at the time of the last recovery reading or as directed by the Engineer.

For over-water test sites, when shown in the Plans or directed by the Engineer, the Contractor shall drive an H pile through a 36 inch casing to provide a stable support for the level and to protect it against wave action interfering with level measurements. Provide a suitable movable jig for the surveyor to stand. Use a jig that has a minimum of three legs, has a work platform providing at least 4 feet width of work area around the casing, and is approved by the Engineer before use. The described work platform may be supported by the protective casing when approved by the Engineer.

455-2.4 Load Test Instrumentation:

1. General: The intent of the load test instrumentation is to measure the test load on top of the pile/shaft and, when provided in the Contract Documents, its distribution between side friction and end bearing to provide evaluation of the preliminary design calculations and

settlement estimates and to provide information for final pile/shaft length design. Ensure that the instrumentation is as described in the Contract Documents.

When requested by the Engineer, provide assistance during installation of any instrumentation supplied by the Department. Supply 110 V, 60 Hz, 30 A of AC electric power in accordance with the National Electric Code (NEC) to each test pile/shaft site during the installation of the instrumentation, during the load testing, and during any instrumented redrives ordered by the Engineer.

Place all of the internal instrumentation on the rebar cage before installation in the test shaft. Construct the rebar cage at least two days before it is required for construction of the test shaft. Provide assistance during installation of instrumentation supplied by the Department, including help to string, place, and tie the instrumentation and any assistance needed in moving or repositioning the cage to facilitate installation. Place the rebar cage in one segment complete with its instrumentation. The Engineer may require multiple lift points and/or a suitable "stiffleg" (length of H pile or other suitable section) to get the cage in a vertical position without causing damage to the instrumentation. Successfully demonstrate the lifting and handling procedures before the installing instrumentation.

2. Hydraulic Jack and Load Cell: Provide hydraulic jack(s) of adequate size to deliver the required test load to the pile/shaft unless shown otherwise in the Plans. Before load testing begins, submit a certificate from a reputable testing laboratory showing a calibration of gauge readings for all stages of jack loading and unloading for jacks provided. Ensure that the jack has been calibrated within the preceding six months unless approved otherwise. Recalibrate the jack after completing load testing if so directed by the Engineer. Ensure that the accuracy of the gauge is within 5% of the true load.

Provide an adequate load cell approved by the Engineer that has been calibrated within the preceding six months. Provide an approved electrical readout device for the load cell. Submit a certificate from an independent testing laboratory showing a calibration of readings for all stages of loading and unloading for load cells furnished by the Contractor and obtain the approval of the Engineer before beginning load testing. Ensure that the accuracy of the load cell is within 1% of the true load.

3. Telltales: When shown in the Contract Documents, furnish and install telltales that consist of an unstressed steel rod placed, greased for reducing friction and corrosion, with appropriate clearance inside a constant-diameter pipe that rests on a flat plate attached to the end of the pipe at the point of interest shown in the Contract Documents. Construct telltales in accordance with the Contract Documents. Install dial gauges reading to 0.001 inch with 1 inch minimum travel as directed by the Engineer to measure the movement of the telltale with respect to the top of the pile/shaft.

4. Embedded Strain Gauges: When shown in the Contract Documents, furnish and install strain gauges in the test shaft to measure the distribution of the load. Ensure that the type, number, and location of the strain gauges are as shown in the Plans or as directed by the Engineer. Use strain gauges that are waterproof and have suitable shielded cable that is unspliced within the shaft.

455-2.5 Support Facilities: Furnish adequate facilities for making load and settlement readings 24 hours per day. Provide such facilities for the instrumented area, and include lighting and shelter from rain, wind, and direct sunlight.

455-2.6 Load Test Personnel Furnished by the Contractor: Provide a certified welder, together with necessary cutting and welding equipment, to assist with the load test setup and to

make any necessary adjustments during the load test. Provide personnel to operate the jack, generators, and lighting equipment, and also provide one person with transportation to assist as required during load test setup and conducting of the load tests. Provide qualified personnel, as determined by a Specialty Engineer or testing lab, required to read the dial gauges, take level measurements, and conduct the load test, except when the Contract Documents show that the Department will provide these personnel.

455-2.7 Cooperation by the Contractor: Cooperate with the Department, and ensure that the Department has access to all facilities necessary for observation of the conduct and the results of the test.

455-2.8 Required Reports: Include in the report of the load test the following information:

1. A tabulation of the time of, and the amount of, the load and settlement readings, and the load and recovery readings taken during the loading and unloading of the pile/shaft.
2. A graphic representation of the test results, during loading and unloading of pile/shaft top movement as measured by the average of the dial gauge readings, from wireline readings and from level readings.
3. A graphic representation of the test results, when using telltales, showing pile/shaft compression and pile/shaft tip movement.
4. The estimated failure and safe loads according to the criteria described herein.
5. Remarks concerning any unusual occurrences during the loading of the pile/shaft.
6. The names of those making the required observations of the results of the load test, the weather conditions prevailing during the load test, and the effect of weather conditions on the load test.
7. All supporting data including jack and load cell calibrations and certificates and other equipment requiring calibration.
8. When the Contract Document requires internal instrumentation of the pile/shaft, furnish all of the data taken during the load test together with instrument calibration certifications. In addition, submit a report showing an analysis of the results of axial load and lateral load tests in which soil resistance along and against the pile/shaft is reported as a function of deflection.

Submit the necessary reports prepared by the Specialty Engineer responsible for collection and interpretation of the data, except when the Contract Documents show that the Department will provide a Geotechnical Engineer.

455-2.9 Disposition of Loading Material: Remove all equipment and materials, which remains the Contractor's property, from the site. Clean up and restore the site to the satisfaction of the Engineer.

455-2.10 Disposition of Tested Piles/Shafts: After completing testing, cut off the tested piles/shafts, which are not to be incorporated into the final structure, and any reaction piles/shafts at an elevation 24 inches below the finished graded surface or as shown in the Plans. Take ownership of the cut-offs and provide areas for their disposal.

B. PILING

455-3 Description.

Furnish and install concrete, steel, or timber piling including driving, jetting, preformed pile holes, cutting off, splicing, dynamic load testing, and static load testing of piling. Prior to driving, clearly mark the piles to facilitate inspection. Provide individual straight-line marks at 1-ft intervals legibly numbered at least every 5 ft. Use markers or lumber crayons or paint marks that can be easily observed by the inspector. Ensure marks are spaced uniformly and perpendicular to the face of the pile. Face pile so that the pile markings are readable by the pile inspector. When set checks or practical refusal checks are required, provide inch marks as directed by the Engineer.

In the event a pile is broken or otherwise damaged by the Contractor to the extent that the damage is irreparable due to mishandling or incorrect installation, in the opinion of the Engineer, the Contractor shall extract and replace the pile at no additional expense to the Department. In the event that a pile is mislocated by the Contractor, the Contractor shall extract and replace the pile, at no expense to the Department, except when a design change proposed by the Contractor is approved by the Department as provided in 455-5.16.5. In the event a pile is broken or otherwise damaged by no fault of the Contractor, the pile extraction and replacement will be paid for as Unforeseeable Work.

455-4 Classification.

The Department classifies piling as follows:

1. Treated timber piling.
2. Prestressed concrete piling.
3. Steel piling.
4. Test piling.
5. Sheet piling.
    a. Concrete sheet piling.
    b. Steel sheet piling.
6. Polymeric Piles (see Section 471 for requirements).

455-5 General Requirements.

455-5.1 Predrilling of Pile Holes: Predrilled pile holes are either starter holes to the depth described in this Subarticle or holes drilled through embankment/fill material down to the natural ground surface. When using low displacement steel piling such as structural shapes, drive them through the compacted fill without the necessity of drilling holes through the fill except when the requirements for predrilling are shown in the Plans. When using concrete or other high displacement piles, drill pile holes through fill, new or existing, to at least the elevation of the natural ground surface. Use a drill with a diameter not greater than the largest dimension of the pile. Accurately drill the pile holes with the hole centered over the Plan location of the piling. Maintain the location and vertical alignment within the tolerances allowed for the piling.

For predrilled holes required through rock or other hard materials shown in the Plans that may damage the pile during installation, predrill hole diameters approximately 2 inches larger than the largest dimension across the pile cross-section. Fill the annular space around the piles as described in 455-5.10.1 with clean sand.

In the setting of permanent and test piling, the Contractor may initially predrill holes to a depth up to 20% of the test pile length, unless approved otherwise by the Engineer or

required by the Plans. Predrill holes for production piles in the same manner as the test piles. With prior written authorization from the Engineer, the Contractor may predrill holes to greater depths to minimize the effects of vibrations on existing structures adjacent to the work and/or for other reasons the Contractor proposes.

455-5.2 Underwater Driving: Underwater driving is defined as any driving through water which is above the pile head at the time of driving.

When conducting underwater driving, provide a diver equipped with voice communications to aid in placing the hammer back on the pile for required cushion changes or for subsequent redriving, to attach or recover instrumentation the Engineer is using, to inspect the condition of the pile, or for other assistance as required.

Select one of the following methods for underwater driving:

1. Accomplish underwater driving using conventional driving equipment and piling longer than authorized so that the piling will extend above the water surface during final driving. When choosing this option, furnish a pile hammer that satisfies the requirements of this Section for use with the longer pile.

2. Accomplish underwater driving using an underwater hammer that meets the requirements of this Section and is approved by the Engineer. When choosing this option, provide at least one pile longer than authorized at each pile group, extending above the water surface at final driving. At each group location, drive the longer pile first. The Engineer will evaluate the adequacy of the underwater driving system. The Engineer may use the pile tip elevation of the longer pile that the Contractor has driven and the Engineer has accepted, to evaluate the acceptability of the piles driven with the underwater hammer.

3. Accomplish underwater driving using conventional driving equipment with a suitable approved pile follower. When choosing this option, provide at least one pile longer than required at each pile group, extending above the water surface at final driving. At each group location, drive the full length pile first without using the follower. The Engineer will evaluate the adequacy of the follower used for underwater driving. The Engineer may choose to perform a dynamic load test on the first pile the Contractor drives with the follower in each group. The Engineer may use the pile tip elevation of the longer pile, that the Contractor has driven and the Engineer has accepted, to evaluate the acceptability of the piles driven with the follower.

Prior to use, submit details of the follower for the Engineer's evaluation and approval along with the information required in 455-10. Include the weight, cross-section details, stiffness, type of materials, and dimensions of the follower.

455-5.3 Pile Hammers: All equipment is subject to satisfactory field performance during and without dynamic testing. Use a variable energy hammer to drive concrete piles. Hammers will be rated based on the theoretical energy of the ram at impact. Supply driving equipment which provides the required resistance at a blow count ranging from 3 blows per inch (36 blows per foot) to 10 blows per inch (120 blows per foot) at the end of initial drive, unless approved otherwise by the Engineer after satisfactory field trial. Ensure the hammer is capable of driving to a resistance equal to at least 2.0 times the factored design load plus the scour and down drag resistance shown in the Contract Documents, without overstressing the piling in compression or tension and without reaching or exceeding 20 blows per inch. When the Engineer determines the stroke height or bounce chamber pressure readings do not adequately determine the energy of the hammer, provide and maintain a device to measure the velocity of the ram at impact. Determine the actual hammer energy in the field so that it is consistent with the hammer energy used for

each bearing capacity determination. When requested, submit to the Engineer all technical specifications and operating instructions related to hammer equipment.

455-5.3.1 Air: Variable energy air hammers shall be capable of providing at least two ram stroke lengths. The short ram stroke length shall be approximately half of the full stroke for hammers with strokes up to 4 feet and no more than 2 feet for hammers with maximum strokes lengths over 4 feet. Operate and maintain air hammers within the manufacturer's specified ranges. Use a plant and equipment for air hammers with sufficient capacity to maintain, under working conditions, the hammer, volume and pressure specified by the manufacturer. Equip the plant and equipment with accurate pressure gauges which are easily accessible to the Engineer. The Engineer will not accept final bearing on piles the Contractor drives with air hammers unless the Contractor operates the hammers within 10% of the manufacturer's rated speed in blows per minute, unless otherwise authorized by the Engineer. Provide and maintain in working order for the Engineer's use an approved device to automatically determine and display the blows per minute of the hammer.

455-5.3.2 Diesel: Variable energy diesel hammers shall have at least three fuel settings that will produce reduced strokes. Operate and maintain diesel hammers within the manufacturer's specified ranges. Determine the rated energy of diesel hammers using measured ram stroke length multiplied by the weight of the ram for open end hammers and by methods recommended by the manufacturer for closed end hammers.

Equip closed-end (double acting) diesel hammers with a bounce chamber pressure gauge, in good working order, mounted near ground level so the Engineer can easily read it. Also, submit to the Engineer a chart, calibrated to actual hammer performance within 30 days prior to initial use, equating bounce chamber pressure to either equivalent energy or stroke for the closed-end diesel hammer to be used.

455-5.3.3 Hydraulic: Variable energy hydraulic hammers shall have at least three hydraulic control settings that provide for predictable energy or equivalent ram stroke. The shortest stroke shall be a maximum of 2 feet for the driving of concrete piles. The remaining strokes shall include full stroke and approximately halfway between minimum and maximum stroke.

Supply hammer instrumentation with electronic read out, and control unit that allows the Engineer to monitor, and the operator to read and adjust the hammer energy or equivalent ram stroke. When pressure measuring equipment is required to determine hammer energy, calibrate the pressure measuring equipment before use.

455-5.3.4 Vibratory: Vibratory hammers of sufficient capacity (force and amplitude) may be used to drive steel sheet piles and, with approval of the Engineer, to drive steel bearing piles a sufficient distance to get the impact hammer on the pile (to stick the pile). The Engineer will determine the allowable depth of driving using the vibratory hammer based on site conditions. However, in all cases, use a power impact hammer for the last 15 feet or more of the final driving of steel bearing piles for bearing determinations after all piles in the bent/pier have been driven with a vibratory hammer. Do not use vibratory hammers to install concrete piles, or to install support or reaction piles for a load test.

455-5.3.5 Pile Inspection Device: Provide a pile inspection device that displays and stores electronically for every hammer blow along with a timestamp: stroke for open-ended diesel hammers and blows per foot and blows per minute for all hammers. The device must auto-generate the Department's Pile Driving Record form and export the non-editable electronic data

in a format compatible with the Pile Driving Record form. Use this device during the inspection of test piles and production piles.

455-5.4 Cushions and Pile Helmet:

455-5.4.1 Capblock: Provide a capblock (also called the hammer cushion) as recommended by the hammer manufacturer. Use commercially manufactured capblocks constructed of durable manmade materials with uniform known properties. Do not use wood chips, wood blocks, rope, or other material which permit excessive loss of hammer energy. Do not use capblocks constructed of asbestos materials. Obtain the Engineer's approval for all proposed capblock materials and proposed thickness for use. Maintain capblocks in good condition, and replace them when charred, melted, or otherwise significantly deteriorated. The Engineer will inspect the capblock before driving begins and at appropriate intervals determined by the Engineer based on field trial. Replace or repair any capblock which loses more than 25% of its original thickness, in accordance with the manufacturer's instructions, before permitting further driving.

455-5.4.2 Pile Cushion: Provide a pile cushion that is adequate to protect the pile from being overstressed in compression and tension during driving. Use a pile cushion sized so that it will fully fill the lateral dimensions of the pile helmet minus one inch but does not cover any void or hole extending through the top of the pile. Determine the thickness based upon the hammer-pile-soil system. For driving concrete piles, use a pile cushion made from pine plywood or oak lumber. Alternative materials may be used with the approval of the Engineer. Do not use materials previously soaked, saturated or treated with oil. Maintain pile cushions in good condition and replace them when charred, splintered, excessively compressed, or otherwise deteriorated to the point it will not protect the pile against overstressing in tension or compression. Protect cushions from the weather, and keep them dry. Do not soak the cushions in any liquid. Provide a new cushion for each pile unless approved otherwise by the Engineer after satisfactory field trial during dynamic testing.

During dynamic load tests, replace the pile cushion when any of the pile stress measurements exceed the maximum allowed pile stress determined by 455-5.12.2. When driving a pile without dynamic testing, replace the pile cushion when the cushion is either compressed more than one-half the original thickness, begins to burn, or as directed by the Engineer after field performance.

Reuse pile cushions in good condition to perform all set-checks and redrives. Use the same cushion to perform the set-check or redrive as was used during the initial driving, unless this cushion is unacceptable due to deterioration, in which case use a similar cushion.

455-5.4.3 Pile Helmet: Provide a pile helmet suitable for the type and size of piling being driven. Use a pile helmet deep enough to adequately contain the required thickness of pile cushion and to assist in maintaining pile-hammer alignment. Use a pile helmet that fits loosely over the pile head and is at least 1 inch larger than the pile dimensions. Use a pile helmet designed so that it will not restrain the pile from rotating.

455-5.5 Leads: Provide pile leads constructed in a manner which offers freedom of movement to the hammer and that have the strength and rigidity to hold the hammer and pile in the correct position and alignment during driving. When using followers, use leads that are long enough and suitable to maintain position and alignment of the hammer, follower, and pile throughout driving.

455-5.6 Followers: When using followers, perform dynamic load testing as per 455-5.14. Obtain the Engineer's approval for the type of follower, when used, and the method of connection to the leads and pile. Use followers constructed of steel with an adequate cross-section to withstand driving stresses. When driving concrete piles, ensure that the cross-sectional area of the follower is at least 18% of the cross-sectional area of the pile. When driving steel piles, ensure that the cross-sectional area of the follower is greater than or equal to the cross-sectional area of the pile. Provide a pile helmet at the lower end of the follower sized according to the requirements of 455-5.4.3. Use followers constructed that maintain the alignment of the pile, follower, and hammer and still allow the pile to be driven within the allowable tolerances. Use followers designed with guides adapted to the leads that maintain the hammer, follower, and the piles in alignment.

Use information from dynamic load tests described in 455-5.14 to evaluate the adequacy of the follower and to determine pile capacity.

455-5.7 Templates and Ground Elevations: Provide a fixed template, adequate to maintain the pile in proper position and alignment during driving with swinging leads or with semi-fixed leads. The Engineer may allow the use of templates attached to a barge if the Contractor demonstrates satisfactory that the pile alignment, and the elevation and horizontal position of the template can be maintained during all pile driving operations. Where practical, place the template so that the pile can be driven to cut-off elevation before removing the template. Ensure that templates do not restrict the vertical movement of the pile.

Supply a stable reference close to the pile, which is satisfactory in the opinion of the Engineer, for determination of the pile penetration. At the time of driving piles, furnish the Engineer with elevations of the original ground and template at each pile or pile group location. Note the highest and lowest elevation at each required location and the ground elevation at all piles.

455-5.8 Water Jets: Use jet pumps, supply lines, and jet pipes that provide adequate pressure and volume of water to freely erode the soil. Do not perform jetting without prior approval by the Engineer or unless allowed by the Plans.

Do not perform jetting in the embankment or for end bents. Where conditions warrant, with approval by the Engineer, perform jetting on the holes first, place the pile therein, then drive the pile to secure the last few feet of penetration. Only use one jet for prejetting (jetting before setting the pile). Use at-least two jets when jetting and driving. Position the jet(s) slightly behind the advancing pile tip (approximately 3 feet or as approved by the Engineer). Use at-least two jets when jetting and driving. When using water jets in the driving, determine the pile bearing only from the results of driving after withdrawing the jets, except where using jets to continuously eliminate soil resistance through the scour zone, ensure that they remain in place as directed by the Engineer and operating during pile bearing determination. Where practical, perform jetting on all piles in a pile group before driving begins. When large pile groups or pile spacing and batter make this impractical, or when the Plans specify a jet-drive sequence, set check a sufficient number of previously driven piles in a pile group to confirm their capacity after completing all jetting.

455-5.9 Penetration Requirements: Measure the penetration of piles from the elevation of the natural ground, the existing surface, the deepest scour elevation shown in the Pile Data Table, or the bottom of excavation, whichever is lowest. The Engineer will accept the bearing of a pile only if the Contractor achieves the required bearing when the tip of the pile is at or below

the specified minimum tip elevation and below the bottom of the preformed or predrilled pile hole.

Do not drive piles beyond practical refusal. To meet the requirements in this Subarticle, provide penetration aids, such as jetting or preformed pile holes, when piles cannot be driven to the required penetration without reaching practical refusal.

If the Contractor encounters unforeseeable, isolated obstructions that the Contractor cannot practically penetrate by driving, jetting, or preformed pile holes, and the Contractor must remove the pile to obtain the required pile penetration, the Department will pay the costs for such removal as Unforeseeable Work.

455-5.10 Preformed Pile Holes:

455-5.10.1 Description: Preformed pile holes serve as a penetration aid when all other pile installation methods fail to achieve the minimum tip elevation shown in the Plans or, when authorized by the Engineer, to minimize the effects of vibrations on adjacent structures. The Engineer may require preformed holes for any type of pile. Drive all piles installed in preformed pile holes to determine that the bearing requirements have been met. The bottom of the preformed hole is considered the lowest elevation the preforming operation matched the largest dimension of the pile.

For preformed holes which are required through material that caves during driving to the extent that the preformed hole does not serve its intended purpose, case the hole from the surface through caving material in accordance with the Contract Documents. After installing the pile to the bottom of the casing, remove the casings unless shown otherwise in the Plans. Determine bearing of the pile after removing the casing unless shown otherwise in the Plans. Fill all voids between the pile and soil remaining after driving through preformed holes with clean sand after the pile has achieved the required minimum tip elevation, unless grouting of preformed pile holes is shown in the Plans. If pile driving is interrupted during sand placement, drive the pile at least 20 additional blows after filling all of the voids between the pile and soil with sand at no additional cost to the Department.

455-5.10.2 Provisions for Use of Preformed Pile Holes: The Department will anticipate the necessity for preformed pile holes and include directions in the Plans. The Department considers, but does not limit to, the following conditions as reasons for preformed pile holes:

1. Inability to drive piles to the required penetration with driving and jetting equipment.
2. To penetrate a hard layer or layers of rock or strong stratum that the Engineer considers not sufficiently thick to support the structure.
3. To obtain greater penetration into dense (strong) material and into dense material containing holes, cavities or unstable soft layers.
4. To obtain penetration into a stratum in which it is desired to found the structure.
5. To minimize the effects of vibrations or heave on adjacent existing structures.
6. To minimize the effects of ground heave on adjacent piles.

455-5.10.3 Conditions Under Which Payment Will Be Made: The Department will make payment for preformed pile holes shown in the Plans, required by the Engineer or where the Contractor demonstrates that such work is necessary to achieve the required penetration without overstressing the pile.

455-5.10.4 Construction Methods: Construct preformed pile holes by drilling, or driving and withdrawing a suitable punch or chisel guided by a template or using drilling equipment with fixed leads at the locations of the piles. Construct a hole that is equal to or slightly greater than the largest pile dimension for the entire length of the hole and of sufficient depth to obtain the required penetration. Do not exceed the minimum dimensions necessary to achieve the required penetration of the pile. When the Plans call for grouting the preformed pile holes, provide a pile hole dimension 2 to 4 inches larger than the largest pile dimension. Construct the holes at the Plan position of the pile and the tolerances in location, and ensure the hole is straight and that the batter is the same as specified for the pile. Loose material may remain in the preformed pile hole if the conditions in 455-5.10.1 are satisfied.

455-5.10.5 Grouting of Pile Holes: Clean and grout preformed pile holes for bearing piles, when the Plans require grouting after driving. Use grout that meets the requirements of 455-40 to 455-42 and has a minimum compressive strength of 3,000 psi at 28 days or as specified in the Plans. Prepare cylinders and perform QC testing in accordance with 455-43. LOT size and verification will be in accordance with 455-43. Pump the grout through three or more grout pipes initially placed at the bottom of the preformed hole. Raise the grout pipes when necessary to prevent clogging and to complete the grouting operations. Maintain the grout pipes below the surface of the previously placed grout. Continue grouting until the grout reaches the ground surface all around the pile. Provide divers to monitor grouting operations when the water depth is such that it is impractical to monitor from the ground surface. In the event that the Engineer determines the Contractor must grout and the required grouting is not shown in the Plans, the Department will pay for the grouting work as Unforeseeable Work.

455-5.11 Bearing Requirements:

455-5.11.1 General: Drive piles to provide the bearing required for carrying the loads shown in the Plans. For all types of bearing piles, consider the driving resistance as determined by the methods described herein sufficient for carrying the specified loads as the minimum bearing which is accepted for any type of piles. Determine pile bearing using the method described herein or as shown in the Plans.

For foundations requiring 100% dynamic testing of production piles, ensure each pile has achieved minimum penetration requirements in 455-5.9 and the required bearing for minimum 6 inches of consecutive driving, or when the minimum penetration is achieved, driving has reached practical refusal in firm material and the bearing capacity is obtained in all the refusal blows.

For foundations not requiring 100% dynamic testing of production piles, ensure each pile has achieved the minimum penetration requirements in 455-5.9, the blow count is generally the same or increasing and the minimum required bearing capacity obtained for 24 inches of consecutive driving with less than 1/4 inch rebound per blow, or achieved the minimum penetration requirements in 455-5.9 and driving has reached practical refusal in accordance with 455-5.11.3

With concurrence of the Engineer, the Dynamic Testing Engineer (DTE) may modify the scour resistance shown in the Plans if the dynamic load test is used to determine the actual soil resistance through the scour zone.

455-5.11.2 Bearing Criteria: For foundations requiring 100% dynamic testing, the DTE will determine the bearing of all piles using the data received from dynamic load testing equipment utilizing internally or externally mounted sensors according to the methods described in 455-5.12.1.

For foundations not requiring 100% dynamic testing, the DTE shall forward a signed and sealed driving criteria letter indicating the minimum blow counts at each hammer stroke expected during driving to safely install the pile based on the test pile data and analyses to the Engineer at least one working day before driving the piles. The letter will contain an itemized list of the blow count criteria for acceptance of the piles, maximum strokes, criteria to replace cushions and any other conditions and limitations deemed appropriate for the safe installation of the piles. Drive all piles to the blow count criteria established by the DTE using the methods described herein and presented in the driving criteria letter.

If the pile is driven to approximately 12 inches above cut-off without reaching the required resistance, interrupt driving to perform an instrumented set-check.

455-5.11.3 Practical Refusal: Practical refusal is defined as 20 blows per inch or less than one inch penetration, with the hammer operating at the highest setting determined by the DTE for driving piles without damage and less than 1/4 inch rebound per blow. Stop driving as soon as the pile has reached practical refusal.

455-5.11.4 Set-checks and Pile Redrive:

1. Set-checks: Set-checks consist of redriving the pile after a certain period of time, typically within the same day. Perform set-checks as required and at the waiting periods shown in the Contract Documents. Provide an engineer's level or other suitable equipment for elevation determinations to determine accurate pile penetration during the set-checks. A pile may be accepted when a set-check shows that it has achieved the minimum required pile bearing and has met all other requirements of this Section.

2. Pile Redrive: Pile redrive consists of redriving the pile after the following working day from initial driving to determine time effects, to reestablish pile capacity due to pile heave, or for other reasons.

3. Uninstrumented Set-Checks and Uninstrumented Pile Redrive: Piles may be accepted based on uninstrumented set-checks or uninstrumented pile redrives only when the piles are redriven for at least 24 inches. In these cases, the piles may be considered to have sufficient bearing resistance when the specified blow count criteria is achieved in accordance with 455-5.11.1 and 455-5.11.2. Unless practical refusal is obtained as defined in 455-5.11.3, set-checks or redrives for piles redriven less than 24 inches must be instrumented for pile acceptance.

4. Instrumented Set-Checks and Instrumented Pile Redrive: Use dynamic load tests using at least 6 hammer blows to determine whether the pile bearing is sufficient. The pile may be considered to have sufficient bearing resistance when dynamic measurements demonstrate the static pile resistance exceeds the required pile resistance for at least one hammer blow and the average static pile resistance during the next five hammer blows exceeds 95% of the required pile resistance. If the pile is advanced farther, the static pile resistance during all subsequent blows must exceed 90% of the required pile resistance.

455-5.11.5 Pile Heave: Pile heave is the upward movement of a pile from its originally driven elevation. Drive the piles in an approved sequence to minimize the effects of heave and lateral displacement of the ground. Monitor piles previously driven in a pile group for possible heave during the driving of the remaining piles. Take elevation measurements to determine the magnitude of the movement of piles and the ground surface resulting from the driving process. Redrive all piles that have heaved 1/4 inches or more .

455-5.11.6 Piles with Insufficient Bearing: When the bearing capacity of any pile is less than the required bearing capacity, the Contractor may splice the pile and continue

driving or may extract the pile and drive a pile of greater length, or, if so ordered by the Engineer, drive additional piles.

455-5.11.7 Optional Soil Set-up approach: Production piles that are driven to less than the Nominal Bearing Resistance (NBR) may be accepted based on the anticipated soil setup without set checks on all piles, only if the following criteria are met:

1. Pile tip penetration satisfies the minimum penetration requirements in 455-5.9.

2. End of Initial Drive (EOID) resistance exceeds 1.10 times the Factored Design Load for the pile bent/pier, as determined by the dynamic testing or blow count criteria.

3. The Resistance Factor for computing NBR is taken from the following table:

Table 455-1
Resistance Factors for Pile Installation Using Soil Setup (all structures)

Loading	Design Method	Construction QC Method	Resistance Factor, φ	
			Blow Count Criteria[4]	100% Dynamic Testing[5]
Compression	Davisson Capacity	EDC[1], or PDA/GPC[2]	0.55	0.60
		Static Load Testing[3]	0.65	0.70
		Statnamic Load Testing[3]	0.60	0.65
Uplift	Skin Friction	EDC[1], or PDA/GPC[2]	0.45	0.50
		Static Load Testing[3]	0.55	0.55

1. Using the analysis methods published by Tran et al (2012).
2. Dynamic Load Testing and Signal Matching Analysis.
3. Used to confirm the results of Dynamic Load Testing and Signal Matching Analysis.
4. Initial drive of production piles using Blow Count Criteria.
5. Initial drive of all piles accepted by results of Dynamic Testing of all blows.

4. At least one test pile is driven at each bent/pier with a successful set check at the anticipated production pile tip elevations and one of the following sets of dynamic load testing conditions are met at each bent/pier.

a. The bearing of at least 10% of piles in the bent/pier (round up to the next whole number) is confirmed by instrumented set-check, and all test piles and instrumented set-checks demonstrate the pile resistance exceeds the NBR within seven days after EOID

b. The bearing of at least 20% of piles in the bent/pier (round up to the next whole number) is confirmed by instrumented set-check, and all test piles and instrumented set-checks demonstrate the pile resistance exceeds the NBR within 21 days after EOID.

5. All uninstrumented piles are driven deeper and to a greater EOID resistance than the EOID resistance of all instrumented production piles in the same bent/pier.

455-5.12 Methods to Determine Pile Capacity:

455-5.12.1 General: Dynamic load tests using an externally mounted instrument system and signal matching analyses or embedded gauges will be used to determine pile capacity for all structures or projects unless otherwise shown on the Plans. Notify the Engineer two working days prior to placement of piles within the template and at least one working day prior to driving piles. Do not drive piles without the presence of the Engineer.

455-5.12.2 Wave Equation:

1. Use Wave Equation Analysis for Piles (WEAP) programs to evaluate the suitability of the proposed driving system (including the hammer, follower, capblock and pile

cushions) as well as to estimate the driving resistance, in blows per 12 inches or blows per inch, to achieve the pile bearing requirements and to evaluate pile driving stresses.

Use Wave Equation Analyses to show the hammer meets the requirements described in 455-5.3 and maximum allowed pile stresses are not exceeded.

2. Required Equipment for Driving: Hammer approval is based on satisfactory field performance including dynamic load test results. In the event piles require different hammer sizes, the Contractor may elect to drive with more than one size hammer or with a variable energy hammer, provided the hammer is properly sized and cushioned, will not damage the pile, and will develop the required resistance.

3. Maximum Allowed Pile Stresses:

a. General: The maximum allowed driving stresses for concrete, steel, and timber piles are given below. In the event dynamic load tests show that the hammer will overstress the pile, modify the driving system or method of operation as required to prevent overstressing the pile. In such cases provide additional cushioning, reduce the stroke, or make other appropriate agreed upon changes.

b. Prestressed Concrete Piles: Use the following equations to determine the maximum allowed pile stresses:

$$s_{apc} = 0.7 f'_c - 0.75 f_{cpe} \qquad (1)$$

$$s_{apt} = 6.5(f'_c)^{0.5} + 1.05 f_{cpe} \qquad \text{(2a) for piles less than 50 feet long}$$

$$s_{apt} = 3.25(f'_c)^{0.5} + 1.05 f_{cpe} \qquad \text{(2b) for piles 50 feet long and greater}$$

$$s_{apt} = 500 \qquad \text{(2c) within 20 feet of a mechanical splice}$$

where:

s_{apc}= maximum allowed pile compressive stress, psi
s_{apt}= maximum allowed pile tensile stress, psi
f'_c= specified minimum compressive strength of concrete, psi
f_{cpe}= effective prestress (after all losses) at the time of driving, psi, taken as 0.8 times the initial prestress force divided by the minimum net concrete cross-sectional area of the pile (f_{cpe}= 0 for dowel spliced piles).

c. Steel Piles: Ensure the maximum pile compression and tensile stresses measured during driving are no greater than 0.9 times the yield strength (0.9 f_y) of the steel.

d. Timber Piles: Ensure the maximum pile compression and tensile stresses measured during driving are no greater than 3.6 ksi for Southern Pine and Pacific Coast Douglas Fir and 0.9 of the ultimate parallel to the grain strength for piles of other wood.

455-5.12.3 Temporary Piles: Submit for the Engineers review, an analysis signed and sealed by a Specialty Engineer which establishes the pile lengths for temporary piles required for structures which affect public safety. Submit for the Engineers approval, a Wave Equation analysis signed and sealed by a Specialty Engineer which establishes the driving criteria for temporary piles at least five working days prior to driving temporary production piles. The required driving resistance is equal to the sum of the factored design load plus the scour and

down drag resistances shown in the Plans, divided by the appropriate resistance factor or the nominal bearing resistance shown in the Plans, whichever is higher.

The maximum resistance factor is 0.45 when only wave equation analysis is performed. However, a larger resistance factor may be applicable when additional testing is provided by the Specialty Engineer in accordance with Section 3.5.6 of Volume 1 of the FDOT Structures Manual. If the Contractor elects to perform 100% dynamic load testing submit a certification package prepared by the Specialty Engineer. The certification package shall include a signed and sealed letter by the Specialty Engineer that certifies the piles meet the load requirements and have no integrity deficiencies. The package shall also include the dynamic load test records, all signal matching analysis performed to determine pile capacities and a summary table that indicates the final capacity of every pile.

455-5.12.4 Dynamic Load Tests: Dynamic load testing consists of estimating pile capacity by the analysis of electronic data collected from blows of the hammer during driving of an instrumented pile in accordance with 455-5.14.

455-5.12.5 Static Load Tests: Static load testing consists of applying a static load to the pile to determine its capacity. Use the Modified Quick Test Procedure in accordance with 455-2.2.1.

455-5.12.6 Fender Pile Installation: For piles used in fender systems, regardless of type or size of pile, either drive them full length or jet the piles to within 2 feet of cutoff and drive to cutoff elevation to seat the pile. The Engineer will not require a specific driving resistance unless noted in the Plans. Use methods and equipment for installation that do not damage the piles. If the method or equipment used causes damage to the pile, modify the methods or equipment at no expense to the Department.

455-5.12.7 Structures Without Test Piles: For structures without 100% dynamic testing or test piles, the DTE will dynamically test the first pile(s) in each bent or pier at locations shown in the Plans to determine the blow count criteria for the remaining piles. The DTE shall forward the driving criteria letter to the Engineer in accordance with 455-5.11.2, except that the letter may be submitted as soon as the driving criteria is determined if piles are driven the same day. The DTE will dynamically test or perform an instrumented set-check on at least 5% of the piles at each bent or pier (rounded up to the next whole number).

455-5.13 Test Piles:

455-5.13.1 General: All test piles will have dynamic load tests. Drive piles of the same cross-section and type as the permanent piles shown in the Plans, in order to determine any or all of the following:

1. installation criteria for the piles.
2. nature of the soil.
3. lengths of permanent piles required for the work.
4. driving resistance characteristics of the various soil strata.
5. amount of work necessary to obtain minimum required pile penetration.
6. ability of the driving system to do the work.
7. need for point protection.

Because test piles are exploratory in nature, drive them harder (within the limits of practical refusal), deeper, and to a greater bearing resistance than required for the permanent piling. Except for test piles which are to be statically or Statnamically load tested, drive test piles their full length or to practical refusal. Splice test piles which have been driven

their full length without achieving the required bearing, and proceed with further driving unless otherwise directed by the Engineer.

As a minimum, unless otherwise directed by the Engineer, do not cease driving of test piles until obtaining the required bearing capacity continuously, where the blow count is increasing, for 10 feet unless reaching practical refusal first. Drive test piles which are to be statically or Statnamically load tested as anticipated for the production piles.

When test piles attain practical refusal prior to attaining minimum penetration, perform all work necessary to attain minimum penetration and the required bearing. Where practical, use water jets to break the pile loose for further driving. Where jetting is impractical, extract the pile and install a preformed pile hole through which driving will continue. The Department will consider the work of extracting the pile to be Unforeseeable Work.

When driving test piles other than low displacement steel test piles, have preforming equipment available at the site and water jets as specified in 455-5.8 when jetting is allowed, ready for use, before the test pile driving begins.

The Engineer may elect to interrupt pile driving up to four times on each test pile, two times for up to two hours and two additional times during the next working day of initial driving to determine time effects during the driving of test piles.

455-5.13.2 Location of Test Piles: Drive all test piles in the position of permanent piles at the locations shown in the Plans. Ensure that all test piles designated to be statically load tested are plumb. In the event that all the piles are battered at a static load test site, the Engineer will designate an out-of-position location for driving a plumb pile for the static load test.

455-5.13.3 Equipment for Driving: Use the same hammer and equipment for driving test piles as for driving the permanent piles. Also use the same equipment to redrive piles.

455-5.14 Dynamic Load Tests: The DTE will take dynamic measurements during the driving of piles designated in the Plans or authorized by the Engineer. For concrete piles, install instruments prior to driving and assist the Engineer in monitoring all blows delivered to the pile. For steel production piles, the Engineer may accept instrumented set-checks or redrives. The Engineer will perform dynamic load tests to evaluate any or all of the following:

1. Suitability of the Contractor’s driving equipment, including hammer, capblock, pile cushion, and any proposed follower.
2. Pile capacity.
3. Pile stresses.
4. Energy transfer to pile.
5. Distribution of soil resistance.
6. Soil variables including quake and damping.
7. Hammer-pile-soil system for Wave Equation analyses.
8. Pile installation problems.
9. Pile integrity
10. Other.

Either supply and install embedded gauges in the piles in accordance with Standard Plans, Index 455-003 or attach instruments (strain transducers to measure force and accelerometers to measure acceleration) with bolts to the pile for dynamic testing.

Make each follower and pile to be dynamically tested with externally attached instruments available to drill holes for attaching instrumentation and for wave speed measurements. Support the pile with timber blocks placed at appropriate intervals. Ensure that the pile is in a horizontal position and does not contact adjacent piles. Provide a sufficient clear distance at the sides of the pile for drilling the holes. The Engineer will furnish the equipment, materials, and labor necessary for drilling holes and taking the wave speed measurements. If the Engineer directs dynamic load testing, instrumented set-checks or instrumented redrives, provide the Engineer safe access to the top of the piles for drilling the attachment holes. After placing the leads provide the Engineer safe access to the piles to attach the instruments and for removal of the instruments after completing the pile driving.

The Engineer will monitor the stresses in the piles with the dynamic test equipment during driving to ensure the Contractor does not exceed the maximum allowed stresses. If necessary, add additional cushioning, replace the cushions, or reduce the hammer stroke to maintain stresses below the maximum allowable. If dynamic test equipment measurements indicate non-axial driving, immediately realign the driving system. If the cushion is compressed to the point that a change in alignment of the hammer will not correct the problem, add cushioning or change the cushion as directed by the Engineer.

Drive the pile to the required penetration and resistance or as directed by the Engineer.

When directed by the Engineer, perform instrumented set-checks or redrives. Do not use a cold diesel hammer for a set-check or redrive unless in the opinion of the Engineer it is impractical to do otherwise. Warm up the hammer by driving another pile or applying at least 20 blows to a previously driven pile or to timber mats placed on the ground.

455-5.15 Pile Lengths:

455-5.15.1 Test Pile Length: Provide the length of test piles shown in the Plans or as directed by the Engineer.

455-5.15.2 Production Pile Length:

455-5.15.2.1 Structures with Test Piles: When test pile lengths are shown in the Plans, the production pile bid quantity is based on information available during design and estimated pile lengths. Production pile lengths shall be recommended by the DTE for the Engineer's approval based on all information available before the driving of the permanent piles, including, but not limited to, information gained from the driving of test piles, dynamic load testing, static load testing, supplemental soil testing, etc. When authorized by the Department, soil freeze information obtained during set checks and pile redrives may be used to determine authorized pile lengths for sites with extreme soil conditions.

After completion of the test pile program, production pile lengths shall be recommended in a letter signed and sealed by the DTE. Submit the letter and load test reports to the Engineer including the following electronic files (Windows 10 compatible): dynamic testing data, signal matching data and results, and Wave Equation data and results.

455-5.15.2.2 Structures without Test Piles: Authorized lengths are provided as Production Pile Order Lengths in the Pile Data Table in the Structure Plans. Use these lengths for furnishing the permanent piling for the structure.

455-5.15.3 Authorized Pile Lengths: The authorized pile lengths are the lengths determined by the Engineer after reviewing the pile lengths recommended by the DTE. The Contractor may elect to provide piling with lengths longer than authorized to suit his method of installation or schedule. When the Contractor elects to provide longer than authorized pile

lengths, the Department will pay for the furnished length as either the originally authorized length or the length between cut-off elevation and the final accepted pile tip elevation, whichever is the longer length.

The Engineer will provide an itemized list of authorized pile lengths within three working days after receipt of all test reports and the DTE's recommended pile lengths. Use these lengths for furnishing the permanent piling for the structure. If the Contractor is willing to start the pile driving operations in zones consisting of at least four test piles designated by the Engineer, and if the Contractor so requests in writing at the beginning of the test pile program, the Department will provide pile lengths for these designated phases within three working days after receiving all test reports and the DTE's recommended pile lengths for those designated zones.

On multiple phase projects, the Engineer will not provide pile lengths on subsequent phases until completing the piling on initial phases.

455-5.16 Allowable Driving Tolerances:

455-5.16.1 General: Meet the tolerances described in this Subarticle for the piles that are free standing without lateral restraint (after the template is removed). After the piles are driven, do not move the piles laterally to force them to be within the specified tolerances, except to move battered piles to overcome the dead load deflections caused by the pile's weight. When this is necessary, submit calculations signed and sealed by a Specialty Engineer that verify the amount of dead load deflection prior to moving any piles.

455-5.16.2 Position: Ensure that the final position of the pile head at cut-off elevation is no more than 3 inches, or 1/6 of the diameter of the pile, whichever is less, laterally in the X or Y coordinate from the Plan position indicated in the Plans.

455-5.16.3 Axial Alignment: Ensure that the axial alignment of the driven piles does not deviate by more than 1/4 inches per foot from the vertical or batter line indicated in the Plans.

455-5.16.4 Elevation: Ensure that the final elevation of the pile head is no more than 1-1/2 inches above, or more than 4 inches below, the elevation shown in the Plans, however in no case shall the pile be embedded less than 8 inches into the cap or footing.

For fender piles, cut off piles at the elevation shown in the Plans to a tolerance of plus 0 inches to minus 2 inches using sawing or other means as approved by the Engineer to provide a smooth level cut.

455-5.16.5 Deviation from Above Tolerances: When the Contractor has failed to meet the above tolerances for position of axial alignment, the Contractor may propose a redesign to incorporate out of tolerance piles into pile caps or footings, at no expense to the Department. Ensure the Contractor's Engineer of Record performs any redesign and signs and seals the redesign drawings and computations. Do not begin any proposed construction until the redesign has been reviewed for acceptability and approved by the Engineer. Utilize Standard Plans for treatment of piles driven more than 4 inches below cutoff elevation.

455-5.17 Disposition of Pile Cut-offs, Test Piles, and Load Test Materials:

455-5.17.1 Pile Cut-offs:

Upon completion of all work under the Contract in connection with piling, unless shown otherwise in the Plan, take ownership of any unused cut-off lengths remaining, and remove them from the right-of-way. Provide areas for their disposal.

455-5.17.2 Test Piles: Where so directed by the Plans or the Engineer, cut off, or build-up as necessary, test piles, and leave them in place as permanent piles. Extract and replace

test piles driven in permanent position and found not suitable for use due to actions of the Contractor at no expense to the Department. Pull, or cut off, at an elevation 2 feet below the ground surface or bottom of proposed excavation, test piles driven out of permanent position, and dispose of the removed portion of the test pile.

When test piles are required to be driven in permanent pile positions, the Contractor may elect to drive the test pile out of position, with the approval of the Engineer, provided that a replacement pile is furnished and driven by the Contractor at no expense to the Department in the position that was to be occupied by the test pile. Under this option, the Department will pay for the test pile in the same manner as if it were in permanent position.

Unless otherwise directed in the Plans or by the Engineer, retain ownership of test piles that are pulled or cut off and provide areas for their disposal.

455-5.18 Recording: Provide pile inspectors in accordance with 105-8.13. The qualified pile inspector shall inspect and record all the pile installation activities, including but not limited to handling, jetting, predrilling, preforming and driving on the Department's Pile Driving Record form. Steel piles and dynamically tested concrete piles in accordance with 455-5.14 will not require inspection during handling. Keep a pile driving log for each pile installed whether it is, or is not, instrumented. Within one working day after completing the installation of each pile, submit the Pile Driving Record and dynamic testing records to the Engineer.

455-5.19 Foundation Certification Packages: Submit certification packages of pile foundations to the Engineer prior to Pile Verification Testing. A separate Foundation Certification Package must be submitted for each foundation unit. A foundation unit is defined as all the piles within one bent or pile footing for a specific bridge for each phase of construction. Each Foundation Certification Package shall contain an original certification letter signed and sealed by the DTE certifying the piles have the required minimum tip elevation, axial capacity including compression and uplift, pile integrity, and that the inspection of the pile installation was performed under the supervision of the DTE. The package shall also include all pile driving logs, dynamic testing records, all supplemental dynamic testing raw data and analyses for the foundation unit, and the signed and sealed evaluation performed to address out of tolerance piles in accordance with 455-5.16.5. The certification shall not be contingent on any future repair or testing, or any approval by the Engineer.

455-5.20 Verification: One working day, excluding weekends and Department observed holidays, after receipt of the Foundation Certification Package, the Engineer will determine whether a pile in that foundation unit will be selected for verification testing. Based on its review of the certification package, the Engineer may or may not choose a pile for verification testing in any or all foundation units. For the pile selected by the Engineer for verification testing, the Engineer will provide the dynamic load test equipment and personnel for the Pile Verification Testing. Provide the driving equipment and pile driving crew for the Pile Verification Testing and provide support as needed to prepare the piles for testing. The Engineer will provide the results of the verification testing and identify additional needs for verification testing within one working day of testing.

If the capacity or integrity of any pile is found to be deficient, the Engineer will reject the entire certification package for the foundation unit, and the Contractor shall:

1. Correct the deficiency;
2. Correct the process that led to the deficiency;

3. Demonstrate to the Engineer that the remainder of the piles in the foundation unit are acceptable, including additional dynamic load tests to verify pile capacity and integrity, and;

4. Recertify the foundation unit.

One working day, excluding weekends and Department observed holidays, after receipt of the recertification, the Engineer shall then determine whether additional verification testing is required in that foundation unit. If the capacity or integrity of a verification pile is found to be deficient, additional cycles of deficiency correction and verification testing shall be completed until no more pile capacity or integrity deficiencies are detected. Piles shall not be cut-off nor bent/pier caps placed prior to successful completion of the Pile Verification Testing Program for that foundation unit. In case of disagreement of dynamic testing results, the Engineer's results will be final and will be used for acceptance.

On land foundation units or water foundation units when the pile cutoff is at least six feet above mean high water, the Contractor may cut-off piles prior to a complete submittal of the Certification Package or to a successful completion of the Pile Verification Testing Program at its own risk. If any piles in a foundation unit are cut-off prior to the submittal of a certification package or completion of the Pile Verification Testing Program and the Engineer determines that verification testing is required, the Contractor shall perform, at no expense to the Department, any work and labor required to expose any pile selected for verification to allow the installation of the instruments in dry conditions and to provide references and access to the Engineer for such testing. Piles experiencing damage during the verification testing or requiring build-up after the verification shall be repaired by the Contractor at no expense to the Department. No pile bent/cap shall be poured prior to successful completion of the Pile Verification Testing Program for that foundation unit or notification by the Engineer that no verification will be required.

455-6 Timber Piling.

455-6.1 Description: Drive timber piles of the kind and dimensions specified in the Plans at the locations and to the elevations shown in the Plans, or as directed by the Engineer.

455-6.2 Materials: Meet the timber piling requirements of Section 953. Treat the piles according to the applicable provisions of Section 955. Treat all cuts and drilled holes in accordance with 470-3.

455-6.3 Preparation for Driving:

455-6.3.1 Caps: Protect the heads of timber piles during driving, using a cap of approved type, that will distribute the hammer blow over the entire cross-section of the pile. When necessary cut the head of the pile square before beginning pile driving.

455-6.3.2 Collars: Provide collars or bands to protect piles against splitting and brooming at no expense to the Department.

455-6.3.3 Shoes: Provide piles shod with metal shoes, of a design satisfactory to the Engineer. Shape pile tips to receive the shoe and install according to the manufacturer's directions.

455-6.4 Storage and Handling: Store and handle piles in the manner necessary to avoid damage to the piling. Take special care to avoid breaking the surface of treated piles. Do not use cant dogs, hooks, or pike poles when handling and storing the piling.

455-6.5 Cutting Off: Saw off the tops of all timber piles at the elevation indicated in the Plans. Saw off piles which support timber caps to the exact plane of the superimposed structure so that they exactly fit. Withdraw and replace broken, split, or misplaced piles.

455-6.6 Build-ups: The Engineer will not permit splices or build-ups for timber piles. Extract piles driven below Plan elevation and drive a longer pile.

455-6.7 Pile Heads:

455-6.7.1 Piles with Timber Caps: On piles wider than the timber caps, dress off the part of the pile head projecting beyond the sides of the cap to a slope of 45 degrees. Coat the cut surface with the required preservative and then place a sheet of copper, with a weight of 10 ounces per square foot or greater, meeting the requirements of ASTM B370. Provide a cover measuring at least 4 inches more in each dimension greater than the diameter of the pile. Bend the cover down over the pile and fasten the edges with large head copper nails or three wraps of No. 12 copper wire.

455-6.7.2 Fender and Bulkhead Piles: Paint the heads of fender piles and of bulkhead piles with preservative and then cover with copper as provided above for piles supporting timber caps.

455-7 Prestressed Concrete Piling.

455-7.1 Description: Provide prestressed concrete piles that are manufactured, cured, and driven in accordance with the Contract Documents. When the required lengths are less than or equal to the maximum length as shown in the Standard Plans, provide piles full length without splices. When the pile length exceeds the maximum length according to Standard Plans, and splicing is required, the piles may be spliced and splices will be paid for in accordance with 455-11.8.

When splices are desired for convenience of the Contractor, provide mechanical splices at no additional cost. Include the cost of these splices in the cost of the pile.

455-7.2 Manufacture: Fabricate piles in accordance with Section 450. When embedded gauges will be used for dynamic load testing, supply and install in square prestressed concrete piles in accordance with Standard Plans Index 455-003. Ensure the embedded gauges are installed by personnel approved by the manufacturer.

455-7.3 Storage and Handling:

455-7.3.1 Time of Driving Piles: Drive prestressed concrete piles at any time after the concrete has been cured in accordance with Section 450, and the concrete compressive strength is equal to or greater than the specified 28 day compressive strength.

455-7.3.2 Storage: Support piles on adequate dunnage both in the prestress yard and at the job site in accordance with the locations shown in the Standard Plans to minimize undue bending stresses or creating a sweep or camber in the pile.

455-7.3.3 Handling: Handle and store piles in the manner necessary to eliminate the danger of fracture by impact or of undue bending stresses in handling or transporting the piles from the forms and into the leads. In general, lift concrete piles by means of a suitable bridge or slings attached to the pile at the locations shown in the Standard Plans. Construct slings used to handle piles of a fabric material or braided wire rope constructed of six or more wire ropes which will not mar the corners or the surface finish of the piles. Do not use chains to handle piles. During transport, support concrete piles at the lifting locations shown in the Standard Plans or fully support them throughout 80% or more of their length. In handling piles for use in salty or brackish water, exercise special care to avoid damaging the surface and corners of the pile. If an alternate transportation support arrangement is desired, submit calculations, signed and sealed by the Specialty Engineer, for approval by the Engineer prior to transporting the pile. Calculations must show that the pile can be transported without exceeding the bending moments calculated using the support locations shown in the Plans.

455-7.4 Cracked Piles: The Engineer will reject any pile that becomes cracked in handling to the point that a transverse or longitudinal crack extends through the pile, shows failure of the concrete as indicated by spalling of concrete on the main body of the pile adjacent to the crack, which in the opinion of the Engineer will not withstand driving stresses, or becomes damaged during installation. The Engineer will not reject any pile for the occasional minor surface hairline cracking caused by shrinkage.

Do not drive piling with irreparable damage, which is defined as any cracks that extend through the pile cross-sectional area that are, or will be, below ground or water level at the end of driving. Remove and replace broken piles or piles cracked to the extent described above at no expense to the Department. The Engineer will accept cracks less than 0.005 inches which do not extend through the pile. Using approved methods, cut off and splice or build-up to cut-off elevation piles with cracks greater than 0.005 inches at the pile head or above ground or water level, and piles with cracks above ground or water level which extend through the cross-sectional area of the pile. The Engineer may require correction of pile damage or pile cracks by cutting down the concrete to the plane of sound concrete below the crack and rebuilding it to cut-off elevation, or the Engineer may reject the pile. Extract and replace rejected piles that cannot be repaired, at no expense to the Department.

Take appropriate steps to prevent the occurrence of cracking, whether due to handling, transporting, or driving.

455-7.5 Preparation for Transportation: Cut strands flush with the surface of the concrete using an abrasive cutting blade before transporting the piles from the casting yard.

Cut and patch the metal lifting devices in accordance with 450-9.2.1.

455-7.6 Method of Driving: Unless otherwise directed, drive piles by a hammer or by means of a combination of water jets and hammer when jetting is allowed. When using jets in combination with a hammer, withdraw the jets and drive the pile by the hammer alone to secure final penetration and to rigidly fix the tip end of the pile. Keep jets in place if they are being used to continuously eliminate the soil resistance in the scour zone.

455-7.7 Extensions and Build-ups used to Increase Production Lengths:

455-7.7.1 General: Where splices, extensions and build-ups for concrete piles are necessary, construct them in accordance with the Standard Plans.

These requirements are not applicable to specially designed piling. Make splices for special pile designs as shown in the Plans.

455-7.7.2 Extensions to be Driven or those 21 feet or Longer: Construct extensions to be driven or extensions 21 feet or longer in length in accordance with the details shown in the Standard Plans and in a manner including the requirements, sequences, and procedures outlined below:

1. Cast a splice section in accordance with Section 450 with the dowel steel in the correct position and alignment as shown in the Standard Plans.
2. Drill dowel holes using an approved steel template that will position and align the drill bit during drilling. Drill holes a minimum of 2 inches deeper than the length of the dowel to be inserted.
3. Clean the drilled dowel holes by inserting a high pressure air hose to the bottom of the hole and blowing the hole clean from the bottom upward. Eliminate any oil, dust, water, and other deleterious materials from the holes and the concrete surfaces to be joined.
4. Place forms around joints between the pile sections.

5. Mix the adhesive components in accordance with the manufacturer's directions. Do not mix sand or any other filler material with the epoxy components unless it is prepackaged by the manufacturer for this specific purpose. Use adhesives meeting the requirements of Section 926 for Type AB epoxy compounds.

6. After ensuring that all concrete surfaces are dry, fill the dowel holes with the adhesive material.

7. Insert the dowels of the spliced section into the adhesive filled holes of the bottom section and position the spliced section so that the axes of the two sections are in concentric alignment and the ends of the abutting sections are spaced 1/2 inches apart. The Contractor may use small steel spacers of the required thickness provided they have 3 inches or more of cover after completing the splice. Fill the space between the abutting sections completely with the adhesive.

8. Secure the spliced sections in alignment until the adhesive is cured in accordance with the manufacturer's directions for the time appropriate with the prevailing ambient temperatures. Utilize alignment braces to maintain the proper pile alignment during the epoxy cure time.

9. After curing is completed, remove alignment braces and forms and clean and dress the spliced area to match the pile dimensions.

When dowel splices need to be driven, perform a dynamic load test during the driving of each dowel spliced pile to monitor and control the stresses and verify the splicing integrity. Provide the Engineer two working days advance notification prior to driving spliced piles.

455-7.7.3 Precast Reinforced Non-Drivable Build-ups less than 21 feet: Construct precast reinforced non-drivable build-ups less than 21 feet in accordance with the requirements of this Subarticle, Section 346, and Section 400. Provide the same material for the form surfaces for precast build-ups as was used to form the prestressed piles. Use concrete of the same mix as used in the prestressed pile and dimension the cross-section the same as piling being built up. Install build-ups as specified in 455-7.7.2(2) through 455-7.7.2(9). Apply to the build-ups the same surface treatment or sealant applied to the prestressed piles.

455-7.8 Pre-Planned Splices: Construct splices in accordance with the dowel splice method contained in the Standard Plans or using proprietary splices which are listed on the Department's Approved Product List (APL). Splice test piles in the same manner as the production piles. Include in the pile installation plan, the chosen method of splicing and the approximate locations of the splice. Generally, place the splice at approximately the midpoint between the estimated pile tip and the ground surface, considering scour if applicable. Stagger the splice location between adjacent piles by a minimum of 10 feet. Obtain the Engineer's approval prior to constructing any pile sections.

When dowel splices need to be driven, comply with the requirements of 455-7.7.2.

Mechanical pile splices must be capable of developing the following capacities in the pile section unless shown otherwise in the Plans and capable of being installed without damage to the pile or splice:

1. Compressive strength = (Pile Cross sectional area) x (28 day concrete strength)

2. Tensile Strength = (Pile Cross sectional area) x 900 psi

Table 455-2	
Pile Size (inches)	Bending Strength (kip-feet)
18	245
24	600
30	950

455-7.9 Pile Cut-offs: After the completion of driving, cut piles off which extend above the cut-off elevation with an abrasive saw. Make the cut the depth necessary to cleanly cut through the prestressed strands.

455-8 Steel Piling.

455-8.1 Description: Furnish, splice, drive, and cut off structural steel shapes to form bearing piles. Include in this work the preparation of a smooth and square pile top meeting the requirements of ASTM A252 or API 5L prior to driving, installation of structural steel bracing by bolting or welding, construction of splices and the filling of pipe piles with the materials specified in 455-8.9.

455-8.2 Material: For the material in steel piles, and splices, meet the requirements of Section 962.

455-8.3 Pile Splices: Order and use the full authorized pile length where practicable. Do not splice to obtain authorized lengths less than 50 feet except when shown in the Plans. Locate all field splices in the authorized pile length in portions of the pile expected to be at least 15 feet below the final ground surface after driving. When it is not practicable to provide authorized pile lengths longer than 50 feet in a single length, use no more than one field splice per additional 50 feet of authorized pile length. Shop splices may be used to join single lengths of pile which are at least 20 feet in length. One shorter segment of pile may be used to achieve the authorized pile length when needed.

Where the pile length authorized is not sufficient to obtain the required bearing value or penetration, provide an additional length of pile as directed by the Engineer and splice it to the original length.

Make all splices in accordance with details shown in the Plans and in compliance with the general requirements of AWS D1.1 or American Petroleum Institute Specification 5L (API 5L).

455-8.4 Welding: Make all welded connections to steel piles by electric arc welding, in accordance with details shown in the Plans and in compliance with the general requirements of AWS D1.5. Electroslag welding is not permitted. Welds will be inspected by visual methods.

455-8.5 Pile Heads and Tips: Cut off all piles at the elevation shown in the Plans. If using a cutting torch, make the surface as smooth as practical.

Where foundation material is so dense that the Contractor cannot drive the pile to the required penetration and firmly seat it without danger of crumpling the tip, reinforce the tips with approved cast steel point protectors, as shown in the Plans or required by the Engineer. Construct point protectors in one piece of cast steel meeting the requirements of ASTM A27, Grade 65-35 heat treated to provide full bearing for the piles. Attach points by welding according to the recommendations of the manufacturer.

455-8.6 Pile Bent Bracing Members: Where piles are not driven into position in exact alignment as shown in the Plans, furnish and place all fills and shims required to square and line up faces of flanges for cross bracing at no additional expense to the Department.

455-8.7 Coating: Coat exposed parts of steel piling, wedging, bracing, and splices as shown in the Plans.

455-8.8 Storage and Handling: While handling or transporting the piles from the point of origin and into the leads, store and handle in the manner necessary to avoid damage due to bending stresses. In general, lift steel piles by means of a suitable bridge or a sling attached to the pile at appropriate points to prevent damage. Lift the pile from the horizontal position in a manner that will prevent damage due to bending of the flanges and/or web.

455-8.9 Filling Pipe Piles: Ensure closed-end pipe piles are watertight. When required by the Plans, fill pipe piles with the specified materials. Place concrete in open ended pipes containing water using methods in accordance with 455-15.9 with modified tremie and pump line sizes. Concrete may be placed directly into pipes which are dry. Construct and place reinforcement cages in accordance with 455-16 except the minimum number of spacers per level is three. Reinforcement cages may be installed before concrete placement or after concrete placement is completed if proper alignment and position is obtainable.

455-9 Sheet Piling.

455-9.1 Description: Leave permanent piling in place as part of the finished work and remove temporary piling after each construction phase unless otherwise authorized by the Engineer.

455-9.2 Materials: Meet the following requirements:

Concrete .....Section 346
Bar Reinforcement .....Section 931
Prestressing Reinforcement.....Section 933
Steel Sheet Piles* .....Section 962
*For temporary steel sheet piles meet the requirements specified in the Plans.

455-9.3 Steel Sheet Piling: Drive steel sheet piling and cut off true to line and grade. Install steel sheet piling with a suitable hammer. Remove and replace any section damaged during handling and installation at no additional expense to the Department.

455-9.3.1 Method of Installation: Where rock or strong material is encountered such that the sheet piles cannot be set to grade by driving, remove the strong material by other acceptable means, such as excavation and backfilling, drilling or by punching. When the Plans do not indicate the existence of rock or strong material, work of removing, drilling or punching the strong material or rock will be paid for as Unforeseeable Work.

455-9.4 Concrete Sheet Piling:

455-9.4.1 Description: Ensure that concrete sheet piling is of prestressed concrete construction and manufactured, cured, and installed in accordance with the requirements of the Contract Documents.

455-9.4.2 Manufacture of Piles: Ensure that the piles are fabricated in accordance with Section 450.

455-9.4.3 Method of Installation: Jet concrete sheet piling to grade where practical. Provide water at the nozzles of sufficient volume and pressure to freely erode material adjacent to the piles. Where encountering rock or strong material, such that the sheet piles cannot be set to grade by jetting, remove the strong materials by other acceptable means, such as excavation and backfilling, drilling or by punching with a suitable punch. When the Plans do not indicate the existence of rock or strong material and the piles cannot be set by jetting, the Department will pay for the work of removing, drilling or punching the strong material or rock as Unforeseeable Work.

455-9.4.4 Grouting and Caulking: Concrete sheet piles are generally detailed to have tongues and grooves on their lower ends, and double grooves on their upper ends. Where so detailed, after installation, clean the grooves of all sand, mud, or debris, and fully grout the grooves. Use approved plastic bags (sheaths) which will meet the shape and length of the groove to be grouted to contain the plastic grout within the double grooves. Provide grout composed of one part cement and two parts sand. Use clean A-3 sand or sand meeting the requirements of Section 902 in this grout. In lieu of sand-cement grout, the Contractor may use concrete meeting the requirements of Section 347, using small gravel or crushed stone coarse aggregate. Deposit the grout through a grout pipe placed within a watertight plastic sheath (bag) extending the full depth of the double grooves and which, when filled, completely fills the slot formed by the double grooves.

455-9.5 Storage and Handling: Handle and store all sheet piles in a manner to prevent damage. Handle long sheet piles with fabric slings or braided wire rope constructed of six or more wire ropes placed at appropriate lift points to prevent damage due to excessive bending.

455-10 Pile Installation Plan (PIP).

455-10.1 General: Submit the completed Pile Driving Installation Plan Form (Form No. 700-020-01) with the following information at the preconstruction conference or no later than 30 days before driving the first pile.

1. The names of the CTQP qualified inspectors assigned to inspect the pile installation. If the Dynamic Testing Engineer is also a CTQP qualified pile driving inspector and is able to perform both operations, then an additional pile driving inspector is not required when driving piles using embedded sensors.
2. The quality control processes to ensure the required capacity is achieved in all piles. Include in the PIP the steps and analyses that would be performed when driving conditions change (such as unanticipated tip elevations, hammer modifications, presence of temporary piles and structures, preforming, changes, etc.).
3. The name and contact information for the single representative of the Contractor, independent of field operations personnel, to resolve to the Engineer's satisfaction conflicts in the driving procedures or interpretations of the driving criteria. This person shall be available within two hours notice, and shall have the authority to refer issues to higher levels (corporate, if needed).
4. A letter from the DTE certifying concurrence with the PIP.

Notify the Engineer of any test pile driving and production pile driving at least one week prior to beginning the installation operations of any pile.

455-10.2 Acceptance of Equipment and Procedures: The Engineer will evaluate the PIP for conformance with the Contract Documents. Within five working days, excluding weekends and Department observed holidays, after receipt of the plan, the Engineer will notify the Contractor of any comments and additional information required and/or changes that may be necessary to satisfy the Contract Documents. Submit changes and respond to the Engineer's comments and allow at least two working days, excluding weekends and Department observed holidays, for the Engineer to review the revised PIP.

All equipment and procedures are subject to satisfactory field performance. Make required changes to correct unsatisfactory field performance. The Engineer will give final acceptance after the Contractor makes necessary modifications. Do not make any changes in the driving system after acceptance without a revised PIP with concurrence of the DTE and acceptance by the Engineer. A hammer repaired on site or removed from the site and returned is

considered to have its performance altered (efficiency increased or decreased), which is considered a change in the driving system. Perform a dynamic load test in accordance with 455-5.14 on the first pile driven with this hammer to confirm the driving criteria is still appropriate at no additional compensation.

Acceptance of the PIP by the Engineer does not relieve the Contractor of the responsibility to perform the work in accordance with the Contract Documents. The Engineer's acceptance is not a guarantee that the chosen methods and equipment are capable of obtaining the required results; this responsibility lies with the Contractor.

455-11 Method of Measurement (All Piling).

455-11.1 General:

No adjustments in the length, in feet, of piling will be made if cut-offs are required after the pile has been driven to satisfactory bearing.

455-11.2 Prestressed Concrete Piling:

455-11.2.1 Length: The length of precast concrete piles will be considered as the overall length from head to tip. Final pay length will be based on the casting length as authorized in accordance with 455-5.15.3 subject to provisions of 455-11.2.3, 455-11.2.4, 455-11.8, 455-11.9, 455-11.12, and 455-11.13.

455-11.2.2 Monitoring of Unplanned Epoxy-Bonded Dowel Splice During Driving: If a pile is driven below cut-off and satisfactory bearing is not obtained, and additional driving is required after construction of a satisfactory splice, splicing and additional driving will be paid as Unforeseeable Work.

455-11.2.3 Extracting Piles: In the event that a pile is driven below cut-off without obtaining the required bearing, and the Engineer elects to have the pile extracted and a longer pile substituted, the pile extraction will be paid for as Unforeseeable Work. In the event a pile is damaged or mislocated, and the damage or mislocation is determined to be the Department's responsibility, and the Engineer elects to have the pile extracted, the pile extraction will be paid for as Unforeseeable Work. If a replacement pile is required, compensation will be made under the item for piling, for both the original pile and replacement pile.

The Contractor may substitute a longer pile in lieu of splicing and building-up a pile. In this event, the Contractor will be paid for the original authorized length of the pile, plus any additional length furnished by the Contractor up to the authorized length of the build-up, as piling. The Contractor will be paid 50% of the Contract unit price for piling as full compensation for extracting the original pile.

455-11.2.4 Underwater Driving: When the Contractor selects one of the optional underwater driving methods, payment will be made by selecting the applicable method from the following:

1. Using a pile longer than the authorized length: Measurement for piling will be made only for the authorized length at that location unless the length of pile from cut-off elevation to the final tip elevation is greater than the authorized length, in which case payment for piling will be made from cut-off elevation to final tip elevation. No payment will be made for pile splice, when this option is selected, unless the pile is physically spliced and the splice is driven below cut-off elevation to achieve bearing.

2. Using an underwater hammer or a pile follower: Measurement will be in accordance with 455-11.2.1.

455-11.3 Steel Piling:

455-11.3.1 Length: The length of steel piles will be considered as the overall length from head to tip. Final pay length will subject to provisions of 455-11.8, 455-11.9, 455-11.10, 455-11.12, and 455-11.13.

455-11.3.2 Point Protectors: The quantity to be paid for will be each for the total of point protectors authorized, furnished, and properly installed.

455-11.4 Test Piles: The quantity to be paid for of test piles of various types, will be the length, in feet, of test piling furnished, driven and accepted, according to the authorized length list, and any extensions thereof as approved by the Engineer.

Test piles left in place as permanent piles will be paid for only as test piling. Any extensions necessary to continue driving the pile for test purposes, as authorized by the Engineer, will be paid for as test piles. Other extensions of piles, additional length paid for splicing and build-ups will be included in the quantities of regular piling and will not be paid for as test piling.

455-11.5 Dynamic Load Tests: Payment will be based on the number of and type of dynamic load tests shown in the Plans, required by the Engineer, or required in 455-5.12.7, completed and accepted in accordance with the Contract Documents. No separate payment will be made for dynamic load tests used to evaluate changes in the Contractor's driving equipment. Include all costs associated with dynamically testing production piles with epoxy-bonded dowel splices under Pay Item No. 455-17.

Payment for internal gauges, when shown in the Plans, will be the number of piles with internal gauges successfully installed and used for dynamic testing.

455-11.6 Steel Sheet Piling: The quantity to be paid for will be the plan quantity area, in square feet, measured from top of pile elevation to the bottom of pile elevation and beginning and end wall limits as shown in the Plans with no allowance for variable depth surface profiles. Approved alternate support structures would be paid for as plan quantity computed for sheet pile. No separate payment will be made for sheet piling used in cofferdams and to incorporate the Contractor's specific means and methods, and not ordered by the Engineer.

455-11.7 Concrete Sheet Piling: The quantity to be paid for will be the plan quantity area, in square feet, with no area reduction for chamfered bottom ends or top recesses, measured from top of pile elevation to the bottom of pile elevation and beginning and end wall limits as shown in the Plans.

When the Engineer approves, the Contractor may furnish the concrete sheet piling in widths wider than shown in the Plans; then the number of piles shall be the actual number of units completed times the width used divided by the width in the Plans.

455-11.8 Pile Splices: The quantity to be paid for will be the number of authorized drivable splices and build-ups greater than 5 feet in length in concrete piling, and test piling, which are made for the purpose of obtaining authorized pile lengths longer than shown as the maximum length in the Standard Plans, for obtaining greater lengths than originally authorized by the Engineer, to incorporate test piling in the finished structure, for further driving of test piling, or for splices shown in the Plans.

The quantity to be paid for will be the number of authorized splices in steel piling and test piling, for the purpose of obtaining lengths longer than the lengths originally authorized by the Engineer.

455-11.9 Set-Checks and Redrives:

455-11.9.1 Set Checks/Test Piles: There will be no separate payment for the initial four set-checks performed the day of and the working day following initial driving. Each additional set-check ordered by the Engineer will be paid as a redrive.

455-11.9.2 Set Checks/Production Piles: There will be no separate payment for the initial set-check performed the day of initial driving. Each additional set-check ordered by the Engineer will be paid as a redrive.

455-11.9.3 Redrives: The quantity of redrives to be paid for, when shown in the Plans, will be the number of redrives, each, authorized by the Engineer. Redrives required by the Engineer, when not shown in the Plans, will be paid for as Unforeseeable Work.

455-11.10 Pile Extraction: Piles authorized to be extracted by the Engineer and successfully extracted as provided in 455-11.2.3 will be paid for as described in 455-11.2.3. No payment for extraction will be made for piles shown in the Plans to be extracted or piling damaged or mislocated by the Contractor that are ordered to be extracted by the Engineer.

455-11.11 Static Load Tests: The quantity to be paid for will be the number of static load tests of the designated tonnages, each, as shown in the Plans or authorized by the Engineer, actually applied to piles, completed and accepted in accordance with the Plans and these Specifications.

455-11.12 Preformed Pile Holes: The quantity to be paid for will be the length of completed preformed pile holes from existing surface or the bottom of any required excavation, whichever is lower, to the bottom of preformed hole shown in the Plans acceptably provided, for the installation of the bearing piles, regardless of the type of pile (test pile or production pile) installed therein. Only those holes authorized to be paid for, as provided in 455-5.10.3, will be included in the measurement for payment. The Engineer will authorize payment for preformed pile holes only when the pile has been placed in proper position and has achieved the required penetration. When preformed pile holes are not shown in the Plans, the work will be considered Unforeseeable Work.

455-11.13 Grouted Preformed Pile Holes: The quantity to be paid will be the length of grouted preformed pile holes from the bottom of preformed hole acceptably provided to the required top of grouting, regardless of the type of pile (test pile or production pile) installed therein. Only those holes required to be grouted, will be included in the measurement for payment.

455-11.14 Casing for Preformed Pile Holes: The quantity to be paid will be the cased length of preformed pile holes authorized by the Engineer or shown in the Plans, regardless of the type of pile (test pile or production pile) installed therein. When casing for preformed pile holes is not shown in the Plans, the work will be considered Unforeseeable Work.

455-11.15 Preformed Pile Holes For Sheet Piles: The quantity to be paid for will be the area, in square feet, completed and accepted, bounded by the existing ground surface or the bottom of any required excavation, whichever is lower, to the preform elevation and beginning and end limits of required preforming.

455-11.16 Pile Inspection: The quantity to be paid will be the number of piles and test piles inspected, driven, and accepted by a dedicated, qualified inspector.

455-11.17 Verification Test: The quantity to be paid will be the number of piles tested and accepted.

455-12 Basis of Payment (All Piling).

455-12.1 Treated Timber Piling: Price and payment will be full compensation for all labor, equipment, and materials required for furnishing, pile marking and installing all materials,

including collars, metal shoes, copper cover sheets, preservatives and tar, and for wrapping pile clusters with wire cable, where so shown in the Plans.

455-12.2 Prestressed Concrete Piling: Price and payment will be full compensation for all labor, equipment, and materials required for furnishing, pile marking and installing all concrete piling, predrilling pile holes described in 455-5.1, and furnishing the material for and wrapping pile clusters with wire cable where so shown in the Plans.

455-12.3 Steel Piling: Price and payment will be full compensation for all labor, equipment, and materials required for furnishing, marking and installing steel piling, including welding and painting as specified and the cost of predrilling pile holes described in 455-5.1. The cost of any concrete fill and reinforcing steel in pipe piles will be included in the price for steel piling.

Bracing and other metal parts attached to or forming a part of piling or bracing and not otherwise classified, will be measured and paid for as provided in Section 460.

455-12.4 Test Piles: Price and payment will be full compensation for all incidentals necessary to complete all the work of this item except splices, build-ups, pile extractions and preformed pile holes authorized by the Engineer and paid for under other pay items or payment methods.

455-12.5 Dynamic Load Tests:

455-12.5.1 Dynamic Load Tests/Test Piles: All test piles will require dynamic load tests. Include all costs associated with engaging a specialty engineer and perform the dynamic load tests in the pay items for test piles.

455-12.5.2 Dynamic Load Tests/Production Piles: Payment will be full compensation for all costs associated with engaging a specialty engineer and perform the dynamic load tests.

455-12.5.3 Dynamic Load Tests/Internal Gauges: Payment will be full compensation for all costs associated with supplying and installing internal gauges for dynamic testing.

455-12.6 Steel Sheet Piling:

455-12.6.1 Permanent Sheet Piling: Price and payment will be full compensation for all labor, equipment, and materials required for furnishing and installing steel sheet piling and coating but will not include furnishing and placing anchors when an anchored wall system is designed and detailed in the Plans. In such cases, furnishing and installing anchors will be paid separately.

455-12.6.2 Temporary Sheet Piling: For critical temporary steel sheet pile walls, walls which are necessary to maintain the safety of the traveling public or structural integrity of nearby structures, roadways and utilities during construction, that are detailed in the Plans, price and payment will be full compensation for all labor, equipment, and materials required for furnishing and installing steel sheet piling including preformed holes when shown in the Plans, and including wales, anchor bars, dead men, soil anchors, proof tests, performance tests, creep tests, and other incidental items when an anchored wall system is required. Removal of the sheet piling, anchors, and incidentals will be included in the cost per square foot for steel sheet piling (critical temporary). When the temporary steel sheet pile walls are not detailed in the Plans, the cost of furnishing and installation shall be incidental to cost of other related items and no separate payment shall be made. If the wall is not shown in the Plans, but deemed to be critical as determined by the Engineer, then a design shall be furnished by the Department and paid for separately under steel sheet piling (critical temporary).

455-12.7 Concrete Sheet Piling: Price and payment will be full compensation for all labor, equipment, and materials required for furnishing and installing concrete sheet piling, including reinforcing steel, grouting, filter fabric, and installation.

455-12.8 Preformed Pile Holes: Payment will be full compensation for all labor, equipment, and materials required to perform this work.

455-12.8.1 Grouted Preformed Pile Holes: Payment will be full compensation for all labor, equipment, and materials required to perform this work.

455-12.8.2 Casing for Preformed Pile Holes: Payment will be full compensation for all labor, equipment, and materials required to perform this work.

455-12.9 Point Protectors: Price and payment will be full compensation for all labor, equipment, and materials required for furnishing and installing point protectors.

455-12.10 Static Load Tests: Price and payment will be full compensation for all labor, equipment, and incidentals required to perform this work, including instrumentation, data collection and professional services to prepare the report.

455-12.11 Pile Cut-Off: Anticipate all piles will require cutting-off, and include all costs associated with pile cut-off in the pay items for piling.

455-12.12 Pile Redrives: Payment will be full compensation for all labor, equipment, and materials required to perform this work.

455-12.13 Pile Inspection: Price and payment will be full compensation for all labor, equipment, and incidentals required to perform this work, including providing the pile inspection device, data collection and submitting the records.

455-12.14 Verification Tests: Payment will be full compensation for all costs associated with assisting the Engineer in performing the dynamic load tests to verify the resistance and integrity of the tested pile.

455-12.15 Payment Items: Payment will be made under:

Item No. 455- 2-	Treated Timber Piling - per foot.
Item No. 455- 14-	Concrete Sheet Piling - per square foot.
Item No. 455- 15-	Preformed Pile Holes
Item No. 455- 17-	Pre-planned Pile Splices - each.
Item No. 455- 20-	Pile Inspection - each.
Item No. 455- 34-	Prestressed Concrete Piling - per foot.
Item No. 455- 35-	Steel Piling - per foot.
Item No. 455- 36-	Concrete Cylinder Piling - per foot.
Item No. 455-115-	Pile Redrive - each.
Item No. 455-119-	Test Loads - each.
Item No. 455-120-	Point Protection - each.
Item No. 455-133-	Sheet Piling - per square foot.
Item No. 455-137-	Dynamic Load Tests - each.
Item No. 455-143-	Test Piles (Prestressed Concrete) - per foot.
Item No. 455-144-	Test Piles (Steel) - per foot.
Item No. 455-145-	Test Piles (Concrete Cylinder) - per foot.

C. DRILLED SHAFTS

455-13 Description.

Construct drilled shaft foundations consisting of reinforced concrete drilled shafts.

455-14 Materials.

455-14.1 Concrete: Use concrete meeting the requirements of Section 346, unless otherwise shown in the Plans.

455-14.2 Reinforcing Steel: Meet the reinforcing steel requirements of Section 415.

455-14.3 Polymer Slurry: Use a product listed on the Department's Approved Product List (APL) meeting the requirements of 932-5.

455-15 Construction Methods and Equipment.

455-15.1 General Requirements:

455-15.1.1 Templates: When drilling from a barge, provide a fixed template, adequate to maintain shaft position and alignment during all excavation and concreting operations. Do not use floating templates (attached to a barge). When the Contractor fails to properly maintain shaft position and alignment without use of a template when drilling on land, the Engineer will require a fixed template, adequate to maintain shaft position and alignment during all excavation and concreting operations.

455-15.1.2 Drilled Shaft Installation Plan (DSIP): At the preconstruction conference submit a DSIP for review by the Engineer. Final approval will be subject to satisfactory performance. Include in this plan the following details:

1. Name and experience record of drilled shaft superintendent or foreman in responsible charge of drilled shaft operations. Ensure the drilled shaft superintendent or foreman in responsible charge of the drilled shaft operations has a minimum of one year of experience of installing drilled shafts of the size and depth shown in the Plans and a minimum of three years' experience in the construction of drilled shafts using the following methods:
    a. Wet Method (mineral and polymer slurry),
    b. Casings up to the length shown in the Plans,
    c. Shaft drilling operations on water under conditions as shown in the Plans.
2. List and size of proposed equipment, including cranes, drills, augers, bailing buckets, final cleaning equipment, desanding equipment, slurry pumps, core sampling equipment, tremies or concrete pumps, casings, and equipment to install and remove casing.
3. Details of sequence of construction operations and sequence of shaft construction in bents or shaft groups.
4. Details of shaft excavation methods, including casing installation procedures.
5. Details of slurry, including proposed methods to mix, circulate, desand, test methods, and proposed CTQP certified technician that will perform and document the fluid tests.
6. Details of proposed methods to clean the shaft excavation.

7. Details of shaft reinforcement, including methods to ensure centering/required cover, cage integrity during placement, placement procedures, cage support, and tie downs.

8. Details of concrete placement, including elapsed concrete placement times and proposed operational procedures for concrete tremie or pump, including initial placement, raising during placement, and overfilling of the shaft concrete. Include provisions to ensure proper final shaft cutoff elevation.

9. Details of casing removal when removal is required, including minimum concrete head in casing during removal.

10. Required submittals, including shop drawing and concrete design mixes.

11. Details of any required load tests, including equipment and procedures, and recent calibrations for any jacks or load cells.

12. Proposed Cross-Hole Sonic Logging (CSL) and Thermal Integrity Testing for Drilled (TITDS) Specialty Engineer to supervise field testing and report the test results.

13. Methods and equipment proposed to prevent displacement of casing and/or shafts during placement and compaction of fill.

14. Provide the make and model of the shaft inspection device, if applicable.

15. Details of environmental control procedures used to prevent loss of slurry or concrete into waterways or other protected areas.

16. Proposed schedule for test shaft installation, load tests and production shaft installation.

17. For drilled shafts constructed using polymer slurry, identify the polymer slurry, the pH and proposed viscosity ranges and a description of the mixing method to be used. Submit the contact information for the manufacturer's representative available for immediate contact during shaft construction and the representative's schedule of availability.

18. When settlement and vibration monitoring of adjacent structures are required as per 108-2, submit a proposed monitoring plan identifying the proposed equipment, the structures and the specific points that will be monitored.

19. Procedure for grouting non-destructive testing access tubes.

20. Other information shown in the Plans or requested by the Engineer.

The Engineer will evaluate the DSIP for conformance with the Contract Documents. Within 20 days after receipt of the plan, the Engineer will notify the Contractor of any additional information required and/or changes that may be necessary to meet the above requirements and satisfy the Contract Documents. The Engineer will reject any part of the plan that does not meet specifications, plans or has the potential to affect the integrity of adjacent structures or negatively affect the environmental conditions. Submit changes agreed upon for reevaluation. The Engineer will notify the Contractor within seven days after receipt of proposed changes of their acceptance or rejection. All equipment and procedures are subject to trial and satisfactory performance in the field.

Acceptance by the Engineer does not relieve the Contractor of the responsibility to perform the work in accordance with the Contract Documents. The installation plan is for the Contractor to explain the approach to the work and allow the Engineer an

opportunity to comment on the equipment and procedures chosen before field operations begin. The Engineers acceptance is not a guarantee that the chosen methods and equipment are capable of obtaining the required results, this responsibility lies with the Contractor.

455-15.1.3 General Methods & Equipment: Perform the excavations required for the shafts, through whatever materials encountered, to the dimensions and elevations shown in the Contract Documents, using methods and equipment suitable for the intended purpose and the materials encountered. Provide drilling tools with a diameter not smaller than one inch of the shaft diameter required in the Plans. Provide equipment capable of constructing shafts supporting bridges to a depth equal to the deepest shaft shown in the Plans plus 15 foot or plus three times the shaft diameter, whichever is greater, except when the Plans require equipment capable of constructing shafts to a deeper depth. Provide equipment capable of constructing shafts supporting non-bridge structures, including sign, signal, lighting and ITS structures, to a depth equal to the deepest shaft shown in the Plans plus 5 feet.

Construct drilled shafts according to the Contract Documents using generally either the dry method, wet method, casing method, or permanent casing method as necessary to produce sound, durable concrete foundation shafts free of defects. Use the permanent casing method only when required by the Plans or authorized by the Engineer. When the Plans describe a particular method of construction, use this method except when permitted otherwise by the Engineer, after field trial. When the Plans do not describe a particular method, propose a method on the basis of its suitability to the site conditions and submit it for approval by the Engineer.

Set a suitable temporary removable surface casing from at least 1 foot above the ground surface to at least 1-1/2 shaft diameters below the ground surface to prevent caving of the surface soils and to aid in maintaining shaft position and alignment. Do not use a temporary casing larger than 12 inches of the shaft diameter. Fill the oversized temporary casing with drilled shaft concrete at no additional expense to the Department. Withdraw the surface casing after concrete placement. The Engineer may require predrilling with slurry and/or overreaming to the outside diameter of the casing to install the surface casing at some sites.

For drilled shafts installed to support sign, signal, lighting and ITS structures, provide temporary surface casings from at least 1 foot above the ground surface to at least 5 feet below the ground surface. For sign, signal, lighting and ITS structure foundations located within permanent sidewalks or within 5 feet of curb sections, provide temporary surface casings from no lower than the top of sidewalk to at least 5 feet below the ground surface.

For drilled shafts installed to support sign, signal, lighting and ITS structures, do not attempt to excavate the shaft using plain water or natural slurry. Do not attempt to excavate the shaft using dry construction method unless specifically indicated in the Plans or approved by the Engineer.

455-15.2 Dry Construction Method: Use the dry construction method only at sites where the ground water table and soil conditions, generally stiff to hard clays or rock above the water table, make it feasible to construct the shaft in a relatively dry excavation and where the sides and bottom of the shaft are stable and may be visually inspected by the Engineer prior to placing the concrete.

In applying the dry construction method, drill the shaft excavation, remove accumulated seepage water and loose material from the excavation and place the shaft concrete in a relatively dry excavation.

Use the dry construction method only when shaft excavations, as demonstrated in a test hole, have 12 inches or less of seepage water accumulated over a four hour period, the sides and bottom remain stable without detrimental caving, sloughing, or swelling for a four hour period, and the loose material and water can be satisfactorily removed prior to inspection and prior to placing concrete. Use the wet construction method or the temporary casing construction method for shafts that do not meet the requirements for the dry construction method.

455-15.3 Wet Construction Method: Use the wet construction method at all sites where it is impractical to provide a dry excavation for placement of the shaft concrete.

The wet construction method consists of keeping the shaft excavation filled with fluid (mineral slurry, polymer slurry, natural slurry or water), desanding and cleaning the slurry and final cleaning of the excavation by means of a bailing bucket, air lift, submersible pump or other approved devices and placing the shaft concrete (with a tremie or concrete pump extending to the shaft bottom) which displaces the water or slurry during concreting of the shaft excavation.

Where drilled shafts are located in open water areas, construct the shafts by the wet method using exterior casings extending from above the water elevation into the ground to protect the shaft concrete from water action during placement and curing of the concrete. Install the exterior casing in a manner that will produce a positive seal at the bottom of the casing so that there is no intrusion or extrusion of water or other materials into or from the shaft excavation.

455-15.4 Temporary Casing Construction Method: Use the temporary casing method at all sites where it is inappropriate to use the dry or wet construction methods without the use of temporary casings other than surface casings. In this method, the casing is advanced prior to excavation and withdrawn after concrete placement. When a formation is reached that is nearly impervious, seal in the nearly impervious formation. Proceed with drilling as with the wet method to the projected depth. Proceed with the placement of the concrete as with the dry method. In the event seepage conditions prevent use of the dry method, complete the excavation and concrete placement using wet methods.

Where drilling through materials having a tendency to cave, advance the excavation by drilling in a mineral or polymer slurry. In the event that a caving layer or layers are encountered that cannot be controlled by slurry, install temporary removable casing through such caving layer or layers. The Engineer may require overreaming to the outside diameter of the casing. Take whatever steps are required to prevent caving during shaft excavation including installation of deeper casings. If electing to remove a casing and replace it with a longer casing through caving soils, backfill the excavation. The Contractor may use soil previously excavated or soil from the site to backfill the excavation. The Contractor may use other approved methods which will control the size of the excavation and protect the integrity of the foundation soils to excavate through caving layers.

Before withdrawing the casing, ensure that the level of fresh concrete is at such a level that the fluid trapped behind the casing is displaced upward. As the casing is withdrawn, maintain the level of concrete within the casing so that fluid trapped behind the casing is displaced upward out of the shaft excavation without mixing with or displacing the shaft concrete.

The Contractor may use the casing method, when approved by the Engineer, to construct shafts through weak caving soils that do not contribute significant shaft shear resistance. In this case, place a temporary casing through the weak caving soils before beginning excavation. Conduct excavation using the dry construction method where appropriate for site

conditions and the wet construction method where the dry construction method is not appropriate. Withdraw the temporary casing during the concreting operations unless the Engineer approves otherwise.

455-15.5 Permanent Casing Construction Method: Use the permanent casing method when required by the Plans. In this method, place a casing to the prescribed depth before beginning excavation. If the Contractor cannot attain full penetration, the Engineer may direct the Contractor to excavate through the casing and advance the casing until reaching the desired penetration. In some cases, the Engineer may require the Contractor to overream to the outside diameter of the casing before placing the casing.

Construct the shaft in accordance with 455-15.4 except for cutting the casing off at the prescribed elevation upon reaching the proper construction sequence and leaving the remainder of the casing in place.

455-15.5.1 Temporary Extension of Permanent Casing: When the wet method does not provide enough support to excavate and clean the drilled shaft extension below the permanent casing tip elevations shown in the Plans, the permanent casing may be temporarily extended to an elevation deeper than the tip elevation at no additional expense to the Department. The rock socket length must be extended as specified in 455-15.7 and the casing raised to the original casing tip elevation shown in the Plans after the concrete placement. Include details of this procedure in the DSIP for the Engineer's review and approval.

455-15.5.2 Temporary Casing to Stabilize Excavation below the Permanent Casing: To stabilize the excavation below the permanent casing tip elevation, a temporary casing inside an oversized permanent casing may be used at no additional expense to the Department. The permanent casing must have an inside diameter no more than 6 inches larger than the drilled shaft diameter specified in the Plans.

The following requirements apply:

1. Excavate and clean the materials from inside the permanent casing. Ensure all materials are removed from the inside wall of the permanent casing.
2. Install the temporary casing prior to excavating below the permanent casing tip elevation. The temporary casing must have a minimum internal diameter equal to the shaft diameter required in the Plans.
3. If the temporary casing is advanced deeper than the minimum top of rock socket elevation as shown in the Plans, or the top of rock elevation if deeper, extend the rock socket length in accordance with 455-15.7.
4. Place concrete in accordance with 455-15.9.3 through the temporary casing. Do not allow concrete to fall or overflow into the annular space between the temporary and permanent casing.
5. After placement of the concrete, remove the temporary casing in accordance with 455-15.4, 455-15.7 and 455-17. During withdrawal of the temporary casing, maintain adequate concrete head in both the temporary and permanent casings to avoid breaching, caving, or contamination of the concrete.

Include details of this procedure in the DSIP for the Engineer's review and approval.

455-15.6 Excavations: When pilot holes and/or load tests are performed, the Engineer will use the pilot hole and/or load test results to determine the authorized tip elevations and/or the authorized installation criteria of the drilled shafts. Drilled shaft construction shall not begin until pilot hole and/or load test reports are approved by the Engineer. Shaft tip elevations based

on pilot hole results and/or load tests may vary from the tip elevations presented in the Plans. Extend drilled shaft excavations deeper by extra depth excavation when the Engineer determines the material encountered while drilling the shaft excavation is unsuitable and/or is not the same as anticipated in the design of the drilled shaft. In the absence of suitable strength tests or load tests to evaluate materials excavated, construct the shafts no higher than the tip elevations shown in the Plans.

455-15.6.1 Pilot Hole: When pilot holes are shown in the Plans core a pilot hole, prior to shaft excavation, in accordance with ASTM D2113 Standard Practice for Rock Core Drilling and Sampling of Rock for Site Excavation and the Department's Soils & Foundations Handbook using a double or triple wall core barrel through part or all of the shaft, to a depth of 3 times the diameter of the drilled shaft below the tip elevation shown in the Plans, as directed by the Engineer. The Engineer may require the Contractor to cut any core to a total depth below the bottom of the drilled shaft excavation of up to 5 times the diameter of the drilled shaft.

455-15.6.2 Cores: Take cores when shown in the Plans or directed by the Engineer to determine the character of the material directly below the shaft excavation. Provide equipment to retrieve the core from a depth of 5 times the diameter of the drilled shaft below the bottom of the drilled shaft excavation in accordance with ASTM D2113 Standard Practice for Rock Core Drilling and Sampling of Rock for Site Excavation. Cut the cores with an approved core barrel to a minimum depth of 3 times the diameter of the drilled shaft below the bottom of the drilled shaft excavation after completing the shaft excavation, as directed by the Engineer. The Engineer may require the Contractor to cut any core to a total depth below the bottom of the drilled shaft excavation of up to 5 times the diameter of the drilled shaft.

For cores or pilot holes, use only a double or triple wall core barrel designed:

1. to cut a core sample from 4 inches to 6 inches in diameter, at least 5 feet in length, and,

2. so that the sample of material cored can be removed from the shaft excavation and the core barrel in an undisturbed state.

The Engineer will inspect the cores and determine the depth of required excavation. When considered necessary by the Engineer, take additional cores. Place the core samples in suitable containers, identified by shaft location, elevation from and to, and job number, and deliver to the Department within 48 hours after cutting. When called for in the Plans, substitute Standard Penetration Tests (SPT) for coring. In such cases, supply these tests at no additional cost per foot to the Department above that bid for core (shaft excavation).

Provide areas for the disposal of unsuitable materials and excess materials as defined in 120-5 that are removed from shaft excavations, and dispose of them in a manner meeting all environmental requirements.

Furnish the additional drilled shaft concrete over the theoretical amount required to complete filling any excavations for shafts which are larger than required by the Plans or authorized by the Engineer, at no expense to the Department.

455-15.7 Casings: Ensure that casings are metal, of ample strength to withstand handling and driving stresses and the pressure of concrete and of the surrounding earth materials, and that they are smooth and water tight. Ensure that the inside diameter of casing is not less than the specified size of shaft except as provided below. The Department will not allow extra compensation for concrete required to fill an oversize casing or oversize excavation.

The Engineer will allow the Contractor to supply casing with an outside diameter equal to the specified shaft diameter (O.D. casing) provided additional shaft length is supplied at the shaft tip. Determine the additional length of shaft required by the following relationship:

$$Additional\ Length = \frac{(D_1 - D_2)\,L}{D_2}$$

where:

D_1= casing inside diameter specified = shaft diameter specified
D_2= casing inside diameter provided ($D_2 = D_1$ minus twice the wall thickness).
L= authorized shaft length below ground for temporary casing methods or below casing for permanent casing methods.

Bear all costs relating to this additional length including but not limited to the cost of extra excavation, extra concrete, and extra reinforcing steel.

Install and remove casing by rotating, exerting downward pressure, or with a vibratory hammer, unless otherwise shown in the Contract Documents. Remove all casings from shaft excavations except those used for the Permanent Casing Method. Ensure that the portion of casings installed under the Permanent Casing Method of construction below the shaft cut-off elevation remains in position as a permanent part of the drilled shaft. The Contractor may leave casings if in the opinion of the Engineer the casings will not adversely affect the shaft capacity in place. When casings that are to be removed become bound in the shaft excavation and cannot be practically removed, drill the shaft excavation deeper as directed by the Engineer to compensate for loss of capacity due to the presence of the casing. The Department will not compensate for the casing remaining. The Department will pay for the additional length of shaft under Pay Item No. 455-88.

If temporary casing is advanced deeper than the minimum top of rock socket elevation shown in the Plans or actual top of rock elevation if deeper, withdraw the casing from the rock socket and overream the shaft. If the temporary casing cannot be withdrawn from the rock socket before final cleaning, extend the length of rock socket below the authorized tip elevation one-half of the distance between the minimum top of rock socket elevation or actual elevation if deeper, and the temporary casing tip elevation.

Form drilled shafts extending through a body of water with permanent casings. When the shaft extends above ground or a body of water, the Contractor may form the exposed portion with removable casing, unless otherwise specified in the Plans. Remove the portion of metal casings between an elevation 2 feet below the lowest water elevation, or 2 feet below ground, whichever is higher and the top of shaft elevation after the concrete is cured. Remove casings to expose the concrete as required above in a manner which will not damage the drilled shaft concrete. Dismantle removable casings in accordance with the provisions of 455-17.5.

When practical, do not start casing removal until completing all concrete placement in the shaft. Extract casing at a slow, uniform rate with the pull in line with the axis of the shaft. Withdraw temporary casings while the concrete remains fluid.

When conditions warrant, the Contractor may pull the casing in partial stages. Maintain a sufficient head of concrete above the bottom of the casing to overcome the hydrostatic pressure of water outside the casing. At all times maintain the elevation of the

concrete in the casing high enough to displace the drilling slurry between the outside of the casing and the edge of the hole while removing the casing.

The Contractor may use special casing systems in open water areas, when approved, which are designed to permit removal after the concrete has hardened. Design special casings so that no damage occurs to the drilled shaft concrete during their removal.

Expandable or split casings that are removable are not permitted for use below water.

455-15.8 Slurry and Fluid in Excavation:

455-15.8.1 General: Thoroughly premix the slurry in a mixing tank with clean fresh water prior to introduction into the shaft excavation. Introduce slurry before the excavation advances below the bottom of the casing. Ensure that the percentage of polymer or mineral admixture used to make the suspension is such as to maintain the stability of the shaft excavation. Provide adequate water and/or slurry tanks to perform the work in accordance with this Section. The Engineer will not allow excavated pits on projects requiring slurry tanks without the written permission of the Engineer. Take the steps necessary to prevent the slurry from "setting up" in the shaft; including, but not limited, to agitation, circulation, and adjusting the composition and properties of the slurry. Provide suitable offsite disposal areas and dispose of all waste slurry in a manner meeting all requirements pertaining to pollution.

For shafts to support sign, signal, lighting, and ITS structures, polymer slurry may be mixed in the casing portion, in accordance with the APL approved instructions if the following conditions are met:

1. Contractor tests and verifies the polymer slurry meets the property requirements of 455-15.8.3, before continuing the excavation below the casing.
2. Polymer mix continues to be added as required below the bottom of the casing, to maintain the slurry properties during the excavation within compliance of 455-15.8.3.
3. Slurry sampling and testing is performed at intervals not exceeding one hour, in the middle of the excavation depth at the time of testing to verify the properties are maintained within compliance throughout the excavation.
4. If failing to demonstrate the properties are maintained within compliance of 455-15.8.3, discontinue this mixing method and use a slurry pre-mixed in a tank.

Provide a CTQP qualified drilled shaft inspector to perform control tests using suitable apparatus on the slurry mixture to determine the slurry and fluid properties as specified in 455-15.8.2 to 455-15.8.4.

Measure the viscosity of the freshly mixed slurry regularly as a check on the quality of the slurry being formed using an approved measuring device.

Perform tests from the fluid in the excavation to determine density, viscosity, and pH value to establish a consistent working pattern, taking into account the mixing process and blending of freshly mixed slurry and previously used slurry. Repeat tests to determine density, viscosity, and pH value at intervals not exceeding 2 hours during the first 8 hours slurry is in use and every 4 hours thereafter, including overnight, until concrete placement. Perform density, viscosity, and pH tests again when the excavation reaches the midpoint. When the contractor operations require the shaft excavation to be interrupted and performed in multiple shifts, the continuous testing may be waived if the excavation at the time of suspension of the operations is not deeper than the bottom of the casing provided.

For shafts to support sign, signal, lighting, and ITS structures up to 6 feet in diameter and up to 40 feet in depth, when the contractor operations require the shaft to be

constructed in multiple shifts, the continuous testing may be waived if the excavation at the time of operations suspension is not deeper than the bottom of the casing provided, or if all the conditions below are met:

1. The shaft location is not within a distance equal to the shaft depth, or five shaft diameters, whichever is greater, from an edge of an adjacent lane, utility structure, or any structure.

2. Slurry testing is performed at the time of suspending operations and at a time not exceeding 12 hours after that or at the time the operations resume whichever comes first. Testing shall be performed at intervals not exceeding 2 hours for the first 8 hours after resuming operations and every 4 hours thereafter.

3. Slurry testing shall be performed on at least two samples each time, one sample approximately three feet from the bottom and one sample from the middle of the excavation depth at the time the operations were suspended. The results must indicate the polymer slurry meets the viscosity requirements of 455-15.8.3. If this requirement is not met, do not continue without testing for more than 4 hours including the time periods between shifts.

4. The contractor performs soundings of the fluid level, at intervals of 15 minutes or longer, that demonstrate the fluid level is stable over two consecutive soundings.

5. If when resuming operations, slurry does not meet density, pH, or both, adjust the slurry to meet all property requirements of 455-15.8.3. Re-test slurry to verify properties meet the requirements, before resuming operations. Continue testing the slurry every 4 hours after resuming operations until completion of the excavation.

The Department may perform comparison tests as determined necessary during the mineral and polymer slurry operations.

If, at any time in the opinion of the Engineer, the wet construction method fails to stabilize the excavation, discontinue this method of construction, backfill the excavation and submit modifications in procedure or alternate means of construction for approval.

455-15.8.2 Mineral Slurry: When mineral slurry is used in an excavation, use only processed attapulgite or bentonite clays with up to 2% (by dry weight) of added polymer. Use mineral slurry having a mineral grain size such that it will remain in suspension and having viscosity and gel characteristics to transport excavated material to a screening system. Use a percentage and specific gravity of the material to make a suspension able to maintain the stability of the excavation and to allow proper placement of concrete. Ensure that the material used to make the slurry is not detrimental to concrete or surrounding ground strata. During construction, maintain the level of the slurry at a height sufficient to prevent caving of the hole. In the event of a sudden significant loss of slurry such that the slurry level cannot be maintained by adding slurry to the hole, backfill the excavation and delay the construction of that foundation until an alternate construction procedure has been approved.

Perform the following tests on the mineral slurry supplied to and in the shaft excavation and ensure that the results are within the ranges stated in the table below:

Table 455-3		
Item to be measured	Range of Results at 68ºF fluid temperature	Test Method
Density	64 to 73 lb/ft^3 (in freshwater environment) 66 to 75 lb/ft^3 (in saltwater environment)	Mud density balance: FM 8-RP13B-1
Viscosity	30 to 40 seconds	Marsh Cone Method: FM 8-RP13B-2
pH	8 to 11	Electric pH meter or pH indicator paper strips: FM 8-RP13B-4
Sand Content	4% or less	FM 8-RP13B-3

The Contractor may adjust the limits in the above table when field conditions warrant as successfully demonstrated in a test hole or with other methods approved by the Engineer. The Engineer must approve all changes in writing before the Contractor can continue to use them.

During construction, maintain the level of mineral slurry in the shaft excavation within the excavation and at a level not less than 4 feet above the highest expected piezometric water elevation along the depth of a shaft.

455-15.8.3 Polymer Slurry: A representative of the manufacturer must be on-site or available for immediate contact to assist and guide the construction of the first three drilled shafts at no additional cost to the Department. This representative must also be available for on-site assistance or immediate contact if problems are encountered during the construction of the remaining drilled shafts as determined by the Engineer. Use polymer slurry only if the soils below the casing are not classified as organic, and the pH of the fluid in the hole can be maintained in accordance with the manufacturer's recommendations.

Perform the following tests on the polymer slurry supplied to and in the shaft excavation and ensure that the results are maintained within the ranges stated in the table below:

Table 455-4 Mixed Polymer Slurry Properties		
Item to be measured	Range of Results at 68ºF fluid temperature	Test Method
Density	62 to 65 lb/ft^3 (in freshwater environment) 64 to 67 lb/ft^3 (in saltwater environment)	Mud density balance: FM 8-RP13B-1
Viscosity for bridges and main structure foundations	50 seconds to upper limit defined by the APL	Marsh Cone Method: FM 8-RP13B-2
Viscosity for miscellaneous structure foundations	50 seconds to upper limit recommended by the manufacturer based on soil type	Marsh Cone Method: FM 8-RP13B-2

Table 455-4 Mixed Polymer Slurry Properties		
Item to be measured	Range of Results at 68ºF fluid temperature	Test Method
pH	Range published by the manufacturer for materials excavated	Electric pH meter or pH indicator paper strips: FM 8-RP13B-4
Sand Content	0.5% or less	FM 8-RP13B-3

If desired, sodium bicarbonate or soda ash may be added to the fluid in the hole to raise the pH. Premix polymer slurry in accordance with the manufacturer's published procedures. Do not mix the slurry in the excavation as a means to prepare slurry. When approved by the Engineer, adjustments to slurry properties can be made in the excavation.

During construction, maintain the level of the slurry at a height sufficient to prevent caving of the hole and which should not be lower than 4 feet above the highest expected piezometric water elevation along the depth of the shaft.

Ensure the method of disposal meets the requirements of local authorities.

455-15.8.4 Fluid in Excavation at Time of Concrete Placement: When any fluid is present in any drilled shaft excavation, including shafts to support sign, signal, lighting and ITS structures, the applicable test methods and reporting requirements described in 455-15.8.1, 455-15.8.2 and 455-15.8.3 apply to tests of fluid in the shaft prior to placing the concrete.

When mineral slurries are used, ensure the properties at the time of concrete placement are within the acceptable ranges indicated in 455-15.8.2. When polymer slurries are used ensure the properties of the polymer slurry are within the following acceptable ranges at the time of concrete placement:

Table 455-5 Polymer Slurry Properties at Time of Concrete Placement		
Item to be measured	Range of Results at 68ºF fluid temperature	Test Method
Density	62 to 65 lb/ft^3 (in freshwater environment) 64 to 67 lb/ft^3 (in saltwater environment)	Mud density balance: FM 8-RP13B-1
Viscosity	50 seconds to upper limit defined by the APL	Marsh Cone Method: FM 8-RP13B-2
pH	Range published by the manufacturer for materials excavated	Electric pH meter or pH indicator paper strips: FM 8-RP13B-4
Sand Content	0.5% or less	FM 8-RP13B-3

Test samples of the fluid in the shaft from within 1 inch of the base of the shaft and from the middle of the shaft height for shafts up to 60 feet in depth. Test samples of the fluid in the shaft from within 1 inch of the base of the shaft and at intervals not exceeding 30 feet up the shaft for shafts deeper than 60 feet. Use a sampling tool designed to sample over a depth range of 12 inches or less. Take whatever action is necessary prior to placing the concrete to

bring the fluid within the specification and reporting requirements, outlined in the tables in 455-15.8.2 and 455-15.8.3, except as follows:

The Engineer will not require tests for pH or viscosity, nor require the fluid to meet the minimum density specified in 455-15.8.2 and 455-15.8.3 when neither polymer nor mineral slurry has been introduced into the shaft excavation.

455-15.9 Tremies and Pumps:

455-15.9.1 General: The requirements of the applicable provisions of Section 400 will apply when using a tremie or a pump to place drilled shaft concrete.

455-15.9.2 Dry Excavations: Ensure that the tremie for depositing concrete in a dry drilled shaft excavation consists of a tube of solid construction, a tube constructed of sections which can be added and removed, or a tube of other approved design. The Contractor may pass concrete through a hopper at the top of the tube or through side openings as the tremie is retrieved during concrete placement. Support the tremie so that the free fall of the concrete is less than 5 feet at all times. If the free falling concrete causes the shaft excavation to cave or slough, control the movement of concrete by reducing the height of free fall of the concrete and/or reducing the rate of flow of concrete into the excavation.

455-15.9.3 Wet Excavations: Construct the tremie or pump line used to deposit concrete beneath the surface of water so that it is water-tight and will readily discharge concrete. Construct the discharge end of the tremie or pump line to prevent water intrusion and permit the free flow of concrete during placement operations. Ensure that the tremie or pump line has sufficient length and weight to rest on the shaft bottom before starting concrete placement.

During placement operations, ensure that the discharge end of the tremie or pump line is within 6 inches of the bottom of the shaft excavation until at least 10 feet of concrete has been placed. Ensure the discharge end of the tremie or pump line is continuously embedded at least 10 feet into the concrete after 10 feet of concrete has been placed and until the casing is overpoured sufficiently to eliminate all contaminated concrete. Ensure that the free fall of concrete into the hopper is less than 5 feet at all times. Support the tremie so that it can be raised to increase the discharge of concrete and lowered to reduce the discharge of concrete. Do not rapidly raise or lower the tremie to increase the discharge of the concrete. Maintain a continuous flow of concrete and a positive pressure differential of the concrete in the tremie or pump line at all times to prevent water or slurry intrusion into the shaft concrete.

455-15.10 Excavation and Drilling Equipment:

455-15.10.1 General: All shaft excavation is unclassified shaft excavation. The Engineer will require drilled shaft sidewall overreaming when inspections show it to be necessary. These terms are defined in 455-15.10.2, 455-15.10.3, and 455-15.10.4, respectively.

Use excavation and drilling equipment having adequate capacity, including power, torque, and crowd (downthrust), and excavation and overreaming tools of adequate design, size, and strength to perform the work shown in the Plans or described herein. When the material encountered cannot be drilled using conventional earth augers and/or underreaming tools, provide special drilling equipment, including but not limited to rock augers, core barrels, rock tools, air tools, blasting materials, and other equipment as necessary to continue the shaft excavation to the size and depth required. In the event blasting is necessary, obtain all necessary permits. The Contractor is responsible for the effects of blasting on already completed work and adjacent structures. The Engineer must approve all blasting.

455-15.10.2 Unclassified Shaft Excavation: Unclassified shaft excavation is defined as all processes required to excavate a drilled shaft of the dimensions shown in the

Contract Documents to the depth indicated in the Plans plus 15 feet or plus 3 shaft diameters, whichever is deeper, completed and accepted. Include in the work all shaft excavation, whether the material encountered is soil, rock, weathered rock, stone, natural or man-made obstructions, or materials of other descriptions.

455-15.10.3 Unclassified Extra Depth Excavation: Unclassified extra depth excavation is defined as all processes required to excavate a drilled shaft of plan dimensions which is deeper than the limits defined as unclassified shaft excavation.

455-15.10.4 Drilled Shaft Sidewall Overreaming: Drilled shaft sidewall overreaming is defined as the unclassified excavation required to roughen its surface or to enlarge the drilled shaft diameter due to softening of the sidewalls or to remove excessive buildup of slurry cake when slurry is used. Increase the shaft radius a minimum of 1/2 inch and a maximum of 3 inches by overreaming. The Contractor may accomplish overreaming with a grooving tool, overreaming bucket, or other approved equipment.

Meet the limit for depth of sidewall overreaming into the shaft sidewall material and the elevation limits between which sidewall overreaming is required.

455-15.11 Inspection of Excavations:

455-15.11.1 Dimensions and Alignment: Provide equipment for checking the dimensions and alignment of each permanent shaft excavation. Determine the dimensions and alignment of the shaft excavation under the observation and direction of the Department. Generally, check the alignment and dimensions by any of the following methods as necessary:

1. Check the dimensions and alignment of dry shaft excavations using reference stakes and a plumb bob.

2. Check the dimensions and alignment of casing when inserted in the excavation.

3. Insert any casing, rod or pipe assembly, or other device used to check dimensions and alignment into the excavation to full depth.

455-15.11.2 Depth: Generally, reference the depth of the shaft during drilling to appropriate marks on the Kelly bar or other suitable methods. Measure final shaft depths with a suitable weighted tape or other approved methods after final cleaning.

455-15.11.3 Shaft Inspection Device (SID): When shown in the Plans, furnish all power and equipment necessary for the Engineer to inspect the bottom conditions of a drilled shaft excavation and to measure the thickness of bottom sediment or any other debris using a SID. Provide a means to position and lower the SID into the shaft excavation to enable the bell housing to rest vertically on the bottom of the excavation. Include all cost related to the inspection device in the cost of drilled shaft items.

Furnish a SID meeting the following requirements:

1. A remotely operated, high resolution, color video camera sealed inside a watertight bell housing.

2. Provides a clear view of the bottom inspection on a video monitor at the surface in real time.

3. Provides a permanent record of the entire inspection with voice annotation on a quality DVD with a resolution of not less than 720 x 480.

4. Provides a minimum field of vision of 110 square inches, with at least two graduated measuring devices to record the depth of sediment on the bottom of the shaft excavation to a minimum accuracy of 1/2 inch and a length greater than 1-1/2 inches.

5. Provides sufficient lighting to illuminate the entire field of vision at the bottom of the shaft in order for the operator and inspector to clearly see the depth measurement scale on the video monitor and to produce a clear recording of the inspection.

6. Provides a regulated compressed air or gas system to precisely adjust the drilling fluid level within the bell housing and a pressurized water system to assist in determination of bottom sedimentation depth.

Obtain the Engineer's approval of the device in advance of the first inspection contingent on satisfactory field performance. Notify the Engineer for approval before a different device is used for any subsequent inspection.

455-15.11.4 Shaft Cleanliness Requirements: Adjust cleaning operations so a minimum of 50% of the bottom of each shaft will have less than 1/2 inches of sediment at the time of placement of the concrete. Ensure the maximum depth of sedimentary deposits or any other debris at any place on the bottom of the shaft excavation does not exceed 1-1/2 inches. The Engineer will determine shaft cleanliness by visual inspection for dry shafts, using divers or an inspection device or other methods the Engineer deems appropriate for wet shafts.

When using slurry, meet the requirements of 455-15.8 at the time of concrete placement.

455-15.11.4.1 Exceptions for Shafts for Sign, Signal, Lighting and ITS Structures: Ensure the depth of sedimentary deposits or other debris does not exceed 1 inch over the bottom of the shaft when installing drilled shafts to support sign, signal, lighting and ITS structures.

455-15.11.5 Time of Excavation: Overream the sidewalls of any unclassified excavation work using mineral slurry lasting more than 36 hours (measured from the beginning of excavation for all methods except the Temporary or Permanent Casing Method, which begins at the time excavation begins below the casing) before placement of the concrete. Ensure that the minimum depth of overreaming the shaft sidewall is 1/2 inch and the maximum depth is 3 inches. Provide any overreaming required at no expense to the Department when exceeding the 36 hour limit unless the time limit is exceeded to accomplish excavating deeper than the elevation shown in the Plans as ordered by the Engineer. The Department will pay the Contractor for authorized overreaming when excavating deeper than the elevation shown in the Plans as ordered by the Engineer exceeds the 36 hour time limit as Extra Work.

When using mineral slurry, adjust excavation operations so that the maximum time that slurry is in contact with the bottom 5 feet of the shaft (from time of drilling to concreting) does not exceed 12 hours. If exceeding the 12 hour time limit, overream the shaft socket or the full shaft when socket is not specified, at no additional expense to the Department prior to performing other operations in the shaft.

455-16 Reinforcing Steel Construction and Placement.

455-16.1 Cage Construction and Placement: Completely assemble and place as a unit the cage of reinforcing steel, consisting of longitudinal bars, ties, and cage stiffener bars, immediately after the Engineer inspects and accepts the shaft excavation and immediately prior to placing concrete. Tie all intersections of drilled shaft reinforcing steel with cross ties or "figure 8" ties. Use double strand ties, ties with larger tie wire, U-bolts, or similar when necessary. The Engineer will give final approval of the cage construction and placement subject to satisfactory performance in the field.

455-16.2 Splicing Cage: If the bottom of the constructed shaft elevation is lower than the bottom of the shaft elevation in the Plans, extend a minimum of one half of the longitudinal bars

required in the upper portion of the shaft the additional length. Continue the tie bars for the extra depth, spaced on 2 foot centers, and extend the stiffener bars to the final depth. The Contractor may lap splice these bars or use unspliced bars of the proper length. Do not weld bars to the planned reinforcing steel unless shown in the Contract Documents.

For drilled shafts supporting sign, signal, lighting and ITS structures, if the shaft cleaning operations result in excavating below the required tip elevation, the reinforcing steel cage does not need to be extended. The reinforcing steel cage may be spliced to rest on the bottom of the excavation or suspended in place from the top.

455-16.3 Support, Alignment, and Tolerance: Tie and support the reinforcing steel in the shaft so that the reinforcing steel will remain within allowable tolerances as specified in 455-20 and Section 415.

Ensure concentric spacing for the entire length of the cage. As a minimum, use centering devices consisting of wheels or other approved noncorrosive spacing devices within 3 feet of the bottom, within 6 feet of the top, and intervals not exceeding 10 feet along the cage length. Do not use block or wire type spacers. Ensure no permanent metallic elements will be within the concrete cover space. Use a minimum of one spacer per 30 inches of circumference of cage with a minimum of four at each level. Provide spacers at the bottom of the drilled shaft reinforcing cage as required to maintain the proper position of the cage.

For shafts to support sign, signal, lighting and ITS structures, when a casing with an inside diameter (I.D.) larger than the required shaft diameter is used, provide, within the portion of the oversized casing, centering devices specially dimensioned or other means to ensure the shaft, the cage and the upright are concentric. Provide spacers within 3 feet of the bottom and at intervals not exceeding 10 feet along the reinforcement, with a minimum of two levels of spacers below the bottom of the casing.

Check the elevation of the top of the steel cage before and after placing the concrete. If the cage is not within the specified tolerances, correct, and submit a revised DSIP to the Engineer for approval. Do not construct additional shafts until receiving approval from the Engineer.

455-16.4 Nondestructive Integrity Testing Access Tubes: Install access tubes full length in all drilled shafts from the tip of shaft to a point high enough above top of shaft to allow thermal integrity testing for drilled shafts (TITDS) and cross-hole sonic logging (CSL) testing, but not less than 30 inches above the top of the drilled shaft, ground surface or water surface, whichever is higher. Equally space tubes around circumference of drilled shaft. Securely tie access tubes to the inside of the reinforcing cage and align tubes to be parallel to the vertical axis of the center of the cage. Access tubes from the top of the reinforcing cage to the tip of the shaft shall be NPS 1-1/2 Schedule 40 black iron or black steel (not galvanized) pipe. Access tubes above the top of the reinforcing cage may be the same black iron or black steel pipe or Schedule 40 PVC pipe. Ensure that the access tubes are free from loose rust, scale, dirt, paint, oil and other foreign material. Couple tubes as required with threaded couplers, such that inside of tube remains flush. Seal the bottom and top of the tubes with threaded caps. The tubes, joints and bottom caps shall be watertight. Seal the top of the tubes with lubricated, threaded caps sufficient to prevent the intrusion of foreign materials. Stiffen the cage sufficiently to prevent damage or misalignment of access tubes during the lifting and installation of the cage. Exercise care in removing the caps from the top of the tubes after installation so as not to apply excess torque, hammering or other stress which could break the bond between the tubes and the concrete.

Provide the following number (rounded up to the next whole number of tubes) and configuration of access tubes in each drilled shaft based on the diameter of the shaft.

Table 455-6		
Shaft Diameter	Number of Tubes Required	Configuration around the inside of Circular Reinforcing Cage
36 to 48 inches	4	90 degrees apart
Greater than 48 inches	1 tube per foot of Shaft Diameter	360 degrees divided by the Number of Tubes

Insert simulated or mock probes in each access tube prior to concreting to ensure the serviceability of the tube. Fill access tubes with clean potable water and recap prior to concreting. Repair or replace any leaking, misaligned or unserviceable tubes as in a manner acceptable to the Engineer prior to concreting.

For method shafts for bridge foundations, in addition to the access tubes, provide embedded thermal wires equally spaced around the reinforcing cage.

For drilled shaft foundations requiring anchor bolts, verify access tubes will not interfere with anchor bolt installation before excavating the shaft. When access tube locations conflict with anchor bolt locations, move the access tube location plus or minus 2 inches along the inner circumference of the reinforcing cage. Notify the Engineer before excavating the shaft if the access tube locations cannot be moved out of conflict with anchor bolt locations.

For drilled shafts supporting sign, signal, lighting and ITS structures, if the shaft cleaning operations result in excavating below the required tip elevation, the access tubes do not need to be extended. If the reinforcing steel cage is suspended in place from the top rather than resting on the bottom of the excavation, clearly mark the top of shaft location on each tube.

When called for in the Contract Documents, provide embedded thermal wires and equipment to allow TITDS in accordance with ASTM D7949 Method B.

455-17 Concrete Placement.

455-17.1 General: Place concrete in accordance with the applicable portions of Sections 346 and 400, 455-15.2, 455-15.3, 455-15.4, 455-15.5, 455-15.8, 455-15.9, and the requirements herein.

Place concrete as soon as possible after completing all excavation, cleaning the shaft excavation, inspecting and finding it satisfactory, and immediately after placing reinforcing steel. Continuously place concrete in the shaft to the top of the casing. Continue placing concrete after the casing is full until good quality concrete is evident at the top of the casing. Place concrete through a tremie or concrete pump using approved methods. After the shaft is overpoured sufficiently to eliminate all contaminated concrete, additional concrete may be added to the shaft without the use of a tremie or pump in accordance with Section 400.

If the pressure head is lost during concrete placement for any reason, the Engineer may direct the Contractor to perform integrity testing at no expense to the Department.

Immediately after concreting, check the water levels in the CSL access tubes and refill as necessary. If tubes become unserviceable, core new holes in the drilled shaft as directed by the Engineer.

455-17.2 Placement Time Requirements: The elapsed time for placing drilled shaft concrete includes the concrete mixing and transit time, the concrete placement time, the time

required to remove any temporary casing that causes or could cause the concrete to flow into the space previously occupied by the casing, and the time to insert any required column steel, bolts, weldments, etc. The elapsed time begins at the time the first truck load placed in the shaft is batched. Maintain a minimum slump of 5 inches throughout the elapsed time. Use materials to produce and maintain the required slump through the elapsed time that meets the class of concrete specified. Provide slump loss tests that demonstrate to the Engineer that the concrete will maintain a 5 inch or greater slump for the anticipated elapsed time before beginning drilled shaft construction.

455-17.3 Forms: When the top of shaft elevation is above ground or above water, form the portion of the shaft above ground and the portion of the shaft above water with a removable form or another approved method to the dimensions shown in the Plans except when the Permanent Casing Method is specified.

455-17.4 Riser Blocks: The Contractor may cast a riser block of equal diameter as the column and of a maximum height of 6 inches at the top of the completed shaft. When this option is chosen, extend any dowel steel above the top of shaft an additional 6 inches.

455-17.5 Curing: Cure the top surface in accordance with the applicable provisions of Section 400, and construct any construction joint area as shown in the Plans. Protect portions of drilled shafts exposed to a body of water from the action of water by leaving the forms in place for a minimum of seven days after casting the concrete. The Contractor may remove forms prior to seven days provided the concrete strength has reached 2,500 psi or greater as evidenced by cylinder breaks.

455-17.6 Non-Destructive Testing of Drilled Shaft Integrity:

455-17.6.1 Thermal Integrity Testing for Drilled Shafts (TITDS): Perform all TITDS in accordance with ASTM D7949-14, which details two alternative procedures:

Method A: uses a thermal probe lowered into access ducts installed in the deep foundation element during construction.

Method B: uses multiple embedded thermal sensors attached to the reinforcing cage installed in the deep foundation element during construction.

Test method shafts, load test shafts, and all drilled shafts in bridge bents or piers considered nonredundant in the Plans, using TITDS. For all other drilled shafts, perform TITDS only on drilled shafts selected by the Engineer. The minimum number of shafts tested is the number of shafts indicated in the Plans. The Engineer may increase the number of shafts tested as deemed necessary.

Engage a qualified Specialty Engineer to supervise the TITDS. The qualified TITDS Specialty Engineer must have a minimum of six months experience of TITDS, have a Florida Licensed Professional Engineer and supervise the collection and interpretation of data. The individual performing the TITDS in the field must work for the Specialty Engineer firm and have a minimum of six months' experience of TITDS. The Contractor shall provide all necessary assistance to the TITDS Specialty Engineer to satisfactorily perform the testing.

After acceptance of production shafts by the Engineer, remove all water from the access tubes or core holes and fill the tubes or core holes with a structural non-shrink grout meeting the requirements of Section 934 from the bottom via tremie tube. Place the grout utilizing enough pressure to fill the tubes or core holes completely.

If the Contractor determines at any time during the non-destructive testing and evaluation of the drilled shaft that the drilled shaft should be replaced, no further testing or evaluation of that shaft is required.

455-17.6.1.1 Equipment: Furnish TITDS test equipment in accordance with ASTM D7949-14 as follows:

1. Provide thermal probes with four orthogonally oriented infrared sensors able to be used in 1-1/2 inch I.D. pipes.
2. Provide a computer based TITDS data acquisition system for display of signals during data acquisition.
3. Provide a depth encoder sensor to determine probe depths.
4. Provide an air compressor and power supply with sufficient pressure to air lift the water from the access tubes.

455-17.6.1.2 Procedure: For non-bridge structures, perform TITDS testing between the minimum and maximum times shown below after the batching time of the first truck load placed in the drilled shaft, unless otherwise directed by the Engineer.

Table 455-7

Shaft Diameter (inches)	Minimum time (hours)	Maximum time (hours)
36 - 48	24	54
49 - 60	24	72
61 - 72	24	72
73 - 84	24	90
85 - 120	24	108

The Contractor may propose modifications in the above table for site specific and special concrete mix conditions, as demonstrated from lab and field testing and instrumentation. The Engineer must approve all changes to the testing times prior to the Contractor using them.

For bridges, prior to production drilled shaft and load test drilled shaft installation, perform TITDS in accordance with ASTM D7949-14 Method B to determine the temperature variability and time to peak temperature for each project specific concrete mix. Obtain temperature measurements at least every 15 minutes during curing on the method shafts. Submit the TITDS results within three working days of performing the tests, in accordance with 455-17, including the proposed temperature peak time established from the TITDS. The Engineer will review the results of the test and concur with the proposed peak time or revise it. After the peak time is established for each mix, perform TITDS in accordance with ASTM D7949-14 Method A on production drilled shafts and load test shafts, within the following times after batching the first truck:

$$\text{Minimum time (hours)} = \text{Peak time (hours)} - 8$$

$$\text{Maximum time (hours)} = \text{Peak time (hours)} + 4D$$

Where:

D = Drilled shaft diameter in feet.

Peak time: Time after batching the first truck load that was placed in the drilled shaft, at which the maximum temperature is observed.

Furnish information regarding the shaft, tube lengths and depths, construction dates, and other pertinent shaft installation observations and details to the

Department at the time of testing. Verify access tube lengths and their condition in the presence of the Department, at the end of concrete placement. If the access tubes do not provide access over the full length of the shaft, repair the existing tube(s) or core additional hole(s), as directed by the Engineer, at no additional cost to the Department.

Just prior to inserting the thermal probe, remove water from the access tubes. Store the removed water in an insulated container for later replacement. Allow the thermal probe to acclimate in accordance with the equipment manufacturer recommendations. Continuously record temperatures at depth intervals of 3.0 inches or less from the top to the bottom of each access tube. Repeat the test at each access tube until two sets of data from the same access tube provide similar results. Return the warm water to the access tubes immediately after the testing has been completed.

Immediately report any potential defects indicated by low temperature anomalies to the Engineer.

455-17.6.1.3 Required TITDS Reports: Submit the TITDS data and analysis results to the Engineer in a signed and sealed report, together with all electronic data, within three working days of testing. The report shall include as minimum the following items:

1. Graphs displaying all temperature measurements and average temperature versus depth.
2. Indication of unusual temperatures, including cooler local deviations from the average at any depth from the overall average over the entire length.
3. A graph displaying the average temperature and theoretical temperature versus depth.
4. Variations in temperature between access tubes which may indicate variations in cage alignment.
5. When ASTM D7949-14 method B is used, include a chart indicating the variability of temperature vs. time, for all wires and the average. Submit the peak time in hours for the average temperature of the wires.
6. The calculated radius of the shaft throughout the entire depth.
7. Calculated concrete cover throughout the entire depth.
8. Shaft Details, Probe Details, Environmental Details, Tube Run Selection and Shaft Adjustment Data that show the measurements, inputs, and adjustments to the data. Screen captures of these pages from the TIP Reporter software will be acceptable.
9. A conclusion stating whether the tested shaft is free from integrity defects, meets the minimum concrete cover and diameter requirements by the specifications and the cage is properly aligned. When anomalies are detected, include in the report a three-dimensional rendering of the shape of the shaft.

455-17.6.1.4 Evaluation of TITDS Test Results: The Engineer will evaluate the observations during drilled shaft construction and TITDS results to determine whether or not the drilled shaft construction is acceptable. Drilled shafts not meeting the minimum cover and diameter requirements, or having integrity defects, are not acceptable without an engineering analysis.

455-17.6.1.5 Coring and/or Repair of Drilled Shafts: If the Engineer determines a drilled shaft is unacceptable based on the TITDS tests and other testing, or observes problems during drilled shaft construction, core the shaft to allow further evaluation and repair, or replace the shaft as directed by the Engineer. If coring to allow further evaluation of the shaft and repair is chosen, one or more core samples shall be taken from each unacceptable shaft for

full depth of the shaft or to the depth directed by the Engineer. The Engineer will determine the number, location, and diameter of the cores based on the results of the TITDS. Keep an accurate log of cores. Properly mark and place the cores in a crate showing the shaft depth at each interval of core recovery. Submit the coring log and transport the cores to the location designated by the Engineer. Perform strength testing by an AASHTO certified lab on portions of the cores as required by the Engineer. If the TITDS and coring indicate the shaft is defective, propose remedial measures for approval by the Engineer. Such improvement may consist of but is not limited to correcting defective portions of the shaft, providing straddle shafts to compensate for capacity loss, or providing a replacement shaft. Repair all detected defects and conduct post repair integrity testing using horizontal and offset CSL testing and 3-D tomographic imaging as described in 455-17.6.2. Engage a Specialty Engineer to perform gamma-gamma density logging calibrated to 1-1/2 inch black iron access tubes, prior to and after the repair is performed, to verify the integrity of the shaft outside the reinforcing cage in the same locations where the repair was required. When straddle shafts or replacement shafts are used to correct a deficient foundation, perform TITDS in accordance with 455-17.6.1 through 455-17.6.3 to verify integrity of these shafts. Submit all results to the Engineer within five days of test completion for approval. Perform all work described in this subarticle at no additional cost to the Department, and with no increase in Contract Time.

455-17.6.2 Cross Hole Sonic Logging (CSL) and Tomography: When required by the Engineer, perform CSL testing in accordance with ASTM D6760 within 25 days of completion of the shaft. Engage a qualified Specialty Engineer to perform the CSL testing. The qualified CSL Specialty Engineer must be a Professional Engineer in the State of Florida and have a minimum of six months' experience of CSL testing, supervising the collection of CSL data and interpretation of CSL results. The individual performing the CSL testing in the field must work for the Specialty Engineer firm and have a minimum of six months' experience of CSL testing. The Contractor shall provide all necessary access and assistance to the CSL Specialty Engineer to satisfactorily perform the testing.

When a shaft contains four tubes, test every possible tube combination. For shafts with five or more tubes, test all pairs of adjacent tubes around the perimeter, and one-half of the remaining number of tube combinations, as chosen by the Engineer. Pull the probes simultaneously, starting from the bottoms of the tubes, over an electronic depth measuring device. Perform the CSL tests with the source and receiver probes in the same horizontal plane. Continuously record CSL signals at depth intervals of 2-1/2 inches or less from the bottom of the tubes to the top of each shaft. Remove all slack from the cables prior to pulling to provide accurate depth measurements in the CSL records. When the measurements indicate a 30% or greater reduction in velocity between one or more pairs, take one or two concrete cores to allow further evaluation and repair, or replace the shaft as directed by the Engineer. Determine the location of the concrete cores by performing 3D tomographic analysis using the CSL measurements. The core depths shall be at least 5 feet deeper than the bottom of the anomaly determined by the 3D tomography analysis or full depth if the anomaly is within 5 feet of the bottom of the shaft. The Engineer may accept a drilled shaft without concrete cores if an Engineering Analysis Report (EAR) demonstrates that the anomaly does not affect the structural and the geotechnical axial capacity, the structural and geotechnical lateral stability, the settlement behavior of the shaft, and that the anomaly will not impact the durability of the foundation.

When repairs are done, perform CSL measurements in all tube pair combinations with the source and receiver running at the same horizonal plane and at the vertical offsets of 45 degrees above and below. Perform all measurements including the offset measurements from the point where the higher probe is at least 5 feet below the lower limit of the repaired zone to the point where the lower probe is at least 5 feet above the upper limit of the repaired zone. Offset measurements must be as follows: plus 45 degrees (source below receiver) and minus 45 degrees (source above receiver). Use the measurements of these two offsets in combination with the horizontal measurements to perform the 3D tomography. Provide the CSL measurements, CSL logs and 3D tomographic analysis at no additional cost to the Department.

After acceptance of production shafts by the Engineer, fill the tubes or core holes with a structural non-shrink grout in accordance with 455-17.6.1.

If the Contractor determines at any time during the non-destructive testing and evaluation of the drilled shaft that the drilled shaft should be replaced, no further testing or evaluation of that shaft is required.

455-17.6.2.1 Required CSL Reports: Present the CSL data and analysis results to the Engineer in a signed and sealed report. Include CSL logs with analyses of first pulse arrival time (FAT) versus depth and pulse energy/amplitude versus depth. Present a CSL log for each tube pair tested with any defect zones identified on the logs and discussed in the test report as appropriate. When offset measurements are required, perform 3D tomographic analysis using all offset data, and include color coded 3D tomographic images in the report.

455-17.6.2.2 Evaluation of Cross Hole Sonic logging Testing: The Engineer will evaluate the observations during drilled shaft construction and the CSL test results to determine whether or not the drilled shaft construction is acceptable. Drilled shafts with velocity reduction exceeding 30% are not acceptable without an engineering analysis.

455-17.6.2.3 Coring and/or Repair of Drilled Shafts: If the Engineer determines a drilled shaft is unacceptable based on the CSL test and other testing, core the shaft to allow further evaluation and repair, or replace the shaft in accordance with 455-17.6.1.5.

If repairs are performed or additional shafts installed to correct a deficient foundation, conduct integrity testing and submit the results to the Engineer in accordance with 455-17.6.1.5.

455-18 Method Shafts.

The Engineer will use the construction of method shafts (test holes) to determine if the methods and equipment used by the Contractor are sufficient to produce a shaft excavation meeting the requirements of the Contract Documents. During method shaft excavations, the Engineer will evaluate the ability to control dimensions and alignment of excavations within tolerances; to seal the casing into impervious materials; to control the size of the excavation under caving conditions by the use of slurry or by other means; to properly clean the completed shaft excavation; to construct excavations in open water areas; to determine the elevation of ground water; to place reinforcing steel and concrete meeting the requirements of these Specifications within the prescribed time frame; and to execute any other necessary construction operation. Revise the methods and equipment as necessary at any time during the construction of the method shaft when unable to satisfactorily carry out any of the necessary operations described above or when unable to control the dimensions and alignment of the shaft excavation within tolerances.

Construct method shafts out of permanent position at the location shown in the Plans or as directed by the Engineer. Ensure the diameter and depth of the method shaft or holes are the

same diameter and maximum depth as the production drilled shafts. Reinforce the method shaft unless otherwise directed in the Contract Documents. Fill the method shaft with concrete in the same manner production drilled shafts will be constructed. Backfill method shaft which are not filled with concrete with suitable soil in a manner satisfactory to the Engineer. Leave concreted method shaft in place, except remove the top of the shaft to a depth of 2 feet below the finished graded surface. Use the same procedure for shafts constructed in water. Restore the disturbed areas at the sites of method shaft drilled out of position as nearly as practical to their original condition. When the Contractor fails to demonstrate to the Engineer the adequacy of his methods or equipment, and alterations are required, make appropriate modifications and provide additional test holes at no expense to the Department. Include the cost of all method shaft in the cost of the drilled shafts. Make no changes in methods or equipment after initial approval without the consent of the Engineer.

A separate method shaft is not required for drilled shafts installed under sign, signal, lighting and ITS structures. The first production shaft will serve as a method shaft for determining acceptability of the installation method.

455-19 Test Bells.

Test bells are no longer used.

455-20 Construction Tolerances.

Meet the following construction tolerances for drilled shafts:

1. Ensure that the top of the drilled shaft is no more than 3 inches laterally in the X or Y coordinate from the position indicated in the Plans.

2. Ensure that the vertical alignment of the shaft excavation does not vary from the alignment shown in the Plans by more than 1/4 inches per foot of depth.

3. After placing all the concrete, ensure that the top of the reinforcing steel cage is no more than 6 inches above and no more than 3 inches below plan position.

4. Ensure that the reinforcing cage is concentric with the shaft within a tolerance of 1-1/2 inches. Ensure that the horizontal concrete cover is a minimum of 4-1/2 inches unless shown otherwise in the Plans.

5. Ensure that the minimum diameter of the drilled shaft is not smaller than the specified shaft diameter minus 1 inch. All casing diameters shown in the Plans refer to I.D. (inside diameter) dimensions. However, the Contractor may use casing with an outside diameter equal to the specified shaft diameter if the extra length described in 455-15.7 is provided. In this case, ensure that the I.D. of the casing is not smaller than the specified shaft diameter minus 1 inch. When approved, the Contractor may elect to provide a casing larger in diameter than shown in the Plans to facilitate meeting this requirement. When conditions are such that a series of telescoping casings are used, provide the casing sized to maintain the minimum shaft diameters listed above.

6. Except when abutting or encroaching within a sidewalk, ensure that the top elevation of the drilled shaft concrete has a tolerance of plus 1 inch and minus 3 inches from the top of shaft elevation shown in the Plans.

7. When abutting or encroaching within a sidewalk, ensure that the top elevation of the drilled shaft is flush with the sidewalk surface.

8. The dimensions of casings are subject to American Petroleum Institute tolerances applicable to regular steel pipe.

9. Use excavation equipment and methods designed so that the completed shaft excavation will have a flat bottom. Ensure that the cutting edges of excavation equipment are normal to the vertical axis of the equipment within a tolerance of plus or minus 3/8 inches per foot of diameter.

455-21 Drilled Shaft Excavations Constructed out of Tolerance.

Do not construct drilled shaft excavations in such a manner that the concrete shaft cannot be completed within the required tolerances. The Contractor may make corrections to an unacceptable drilled shaft excavation by any combination of the following methods:

1. Overdrilling the shaft excavation to a larger diameter to permit accurate placement of the reinforcing steel cage with the required minimum concrete cover.
2. Increasing the number and/or size of the steel reinforcement bars.

When the tolerances are not met, the Contractor may propose a redesign to incorporate shafts installed out of tolerance into caps or footings. Incorporate shafts installed out of tolerance at no expense to the Department. Ensure the Contractor's Engineer of Record performs any redesign and signs and seals the redesign drawings and computations. Do not begin any proposed construction until the redesign has been reviewed and approved by the Engineer.

Backfill any out of tolerance shafts in an approved manner when directed by the Engineer until the redesign is complete and approved. Furnish additional materials and work necessary, including engineering analysis and redesign, to effect corrections of out of tolerance drilled shaft excavations at no expense to the Department.

455-22 Load Tests.

When the Plans include load testing, perform all load tests in accordance with 455-2 or as shown in the Contract Documents.

455-23 Method of Measurement.

455-23.1 Drilled Shafts: The quantity to be paid for will be the length, in feet, of the reinforced concrete drilled shaft of the diameter shown in the Plans, completed and accepted. The length will be determined as the difference between the top of shaft elevation as shown in the Plans and the final bottom of shaft elevation as authorized and accepted. When the Contractor elects to provide outside diameter (O.D.) sized casing rather than inside diameter (I.D.) sized casing as allowed in 455-15.7, the pay quantity measured as described above will be multiplied by a factor (F) determined as follows:

$$F = \frac{2D_2 - D_1}{D_2}$$

where:

F= factor to adjust pay quantities to compensate for smaller shafts.

D_1= casing inside diameter specified = shaft diameter specified.

D_2= casing inside diameter provided ($D_2 = D_1$ minus twice the wall thickness).

455-23.2 Drilled Shafts (Unreinforced): The quantity to be paid for will be the length, in feet, of unreinforced concrete drilled shaft of the diameters shown in the Plans, completed and accepted. The length will be determined as the difference between the top of shaft elevation as

shown in the Plans and the final bottom of shaft elevation as authorized and accepted. When the Contractor elects to use O.D. casing, the quantity as determined above will be multiplied by the factor "F" determined as described in 455-23.1.

455-23.3 Unclassified Shaft Excavation: The quantity to be paid for will be the length, in feet, of unclassified shaft excavation of the diameter shown in the Plans, completed and accepted, measured along the centerline of the shaft from the ground surface elevation after any required excavation per 455-1.2 to the plan bottom of shaft elevation authorized and accepted plus up to 15 feet or 3 shaft diameters, whichever is deeper, of additional excavation as authorized by the Engineer. When drilled shafts are constructed through fills placed by the Contractor, the existing surface will be used to determine the quantity of unclassified shaft excavation. When the Contractor elects to use O.D. casing, the quantity as determined above will be multiplied by the factor "F" determined as described in 455-23.1.

455-23.4 Unclassified Extra Depth Excavation: When excavation is required by the Engineer to extend more than 15 feet or 3 shaft diameters, whichever is deeper, below the bottom of the shaft elevation shown in the Plans, the work will be considered as Unforeseeable Work.

455-23.5 Method Shafts: The cost of all method shafts will be included in the cost of drilled shafts.

455-23.6 Core (Shaft Excavation): The quantity to be paid for will be the length, in feet, measured from the bottom of shaft elevation to the bottom of the core-hole, for each authorized core drilled below the shaft excavation, completed and accepted. When the Engineer authorizes pilot holes extending through part or all of the shaft, prior to excavation, to some depth below the shaft bottom, the quantity paid as core (shaft excavation) will be the length in feet, measured from the top elevation to the bottom elevation authorized by the Engineer, completed and accepted. When SPT tests are substituted for coring or pilot holes as provided in 455-15.6, the quantity will be determined as described above in this Section.

455-23.7 Casings: The quantity to be paid for will be the length, in feet, of each size casing as directed and authorized to be used. The length will be measured along the casing from the top of the shaft elevation or the top of casing whichever is lower to the bottom of the casing at each shaft location where casing is authorized and used, except as described below when the top of casing elevation is shown in the Plans. Casing will be paid for only when the Permanent Casing Method is specified, when the Plans show a casing that becomes a permanent part of the shaft, or when the Engineer directs the Contractor to leave a casing in place which then becomes a permanent part of the shaft. No payment will be made for casings which become bound or fouled during shaft construction and cannot be practically removed. The Contractor shall include the cost of all temporary removable casings for methods of construction other than that of the Permanent Casing Method in the bid price for unclassified shaft excavation item.

When the Permanent Casing Method and the top of casing elevation are specified, the casing will be continuous from top to bottom. Authorization for temporary casing will not be given unless the Contractor demonstrates that he can maintain alignment of the temporary upper casing with the lower casing to be left in place during excavation and concreting operations. When artesian conditions are or may be encountered, the Contractor shall also demonstrate that he can maintain a positive water-tight seal between the two casings during excavation and concreting operations.

When the top of casing elevation is shown in the Contract Documents, payment will be from the elevation shown in the Plans or from the actual top of casing elevation, whichever is lower, to the bottom of the casing. When the Contractor elects to use an approved

special temporary casing system in open water locations, the length to be paid for will be measured as a single casing as provided above.

455-23.8 Load Tests: The quantity to be paid for will be the number and type of load tests conducted.

455-23.9 Instrumentation and Data Collection: The quantity to be paid for will be at the lump sum price.

455-23.10 Thermal Integrity Testing for Drilled Shafts and Cross-Hole Sonic Logging: The quantity of the TITDS to be paid for will be the number of drilled shafts accepted based on TITDS tests. When TITDS is not performed in accordance with 455-17.6.1, perform CSL testing at no cost to the Department. No payment will be made for any integrity testing when such testing indicates the shaft cannot be accepted based on the integrity testing itself. No payment will be made for integrity testing performed to evaluate the integrity of post-repair work or for CSL testing not requested by the Engineer. When the Engineer requests CSL tests and the results indicate the shaft is acceptable, the testing will be paid as unforeseen work.

455-24 Basis of Payment.

455-24.1 Drilled Shafts: Price and payment will be full compensation for all drilled shafts, including the cost of concrete, reinforcing steel, nondestructive integrity testing access tubes, embedded thermal wires when required by the Contract Documents, and including all labor, materials, equipment, and incidentals necessary to complete the drilled shaft. The cost of the reinforcing steel, including lap lengths, to accommodate shaft lengths longer than shown in the Plans is included in the cost of drilled shafts. Costs associated with repairing defects found in the drilled shaft shall be included in the cost of the drilled shaft.

455-24.2 Drilled Shafts (Unreinforced): Price and payment will be full compensation for all drilled shafts (unreinforced), including the cost of concrete and all labor, equipment, materials, and incidentals necessary to complete the drilled shaft.

455-24.3 Unclassified Shaft Excavation: Price and payment will be full compensation for the shaft excavation (except for the additional costs included under the associated pay items for casing); removal from the site and disposal of excavated materials; restoring the site as required; cleaning and inspecting shaft excavations; using slurry as necessary; using drilling equipment; blasting procedures, special tools and special drilling equipment to excavate the shaft to the depth indicated in the Plans; and furnishing all other labor, materials, and equipment necessary to complete the work in an acceptable manner.

455-24.4 Method Shafts: No separate payment will be made for method shafts (test holes). All cost of method shafts will be included in the cost of drilled shafts.

455-24.5 Core (Shaft Excavation): Price and payment will be full compensation for drilling and classifying the cores/pilot hole, delivering them to the Department, furnishing drilled shaft concrete to fill the core/pilot hole, and all other expenses necessary to complete the work. When SPT tests are substituted for cores/pilot holes as provided in 455-15.6, they will be paid for at the price per foot for coring.

455-24.6 Casings: Price and payment will be full compensation for additional costs necessary for furnishing and placing the permanent casing in the shaft excavation above the costs attributable to the work paid for under associated pay items for unclassified shaft excavation.

455-24.7 Load Tests: Price and payment will include all labor, equipment, materials and incidentals required to perform this work, including instrumentation, data collection and professional services to prepare the report.

455-24.8 Thermal Integrity Testing for Drilled Shafts and Cross-Hole Sonic Logging: Price and payment will include all costs related to the performance of the TITDS and CSL testing and incidentals to the thermal integrity and cross-hole sonic tests.

455-24.9 Payment Items: Payment will be made under:

Item No. 455- 88-	Drilled Shaft - per foot.
Item No. 455-107-	Casing - per foot.
Item No. 455-111-	Core (Shaft Excavation) - per foot.
Item No. 455-119-	Test Loads - each.
Item No. 455-122-	Unclassified Shaft Excavation - per foot.
Item No. 455-147-	Thermal Integrity Testing for Drilled Shafts - each

D. SPREAD FOOTINGS

455-25 Description.

Construct reinforced concrete spread footing foundations, including dewatering when necessary, excavating to the required limits, compacting the underlying soil as required, and constructing seals when required.

455-26 General Requirements.

Meet the following requirements for all spread footings:

1. Perform excavations, including the removal of all material, of whatever nature, necessary for the construction of spread footings. As used herein, the term “soil” shall constitute any material, whether soil, rock, or other materials.

2. Slope excavations as required, or support them with sheeting, and shore them if necessary, to provide a safe excavation that is adequate for construction purposes and that will adequately protect any existing adjacent structures.

3. Ensure that the foundation soils are firm, stable, and, in the opinion of the Engineer, meet or exceed the design bearing and compressibility requirements before constructing the footings or any required seals. The Department may elect to use any type of tests to evaluate the foundation soils that is appropriate in the opinion of the Engineer. Cooperate with the Engineer in the evaluation of the foundation soils, and assist the Engineer as necessary to provide access to the site.

4. The elevation of the bottom of footings or seals and/or the depth of over-excavation shown in the Plans is approximate and the Engineer may order, in writing, such changes as may be necessary to secure a satisfactory foundation.

5. Place all spread footing concrete in the dry.

455-27 Monitor Existing Structures.

Monitor existing structures in accordance with Section 108.

455-28 Dewatering.

The Contractor is responsible for the design, installation, and operation of an adequate dewatering system to dewater excavations for spread footings. Use a well point or well system. Submit a dewatering plan to the Engineer for his records before beginning construction.

Use well points or wells where the piezometric water level is above an elevation 3 feet below the bottom of the excavation. Maintain the water table 3 feet or more below the maximum depth of excavation. Provide continuous dewatering until completing construction of the footing and backfill the excavation at least 3 feet above the piezometric water table elevation. Continue

dewatering until the Engineer considers conditions safe to discontinue dewatering. In the event of a dewatering failure, assist the Engineer as required in determining the effects of such a failure on the foundation soils, and take whatever corrective measures are required at no additional expense to the Department. When the Engineer approves the discontinuing of dewatering, decrease the rate of pumping, allowing the water level to rise slowly. Use a rate, in feet per hour, that the water table is allowed to rise equal to the total number of feet the water table was lowered, divided by ten hours or a rate of 1 foot per hour, whichever is less.

Install one piezometer well approximately every 15 feet of footing perimeter. Provide a minimum of two and a maximum of six piezometers at locations within 2 feet from the outside of the footing perimeter. Install piezometer wells to a depth at least 10 feet below the bottom of footing elevation or as directed by the Engineer. Measure water elevation in the piezometer wells prior to excavation and at 12-hour intervals between excavation and discontinuation of dewatering. Maintain the piezometers in working condition throughout the dewatering process, and repair or replace them when damaged at no expense to the Department.

455-29 Excavations:

If the excavation must be carried deeper than shown in the Plans to obtain a satisfactory foundation, the Engineer will revise the Plans in accordance with the following:

1. When the change in bottom elevation of the footing is 12 inches or less, the Engineer will keep the top of the footing at the elevation shown in the original Plans and will increase the thickness to obtain a satisfactory foundation.

2. When the change in elevation of the bottom of footing exceeds 12 inches, the Engineer will revise the Plans and lower the footing, thereby increasing the height of stem, to obtain a satisfactory foundation. Generally, the Engineer will also increase the thickness and width of footing over that shown in the original Plans.

455-29.1 Dry Excavations: Dry excavations are excavations that can be completed without the need to lower the piezometric water level. Perform dry excavations when the piezometric water level at the time of construction is and, in the opinion of the Engineer, will remain at least 3 feet below the bottom of the authorized excavation or over-excavation. Demonstrate to the Engineer that a stable excavation can be made without dewatering. Make adequate provisions to divert surface runoff and to collect and remove any water entering the excavation.

Excavate to the bottom of footing, to the over-excavation limits shown in the Plans, or as directed by the Engineer. Save any suitable materials for backfill. Provide areas for the disposal of all unsuitable materials, and dispose of them in a satisfactory method. Compact the foundation soils below the footing as shown in the Plans or described herein before constructing the footing.

455-29.2 Dewatered Excavations: Dewatered excavations are excavations made after first lowering the piezometric water level with wellpoints or wells. Perform dewatering as described in 455-28. Excavate in the dry after lowering of the water table.

When dewatering is required, the Contractor may excavate within 3 feet of the ground water table before dewatering begins if the dewatering system is operating and the Contractor has demonstrated that the water level has been lowered to and maintained at acceptable limits. Where large excavations require stage lowering of the water table (additional wellpoint systems installed at lower elevations), the Contractor may continue excavating as long as the water elevation is maintained at least 3 feet below the excavation.

Ensure that surface runoff is diverted from the excavation. Compact the foundation soils as shown in the Plans or as described herein before constructing the footing.

455-29.3 Wet Excavations: Wet excavations are excavations made below the existing water table without prior dewatering. When the Plans show a cofferdam and seal, perform the excavation in the wet. Maintain the water level during excavation at or above the water level outside the cofferdam.

Place the seal directly upon the foundation soils or rock when using wet excavations. Do not compact foundation soils for wet excavations. Ensure that the foundation soils or rock are disturbed as little as practical. Remove all materials that are determined by the Engineer to be loose or disturbed before placing the seal concrete.

455-30 Fill or Backfill.

In all excavations, including over-excavations below the footing, use only fill or backfill materials considered Select in accordance with Standard Plans, Index 120-001. Ensure the material is free of rubble, debris, or rocks that would prevent uniform placement and compaction. Ensure the material below the top of the footing is free of Recycled Asphalt Pavement (RAP). Perform sampling and testing in accordance with 120-10.1.4, except replace FM 1-T99 with FM 1-T180.

455-31 Compaction and Density Requirements.

Compact the bottom of the excavation with suitable equipment. Compact the soil beneath footing excavation (whether dug to the bottom of footing or over-excavated) to a density not less than 95% of the maximum density as determined by FM 1-T180, for a minimum depth of 2 feet below the bottom of the excavation or to the depth shown in the Plans before backfilling begins. For every 500 feet of excavation or isolated compaction operation, perform two Quality Control (QC) density tests with a 12 inch depth of measurement: one QC density test with the gauge placed at an elevation of 1 foot below the bottom of the excavation and one QC density test with the gauge placed at the bottom of the excavation in accordance with FM 1-T310. Compact the backfill in footing excavations which have been over-excavated to a density not less than 95% of the maximum density as determined by FM 1-T180. Ensure that the maximum lift thickness after compaction does not exceed 6 inches. For every 500 feet of backfill or isolated compaction operation, perform at least one QC density test. The Engineer will conduct one density verification test per every 4 QC test, with a minimum of one density test below the bottom of the excavation and one density test in the backfill. Verification comparison criteria and resolution procedures will be in accordance with 120-10.4 except replace FM 1-T99 with FM 1-T180.

For compaction, use an approved heavy vibratory roller with a static drum weight of at least 4 tons. Compact each lift to the required density. Also, compact the final lift below the footing with a suitable sled vibratory compactor to remove any upper disturbance caused by the drum roller. When conditions require use of smaller compaction equipment, obtain the Engineer's approval for the equipment, and reduce the lift thickness to achieve the required density.

Perform backfilling to the existing surface or finished graded surface as required by the Plans in the immediate vicinity by approved mechanical compactors weighing less than 1,000 pounds. The Contractor may compact backfill located more than 15 feet away from the exterior periphery of the footing with heavier compactors. Do not place backfill on the footing until the Engineer has given permission and until the concrete is at least seven days old.

When the plans indicate spread footing abutments on mechanically stabilized earth (MSE) walls, place and compact the backfill material underneath the footing in accordance with the requirements of 548-8.5. Meet the density requirements of 548-9.4.

455-32 Forming.

Form spread footings if it cannot be demonstrated that the natural soil or rock is strong enough to prevent caving during construction. For forms, meet the applicable requirements of 400-5. When forms are not required, meet the requirements of 400-5.4.4.

455-33 Materials.

455-33.1 Concrete: Meet the requirements of Section 346.

455-33.2 Reinforcing Steel: Meet the requirements of Section 415. For spread footing reinforcing steel, use Grade 60.

455-34 Reinforcing Steel Placement.

Place and fasten reinforcing steel for footings according to the applicable provisions of 415-5.

455-35 Concrete Placement.

455-35.1 Placement: Place all footing concrete in the dry and according to the applicable provisions of Section 400. Do not construct joints in footings.

455-35.2 Finish: After placing and consolidating the concrete, strike-off the top surface to the grades shown in the Contract Documents, leaving the surface smooth and free of undesirable cavities and other defects. Do not provide a special finish unless the footing will be visible after construction, in which case, meet the applicable provisions of Section 400.

455-35.3 Curing: Provide continuous-moisture-curing for footings. For cover materials, use clean sand, sawdust, or other materials meeting the approval of the Engineer. Continuously wet the cover materials for a period of 72 hours.

455-36 Method of Measurement.

455-36.1 Dewatering: No separate payment will be made for dewatering.

455-36.2 Excavation: No separate payment will be made for backfill or will separate payment be made for excavation above bottom of footing elevation. The cost of this work will be included in the Contract unit price for concrete (substructure). For footings with excavation (over-excavation) below the bottom of the footing elevation shown in the Plans, the cost of this excavation, backfilling, and compaction will be included in the Contract unit price for excavation for structures. The pay quantity will be the volume in cubic yards bounded by vertical planes 12 inches outside of the limits of the footing and parallel thereto and extending from the bottom of the footing elevation to the authorized bottom of over-excavation or within the pay limits shown in the Plans. If the elevation of a footing as shown in the Plans is changed to a higher or lower elevation, the Engineer will not consider such change as a material change to the original Contract Documents, a waiver of any condition of the Contract, or an invalidation of any of the provisions of the Contract.

455-36.3 Reinforcing Steel: The quantity to be paid for will be the total weight, in pounds, determined as described in Section 415.

455-36.4 Concrete: The quantity to be paid for will be the volume of the classes shown in the Plans, in cubic yards, determined as described in Section 400.

455-37 Basis of Payment.

455-37.1 Dewatering: No separate payment will be made for dewatering of footing excavations, including installing, maintaining, and monitoring piezometer wells. Dewatering will be considered Unforeseeable Work when the Engineer determines that dewatering deeper than the requirements described in 455-28 is required.

455-37.2 Excavation: Price and payment will be full compensation for all work related to over-excavating below the bottom of footing elevation, backfill, and compaction as specified.

455-37.3 Reinforcing Steel: Price and payment will be full compensation for all work required to furnish and place the steel as shown in the Plans and as specified herein.

455-37.4 Concrete: Price and payment will be full compensation for all work required to construct footings and seals as shown in the Plans and described herein.

No separate payment will be made for sheeting and shoring required for excavation and footing construction except when a separate pay item for sheeting and shoring is included in the Plans. The cost of all work not specifically mentioned in the other footing items will be included in the price per cubic yard for substructure concrete.

455-37.5 Payment Items: Payment will be made under:

Item No. 125- 1-	Excavation for Structures - per cubic yard.
Item No. 400- 2-	Class II Concrete - per cubic yard.
Item No. 400- 3-	Class III Concrete - per cubic yard.
Item No. 400- 4-	Class IV Concrete - per cubic yard.
Item No. 415- 1-	Reinforcing Steel - per pound.

E. STRUCTURES (OTHER THAN BRIDGE) FOUNDATIONS-AUGER CAST PILES

455-38 Description.

Furnish and install auger cast piles (ACP), or augered cast-in-place (ACIP) piles, used for structural support, other than bridge foundations.

ACP piles are defined as a foundation made by rotating a hollow-stem auger into the ground to the required pile depth with sufficient crowd (downward thrust) to prevent mining of the soil. A fluid cement grout is injected through the auger shaft under continuous positive pressure as the auger is being withdrawn. A reinforcing steel cage, as specified, is inserted into the column of fluid grout following the completion of grout placement.

455-39 General Requirements.

455-39.1 Contractor's Operations: Submit an Auger Cast Pile Installation Plan in accordance with 455-47. Prior to the start of production piles, demonstrate to the satisfaction of the Engineer, the dependability of the equipment, techniques, and source of materials by construction of a demonstration pile.

455-39.2 Monitor Existing Structures: Monitor existing structures in accordance with Section 108.

455-40 Materials.

Meet the following material requirements:

Portland Cement and Blended Cement .....Section 921
Supplementary Cementitious Materials .....Section 929

Fine Aggregate (Sand)* .....Section 902
Admixtures.....Section 924
Water.....Section 923
Fluidifier** .....ASTM C937
Reinforcing Steel.....Section 415

* The Engineer will only permit Silica Sand except as provided in 902-5.2.3.
** The fluidifier shall not contain chlorides

455-41 Grout Mix Proportions.

Use a grout mix consisting of a mixture of cementitious materials, admixtures, sand and water. Proportion and mix to produce a grout capable of maintaining the solids in suspension without appreciable bleed water which may be pumped without difficulty and will fill open voids in the adjacent soils and rock. The grout mix may include a fluidifier, used in accordance with the manufacturer's technical representative. Proportion these materials to produce a hardened grout of the required strength.

455-42 Mixing and Pumping Cement Grout.

Meet the following requirements:

1. Only use pumping equipment approved by the Engineer in the preparation and handling of the grout. Before using the mixers, remove all oil or other rust inhibitors from the mixing drums, stirring mechanisms, and other portions of the equipment in contact with the grout.

2. Use a quantity of water and mixing time that will produce a homogenous grout having an efflux of not less than 21 seconds, when tested with a flow cone in accordance with ASTM D6449. Reject loads with efflux of less than 21 seconds. Notify the production facility to adjust the mix design. Calibrate the flow cone in accordance with ASTM D6449. Conduct the calibration initially before its first use and as directed by the Engineer, when there is a question of the flow cone's accuracy.

Technicians performing the efflux test must take the Auger Cast Pile course and pass the final examination to be qualified to test for any auger cast pile installations in the field. Assist the Engineer in verifying the technicians meet these requirements.

Conduct tests for efflux time at the beginning of each days grouting operation and as directed by the Engineer to ensure the specification requirements are met.

3. Mix the grout at least one minute. If agitated continuously, the grout may be held in the mixer or agitator for a period not exceeding 2.5 hours at grout temperatures below 70ºF; two hours for temperatures from 70°F to 100ºF. Do not place grout when its temperature exceeds 100ºF. If there is a lapse in the operation of grout injection, recirculate the grout through the pump, or through the mixer drum or agitator.

4. Use mixers capable of combining components into a thoroughly mixed and uniform mass, free from balls or lumps and capable of discharging the grout with a satisfactory degree of uniformity. The Engineer's approval of grout mixers and all other equipment will be contingent on proper performance during construction of the demonstration pile and subsequent production work.

5. Use a screen no larger than 3/4 inch mesh between the mixer and pump to remove large particles which might clog the injection system.

6. Use a positive displacement piston type grout pump equipped with a pressure gauge, capable of developing displacing pressures at the pump not less than 350 psi. The pump must be appropriately sized to the pile diameter. Provide a grout pressure gauge in clear view of the equipment operator. Provide a second pressure gauge near the drill rig where it can be observed by the Engineer.

7. Accurately monitor the volume and pressure of the grout flow. Test and calibrate the equipment during construction of the demonstration pile to demonstrate flow volume measurement accuracy of plus or minus 3% over the range of grouting pressures anticipated during this work. Provide a pump stroke counter in good working condition on the grout pump. Perform a calibration test of the pumping equipment, prior to construction of the demonstration piles, to determine the average volume of grout for every pump stroke, in accordance with FM 5-612. When the Contractor's installation procedure includes priming the grout pump, grouting lines or auger conduit after drilling the hole, perform a priming demonstration to determine the minimum number of pump strokes required to deliver fresh grout throughout the entire system and flow from the grout injection hole at the bottom of the auger. Perform this grout priming demonstration prior to any calibration test.

The Engineer may require additional pump calibrations and priming demonstrations when the pump is repaired, a different pump is used, when the length of the grout lines or hollow auger lengths increase from previous piles for which priming demonstrations were performed and at any time the Engineer determines the grout pump performance may have changed.

455-43 Testing Cement Grout.

Prepare three 4 inches x 8 inches cylinders for each LOT in accordance with ASTM C31, except pour grout in a single lift into cylinders molds without rodding. Plastic properties in accordance with ASTM C31 are not required. A LOT is defined as the lesser of 50 cubic yards of cement grout placed or one day of pile placement. Prepare two additional QC "hold" cylinders on the LOT selected by the Engineer for Verification. Provide curing facilities for all QC and Verification test cylinders in accordance with ASTM C31. Test the cylinders at 28 days, in accordance with ASTM C39.

When one of the three QC cylinders from a LOT is lost, missing, damaged or destroyed, determination of compressive strength will be made by averaging the remaining two cylinders. If more than one QC cylinder from a LOT is lost, missing, damaged or destroyed, core the structure at no additional expense to the Department to determine the compressive strength. Acceptance of LOT may be based on verification data at the discretion of the Engineer. Obtain the approval of the Engineer to core, and of the core location prior to coring. Repair core holes after samples are taken with a product meeting the approval of the Engineer, at no additional cost to the Department.

For each QC cylinder that is lost, missing, damaged or destroyed, payment for that LOT will be reduced by $750.00 per 1,000 psi of the specified design strength [Example: For f'_c=5,500 psi, and the loss of two auger cast pile grout QC cylinders that have no verification data will require the element to be cored and a pay reduction will be assessed (5,500 psi / 1,000 psi) x $750 x 2 = $8,250]. This reduction will be in addition to any pay adjustment for low strength.

The Engineer will cast three verification cylinders and two "hold" cylinders from one of every four consecutive Lots, randomly selected. The Engineer will compare QC and Verification results in accordance with Section 346. If the results do not compare, the Engineer will initiate a Resolution Investigation in accordance with Section 346.

Personnel making/curing grout cylinders shall be certified as ACI Concrete Field Testing Technician Grade I. Personnel performing tests on hardened properties of grout, such as strength determination of cylinders or beams, shall be certified as ACI Concrete Strength Testing Technician.

All low strength cement grout accepted by the Engineer will be subject to reduced payment as follows: $0.80 per cubic yard for each 10 psi of strength test value below the specified minimum strength. The Engineer will use the average compressive strength of the LOT tests for the computation of this pay reduction.

The Engineer will compute the volume of grout for which the reduction will be applied as 115% of the theoretical volume of the auger cast pile diameter required in the Contract Documents. Reduction in pay will be applied to the entire length of all piles containing low strength cement grout, in any quantity. The quantity of cement grout affected by the price reduction may exceed the quantity of cement grout contained in the LOT.

When separate payment for auger grouted piles is provided, the dollar reduction will be equated to an equivalent length of pile not to exceed the total pile length constructed utilizing the subject LOT based on the following formula:

$$PLR = RC/UC$$

Where: PLR = Equivalent Pile Length Reduction in feet
RC = Total Reduction in payment, dollars
UC = Unit Cost of pile, dollars /foot

When a cement grout acceptance strength test falls more than 500 psi below the specified minimum strength perform one of the following:

1. Remove and replace the piles affected fully or partially by the low strength LOT at no additional cost to the Department; or,

2. Submit a structural analysis performed by the Contractor's Engineer of Record. If the results of the analysis, approved by the Department, indicate adequate strength to serve the intended purpose with adequate durability, the grout may remain in place.

Otherwise, abandon and install additional piles to the foundation, or remove and replace the piles affected fully or partially by the low strength LOT of grout at no additional cost to the Department. When installing additional piles to resolve the strength deficiency, submit a foundation redesign to add piles into pile caps or footings, at no expense to the Department in accordance with 455-46.

455-44 Pile Installation.

Meet the following requirements:

1. Locate the piles as shown on the drawings.

2. Should soft, compressible muck, organics, clay or other unsuitable materials (non A-1, A-3, A-2-4 or limestone materials) be encountered, remove the unsuitable material to a maximum depth of 5 feet and a radial distance around the pile centerline of two pile diameters, unless otherwise indicated in the Plans. Backfill with clean granular backfill materials (A-1, A-3, A-2-4), placed and compacted in maximum 12 inch lifts to at least 95% of maximum dry density as determined by FM 1-T180. Complete this work to the Engineer's satisfaction prior to ACP construction. Should more than 5 feet depth or excessive quantities of unsuitable material be encountered, immediately advise the Engineer and proceed with the work as directed by the Engineer.

3. Provide continuous auger flighting from the bottom of the pile to the top of ground at the time of drilling with no gaps or other breaks, except for connections. Ensure the auger flights are uniform in diameter throughout its length, and of the diameter specified for the piles less a maximum of 3%. Provide augers with a distance between flights of approximately half the diameter of the auger.

4. Use augers with the grout injection hole located at the bottom of the auger head below the bar containing the cutting teeth, and with pile auger leads containing a bottom guide.

5. Construct piles of the length and diameter shown on the Plans.

6. Clearly mark the auger leads to facilitate monitoring of the incremental drilling and grout placement. Provide individual foot marks with 5 foot increments highlighted and clearly visible. Provide a clear reference mark on the moving auger assembly to facilitate accurately monitoring the vertical movement of the auger.

7. Place piles by rotating a continuous flight hollow shaft auger into the ground at a continuous rate that prevents removal of excess soil. Stop advancement after reaching the predetermined depth.

8. Should auger penetration to the required depth prove difficult due to hard materials/refusal, the pile location may be predrilled, upon approval of the Engineer, through the obstruction using appropriate drilling equipment, to a diameter no larger than one-half the prescribed finish diameter of the ACP. Commence grouting immediately upon reaching the required tip elevation to minimize ground loss and soil relaxation. Should non-drillable material be encountered preventing placement to the depth required, immediately advise the Engineer and proceed with the work as directed by the Engineer. Refusal is defined as the depth where the penetration of the standard auger equipment is less than 12 inches per minute.

9. Plug the hole in the bottom of the auger prior to advancing into the ground.

10. Pump the grout with sufficient pressure as the auger is withdrawn to completely fill the auger hole, preventing hole collapse and to cause the lateral penetration of the grout into soft or porous zones of the surrounding soil or rock. Prior to commencing withdrawal of the auger, establish a head of at least 5 feet of grout by pumping a volume of grout equivalent to 5 feet of pile volume. Do not include the volume or strokes required to prime the grout pumping system in the volume required to build this initial head. Maintain this head of at least 5 feet of grout above the injection point around the perimeter of the auger to displace and remove any loose material from the hole. Maintain positive rotation of the auger at least until placement of the grout.

11. Once the grout head has been established, greatly reduce the speed of rotation of the auger and commence extraction at a rate consistent with the pump discharge. Maintain extraction at a steady rate to prevent a locked-in auger, necking of the pile, or a substantially reduced pile section. Ensure grout starts flowing out from the hole when the cutting head is at least 5 feet below the ground surface. Place a minimum volume of grout in the hole of at least 115% of the column of the auger hole from a depth of 5 feet to the tip. Place a minimum volume of grout in the hole of at least 100% of the column of the auger hole from the ground surface to a depth of 5 feet. Do not include any grout needed to create surplus grout head in the volume of grout placed into the hole. If the grout does not flow out from the hole when the cutting head is at least 5 feet below the ground surface, redrill the pile under the direction of the Engineer. If grouting is interrupted for any reason, reinsert the auger by drilling at least 5 feet below the tip of the auger when the interruption occurred, and then regrout.

Use this method of placement at all times. Do not depend on the stability of the hole without the earth filled auger.

12. Assume responsibility for the grout volume placed. If less than 115% of the theoretical volume of grout is placed in any 5 foot increment (100% in the top 5 foot increment), reinstall the pile by advancing the auger 10 feet or to the bottom of the pile if that is less, followed by controlled removal and grout injection.

13. Furnish and install the reinforcing steel and anchoring bolts as shown in the Contract Documents. For ACP for miscellaneous structures and low clearance post options for noise walls, use wheels or other approved noncorrosive spacing devices within 3 feet of the bottom, within 3 feet of the top, and intervals not exceeding 10 feet along the pile to ensure concentric spacing for the entire length of the cage. Do not use block or wire type spacers. Use a minimum of one spacer per 30 inches of circumference or perimeter of cage with a minimum of three at each level. For noise wall ACP in which the full reinforcement is attached to the post, spacing devices within 3 ft of the top of the pile are not required.

14. Use reinforcement that is without kinks or nonspecified bends, free of mud, oil or other coatings that could adversely affect the bond. Make splices in reinforcement as shown on the Contract Documents, unless otherwise approved by the Engineer. Place the required steel reinforcement while the grout is still fluid, and immediately after finishing grouting and clearing it from any contaminating material. Install the steel cage into the grout by its own weight or manually. Do not use a mechanical equipment or tool to impact the steel cage or to force it into the grout. If the steel cage cannot be placed completely following this procedure, redrill and regrout the pile.

15. Leave any temporary supports of/for items placed into a grouted pile (reinforcement template, anchor bolt template, precast column supports, etc.) in place for a minimum of 12 hours after completion of the pile. Do not place wall panels or other loads, before piles are accepted and the grout has set a minimum of seven days or reached the 28 day strength.

455-45 Construction Tolerances.

Locate piles as shown in the Plans, or as otherwise directed by the Engineer. Locate pile centers to an accuracy of plus or minus 3 inches. Ensure that the top of pile elevation is within an accuracy of plus or minus 3 inches of the plan elevation. Ensure the tolerances in 534-5.1 can be met.

455-46 Unacceptable Piles.

Repair or replace unacceptable piles, as directed by the Engineer, at no cost to the Department. Unacceptable piles are defined as piles that fail for any reason, including but not limited to the following: piles placed out of position or to improper elevation; piles with reduced cross section, contaminated grout, lack of grout consolidation (honeycombed), or deficient grout strength; and piles with reinforcement, anchor devices or other components cast or placed into the fluid grout out of position. When the Engineer determines that a pile is unacceptable, the Contractor may propose a foundation redesign to add piles into pile caps or footings, at no expense to the Department. The Contractor's Engineer of Record must perform any redesign, and sign and seal the redesign drawings and calculations. Do not begin any proposed construction until the redesign has been reviewed and approved by the Engineer.

455-47 Auger Cast Pile Installation Plan (ACPIP).

At the preconstruction conference, but no later than 30 days before ACP construction begins, submit an ACPIP for approval by the Engineer. Provide the following detailed information on the plan:

1. Name and experience record of ACP superintendent or foreman in responsible charge of ACP operations. Place a person in responsible charge of day to day ACP operations who possesses satisfactory prior experience constructing auger cast piles similar to those described in the Contract Documents. The Engineer will give final approval subject to satisfactory performance in the field.
2. List and size of the proposed equipment, including cranes, augers, concrete pumps, mixing equipment etc.
3. Details of grout mixing procedures and proposed pump calibration procedures.
4. Details of pile installation methods.
5. Details of reinforcement placement and method of centering in pile, including details of all temporary supports for reinforcement, anchor bolts, precast columns, etc.
6. Details of how and by whom the grout volumes will be determined, monitored and documented.
7. Required submittals, including shop drawings and cement grout design mixes.
8. Proposed plan for monitoring settlements of adjacent structures, identifying the proposed equipment, the structures and the specific points that will be monitored.
9. Other information shown in the Plans or requested by the Engineer.

455-48 Inspection and Records.

The Engineer will monitor pile installation.

455-49 Method of Measurement.

455-49.1 Auger Cast Pile: The quantity to be paid for will be at the Contract unit price per foot between tip and required pile top elevations for all piles completed and accepted.

455-50 Basis of Payment.

455-50.1 Auger Cast Piles: Price and payment will be full compensation for all labor, materials, and incidentals for construction of ACP of the sizes and depths indicated on the Contract Documents or as otherwise directed by the Engineer. Price and payment will also include the removal and proper disposal off site of all spoil from the auger operation and all excess grout displaced from the auger hole, unless otherwise approved by the Engineer. Work to remove and replace unsuitable material when necessary as specified in 455-44 will be considered Unforeseeable Work.

455-50.2 Payment Items: Payment will be made under:

Item No. 455-112- Auger Grouted Piles - per foot.

SECTION 458
BRIDGE DECK JOINTS

458-1 Description.

Furnish and install bridge deck joints of the types and at the locations shown in the Plans. This Section covers the following types of joints:

Poured Joint
Poured Joint with Backer Rod System
Strip Seal Joint System
Modular Joint

458-2 Materials.

458-2.1 General: Transport, store and prepare all joint materials and components for all joint types as per the manufacturer's recommendations.

458-2.2 Poured Joint: Furnish a Type D silicone sealant material meeting the requirements of Section 932 that is listed on the Approved Product List (APL).

458-2.3 Poured Joint with Backer Rod System: Furnish poured joint with backer rod systems consisting of Type D silicone sealant material, foam backer rods, sidewalk cover plates (as required) and all associated miscellaneous components.

The Type D silicone sealant material used in the system shall be listed on the APL and meet the requirements of Section 932.

458-2.4 Strip Seal Joint System: Furnish strip seal joint systems that are listed on the APL. Manufacturers seeking evaluation of their product for the APL shall submit an application in accordance with Section 6. Design documentation showing the expansion joint system shall include installation details and temporary or sacrificial support brackets, bolts, clamps, etc. that are compatible with decks constructed with or without block-outs. Furnish joint systems consisting of watertight steel edge rails, strip seal glands and all associated miscellaneous components.

458-2.4.1 Strip Seal Joint Systems with elastomeric glands: Product must meet the requirements of ASTM D5973 and Standard Plans, Index 458-100. Obtain the strip seal elastomeric glands from the edge rail manufacturer.

458-2.4.2 Strip Seal Joint Systems with silicone glands: Product must meet the requirements of Standard Plans, Index 458-100. Adhesives must be supplied by the same manufacturer as the glands and must meet ASTM C793 with no cracking, ozone chalking or degradation.

458-2.5 Modular Joint: Furnish modular joints meeting the requirements of this Section. Submit manufacturer certification that modular joint components meet the following material requirements in Table 458-1.

Table 458-1 Component Material Requirements	
Solid Separation Beams, Steel Extrusions, Support Bars, Plate and Milled Steel Shapes	ASTM A588 or ASTM A572, Grade 50
Box Seals	ASTM D3542
Strip Seals	ASTM D5973
Seal Adhesive	ASTM D4070
Stud Shear Connectors and Threaded Studs	ASTM A108
Stainless Steel Sliding Plates	ASTM A240, Type 316
PTFE Sliding Surface	ASTM D4895
*Provide seals with hardness Type A durometer equal to 55 (plus or minus 5) by ASTM D2240.	

Supply test results from the manufacturer verifying the maximum coefficient of friction between mating surfaces. Testing must be performed by an independent testing laboratory according to the manufacturer's stated precompression values for the system to a minimum of two million cycles. Maximum allowed coefficient of friction is 0.10.

Bond PTFE (polytetrafluorethylene) using a heat cured, high temperature epoxy capable of withstanding temperatures of minus 40°F to plus 250°F.

For springs, bearing, and equidistance devices (i.e. control springs), use the same material composition and formulation, manufacturer, fabrication procedure and configuration as those used in the prequalification test. Components manufactured from polyurethane compounds are not permitted.

458-2.6 Sidewalk Cover Plates: Furnish slip resistant, random hatch matrix or suitable pattern, galvanized steel sidewalk cover plates fabricated from steel meeting the requirements of ASTM A36 or ASTM A709, Grade 36 or 50. Do not use diamond plate or surface applied slip resistant tapes, films, nonmetallic coatings or other similar materials. Fabricate cover plates in accordance with Standard Plans, Indexes 458-100 and 458-110. After shop fabrication, hot-dip galvanize cover plates in accordance with Section 962. Galvanized sidewalk cover plates shall have a minimum coefficient of friction on the top surface of 0.8 in dry condition, and 0.65 in a wet condition, as determined by ASTM F1677-05 or ASTM F1679-04. Furnish flat head stainless steel sleeve anchors in accordance with ASTM F593 Group 1 Alloy 304 for attaching sidewalk cover plates. Install sleeve anchors in accordance with the manufacturer's instructions.

458-3 Calculations and Shop Drawings.

458-3.1 All Joint Types (with the exception of Poured Joints): Submit shop drawings in accordance with Section 5 for any applicable joint system supplied. For format and required details, follow the AASHTO/NSBA Steel Bridge Collaboration "Guideline for Shop Detail Drawing Presentation". The following information must be included on the shop drawings:

1. The name and address of the joint system manufacturer, including the physical address where the fabrication is performed.

2. The joint manufacturer's instructions for proper installation, including the proper width settings for a minimum 100°F temperature range. Shop drawings that are submitted without this information will be returned without review.

3. Show all materials including project specific details and dimensions. Include the joint model number and joint movement range.

458-3.2 Sidewalk Cover Plates: Submit shop drawings for sidewalk cover plates showing all materials, project specific details and dimensions. The submittal must include a certification from the manufacturer that the sidewalk cover plates meet the minimum coefficient of friction requirements.

458-3.3 Strip Seals: Provide the APL number in the shop drawings.

458-3.4 Modular Joints: When support boxes are supported by the deck or abutment, detail in the shop drawings a minimum of 2 inches between the bottom surfaces of the joint elements and the deck blockouts to allow easy placement of concrete and allow for proper consolidation of concrete under and around all parts of the joints.

Detail in the shop drawings at least 6 inches of clear space between the support boxes or anchorages on the ends of support boxes and the periphery of the blockout to permit placing of concrete.

Submittal of shop drawings must include a manufacturer's installation manual in accordance with this Section.

Include design calculations, signed and sealed by a Professional Engineer licensed in the State of Florida, confirming that all load bearing components are in conformance with the requirements of this Section.

458-4 Fabrication and Installation.

458-4.1 General: Install the joint in accordance with the specific requirements of this Section, the plan details, the Standard Plans, and the manufacturer's installation instructions for the particular type of expansion joint to be installed.

458-4.2 Poured Joint: Install the joint at the locations and in accordance with the details shown in the Plans and the manufacturer's recommendations.

458-4.3 Poured Joint with Backer Rod System:

458-4.3.1 Casting Joint Opening: When casting the bridge deck, approach slab or raised sidewalk adjacent to the expansion joint at temperatures other than 70°F, adjust the joint opening (Dim. A as shown in Standard Plans, Index 458-110) at 70°F by the amount of the adjustment per 10°F shown in the Structures Plans, Poured Expansion Joint Data Table. For temperatures above 70°F, decrease the opening. For temperatures below 70°F, increase the opening.

458-4.3.2 Installation of Poured Joint System: After deck profiling, grinding, and grooving operations are complete, install poured joint with backer rod in accordance with the manufacturer's recommendations, when the joint opening is plus or minus 1/4 inch of the design joint opening (Dim A at 70°F) shown in the Structures Plans, Poured Expansion Joint Data Table. The minimum opening must not be less than 1 inch at the time of installation. Place poured joint material only when the ambient temperature is between 55°F and 85°F and is expected to rise for the next three hours minimum to provide for adequate joint opening and compression of the poured joint material during curing.

458-4.4 Strip Seal System:

458-4.4.1 Glands for Joint Seal: Seals must be continuous heavy duty bridge deck glands sized in accordance with the manufacturer's recommendations, to perform satisfactorily for the opening range shown. Minimum movement classification is 4 inches.

458-4.4.1.1 Elastomeric Gland Seals: Shop vulcanization is restricted to use on horizontal turns on skewed bridges at upturn ends where the horizontal turn angle is greater than 35 degrees. Field vulcanization is not permitted.

458-4.4.1.2 Silicone Gland Seals: Meet the following requirements in Table 458-2:

Table 458-2 Silicone Gland Seal Requirements		
Property	Test Method	Range
Durometer (Shore A)	ASTM D2240	55 +/- 5
Elongation	ASTM D412	350% (min)
Tensile	ASTM D412	550 psi (min)
Tearing (die B ppil)	ASTM D624	80 lb/in (min)
Compression Set	ASTM D395	30% max at 350º F
Temperature Range		-60º F to 450º F
Specific Gravity		1.51

458-4.4.2 Edge Rail Fabrication:

1. Furnish extruded, hot rolled or machined solid steel edge rails in accordance with ASTM A709, Grade 36, 50 or 50(W). Furnish edge rails with a minimum mass of 19.2 lb/ft excluding studs, a minimum height of 8 inches, a minimum thickness of 1/2 inch and a maximum top surface (riding surface) width of 2 inches. Edge rails manufactured from built up pieces must have continuous longitudinal welds. Built-up member connections directly supporting wheel loads must use complete penetration welds.

2. Furnish anchor studs in accordance with ASTM A108, and electric arc end-weld anchor studs with complete fusion. Anchor studs may be piggy backed to achieve required lengths.

3. Perform all shop welding in accordance with the Bridge Welding Code ANSI/AASHTO/AWS D1.5. Do not weld to surfaces in contact with the elastomeric seal or the top surface (riding surface) except as shown in the shop splice detail. Do not weld inside seal cavity.

4. Fabricate edge rail assemblies upturns when required to hold the gland in place, integral to the edge rail assemblies by full length welds or extruded sections. Splices in an individual joint are only permitted where a construction joint is specifically required by the Plans, joint segment length exceeds 50 feet, or approved by the Engineer in writing. Shop splice sections of edge rail to obtain the required length by partial penetration double V-groove welds on prepared beveled edges and seal welds as shown in the shop splice detail. Weld all around the joint as far as practical to achieve a watertight seal. Do not use short pieces of edge rail less than 6 feet 0 inches long unless required at curbs, sidewalks or phase construction locations.

5. After shop fabrication, hot-dip galvanize edge rail in accordance with Section 962 and the manufacturer's recommendations.

6. Furnish temporary or sacrificial support brackets, bolts, clamps, etc. that are capable of resisting shipping, handling and construction forces without damage to the edge rail assemblies or galvanized coating and are adjustable to account for variable temperature settings. Do not use temporary or sacrificial support brackets, bolts, clamps, etc. between the faces of the edge rails.

7. Clearly match mark corresponding edge rail assemblies with joint location and direction of stationing.

458-4.4.3 Installation:

1. Install the edge rail assemblies at proper grade and alignment before or after deck planing in accordance with the manufacturer's instructions. When installed after deck planing and grinding, install the edge rail assemblies in the block-outs on a profile tangent between the ends of the deck and/or approach slab to within a plus 0 inch and minus 1/4 inch variation. When installed before deck planing, install the edge rail assemblies 3/8 inches, plus or minus 1/16 inch, below the top surface of the deck or approach slab to compensate for concrete removal during planing and grinding.

2. Bolt, weld or clamp edge rail assemblies in position using temporary or sacrificial brackets as required. For phased construction, install edge rail assemblies in a given subsequent phase to align with those installed in an adjacent prior phase after deflection and rotation due to deck casting of adjoining spans has occurred.

3. For installation of edge rail assemblies at temperatures other than 70°F, adjust the opening of the joint (Dim. A as shown in Standard Plans, Index 458-100) by the amount of the adjustment per 10°F shown in the Structures Plans, Strip Seal Expansion Joint Data Table. For temperatures above 70°F, decrease the opening. For temperatures below 70°F, increase the opening.

4. After galvanizing, do not weld within 2 inches of edge rail surfaces exposed in the completed structure. Do not weld expansion joint components to or electrically ground to reinforcing steel or structural steel. Seal field butt joints and empty shipping and erection holes with caulk before placing deck concrete.

5. Protect galvanized edge rail assemblies during screeding operations per the manufacturer's recommendations. Provide temporary blocking material in the edge rail seal cavities to prevent concrete intrusion during deck pour and finishing.

6. Loosen any temporary or sacrificial support brackets, bolts, clamps, etc. that span across the joint after initial set of concrete, but not more than two hours after conclusion of concrete placement.

7. Install elastomeric seal after completion of deck casting. Remove all joint form material and blocking material prior to installing glands. Field install glands in accordance with manufacturer's recommendations.

458-4.5 Modular Joints

458-4.5.1 Fabrication: Perform all steel fabrication in accordance with the requirements of Section 460.

After fabrication, hot-dip galvanize all non-stainless steel metal surfaces in accordance with Section 962.

Joint systems must be designed in accordance with the latest edition of AASHTO LRFD Bridge Design Specifications or as required by the Contract Documents. Supply joint systems for which identical full-size specimens have been subjected to full life-cycle fatigue testing. Obtain all joint system components from the same manufacturer, fabricated at their approved corporate facilities, using subcomponents meeting the testing requirements of this Section.

Except for sliding plates, provide all load bearing structural steel components with a 3/8 inch minimum thickness in any direction. Construct edge rails consisting of a monolithic steel shape with a machined or extruded retainer cavity. Multiple component welded steel shapes to achieve a final member cross section or seal retainer cavity are not permitted. Attach separation beams to individual support bars with a complete joint penetration weld.

Support each separation beam with a dedicated support bar connected by a complete joint penetration welded connection. Use of bolted connections, yokes, or other means to directly attach separation beams to support bars is not permitted. Maintain equal spacing between separation beams at all stages of movement.

Contain support bars with bearings capable of transferring all imposed loads to the structure and allow the support bar to freely move within the limits of the expansion joint.

Fabricate a full length modular joint system as one piece. Only a minimal number of splices in an individual joint may be permitted where a construction joint is specifically required by the Plans, joint segment length exceeds 50 feet, or approved by the Engineer in writing.

When phased construction is permitted or required by the Contract Documents, fabricate each segment to exactly fit that portion of superstructure, including sidewalks, under construction in each specific phase. Connect segments with a bolted splice to ensure continuity. Fit segments with temporary seals. Lubricant adhesive is not required for temporary seals. Submit watertight seal details for the splice. Shop inspection will be conducted at the discretion of the Engineer in accordance with Article 5-6.

Fabricate final seal assembly as one single, continuous component. Splicing of seals in the field is not permitted.

Provide lifting devices and devices to maintain the preset opening of the joint at a uniform spacing of not greater than 15 feet along the length of the joint. Provide at least three of these preset opening devices per joint segment. Provide lifting and preset opening devices that function and then are removed without damaging the modular joint system assemblies or galvanized coating.

Prior to shipment, preset the joint opening in accordance with the joint opening as shown in the Plans at 70°F.

Prior to installation, place the centerbeam/support bar assembly on a flat surface to verify the support bars lay in a single plane, with no part of the bottom of any support bar exceeding 0.25 inches off the surface. The subassembly may be straightened. No more than three attempts may be made to heat-straighten the subassembly.

Polish stainless steel sliding surfaces to an 8 µ-inch mirror finish.

458-4.5.2 Installation: Clean any metal surface component exhibiting surface rust and field metalize in accordance with Section 562. Replace any component exhibiting pitting and/or section loss with a new component.

Install the joint system in strict compliance with the manufacturer's instructions in the shop drawings and as directed by the manufacturer's installation technician.

458-4.5.2.1 Manufacturer's Installation Manual: Submit the manufacturer's installation manual at least two weeks prior to installation activities, containing complete and detailed installation instructions for the modular expansion joint supplied by the Contractor. The manual must include step-by-step installation instructions and all related manufacturer's recommendations, including bridge deck pouring sequence, restraints, finishing, etc., for successful installation and long term operation and serviceability of the joint.

458-4.5.2.2 Manufacturer's Installation Technician: Provide for a manufacturer's installation technician, under the direct employ of the manufacturer, to be on the jobsite prior to the first joint installation and in sufficient time to train the Contractor's joint installation crews using the shop drawings and the manufacturer's installation manual. The

manufacturer's installation technician must remain on the jobsite and be present for all modular joint installation activities for a minimum of the first two joints for each of the Contractor's installation crews. The manufacturer's installation technician will submit written certification to the Engineer that the Contractor's installation process follows the requirements outlined in the manufacturer's installation manual.

458-4.5.2.3 Field Inspection: The Engineer will inspect the joint system for proper alignment, complete bond between neoprene gland seal and steel, and proper stud placement and effectiveness.

Bends or kinks in the joint system steel are not allowed except as necessary to follow roadway grades. Straightening of any bends or kinks in the steel, whether intentional or inadvertent, is not allowed. Any joint system exhibiting bends or kinks will be rejected, removed from the jobsite, and replaced by a new joint system. Match joint system to the finished roadway profile and grades before final acceptance.

Restore bond of any neoprene gland seal found not fully bonded to steel.

Visually inspect all stud welds. Test a minimum of 10% of the total number of stud welds at the discretion and direction of the Engineer. Any stud found to not have a complete end weld (as evidenced by a ringing sound when struck by a hammer) will require replacement. Any stud located more than one inch in any direction from location shown in the shop drawings will require removal and a new stud placed in the proper location.

458-4.5.2.4 Width: For installation at temperatures other than 70°F, adjust opening of the joint as shown in the Contract Documents by amount of adjustment per 10°F shown in the Contract Documents. For temperatures above 70°F, decrease the opening. For temperatures below 70°F, increase the opening. Release all support brackets as the concrete is being placed and no later than when the concrete takes initial set.

Remove opening devices immediately after the concrete is placed.

458-4.5.2.5 Permanent Seals: When phased construction is necessary, remove temporary neoprene seals and replace with full width permanent seals after joint system is completely installed over full width of structure, including sidewalks.

Clean (SSPC-SP6) all metal surfaces which will be in contact with permanent seals to visual standard CSP6 as defined by SSPC Vis 1-89.

458-4.5.2.6 Final Placement: After modular joint system has been set to its final line and grade, fill any deck joint blockouts with Class II (Bridge Deck) concrete or as specified in the Plans. Prepare contact surfaces in accordance with the same procedure described in this Section. Finish the uppermost surface of concrete placement in accordance with requirements of 400-15, except that machine finishing is not required. Unless otherwise noted in the Plans, include the cost of the pourback in the unit bid price of superstructure concrete.

Construction loads are not allowed on the modular joint for 72 hours after complete installation unless approved by the Engineer. In the event it is necessary to cross the modular joint before the 72 hour prohibition, bridge over the joint in a manner approved by the Engineer.

458-4.5.3 Acceptance: Acceptance of fabricated joint systems will be based on the Engineer's visual inspection at the jobsite and in accordance with requirements of this Section.

Submit certified mill test reports to the Engineer for all steel used to fabricate the joint system.

458-4.5.3.1 Watertight Integrity Test: Test full length of joint system for watertight integrity in accordance with this Section, no more than five working days after each joint system installation is completed. In case of phased construction, perform this test after the full length of joint is installed (after all applicable phases). For the first two joints, perform the watertight integrity test and inspection in the presence of the manufacturer's installation technician and the Engineer. For all remaining joints, perform the watertight integrity test and inspection in the presence of the Engineer.

Cover full length of joint with either water ponded to a minimum 1/2 inch depth, or continuously flowing water directly over full plan area of joint for a 15 minute minimum duration. Inspect underdeck surfaces beneath the joint for any evidence of dripping water or moisture for the 15 minute duration of water application and for 45 minutes after water supply is removed. Watertight integrity of joint system is interpreted as absolutely no free dripping water or moisture on underdeck surfaces beneath joint. Document date, time, and location of joint inspections and submit the report to the Engineer.

Repair joint integrity at every location exhibiting free dripping water or moisture identified during the watertight integrity test and subsequently retest, subject to same conditions and consequences as the initial test. Retest and repair until joints pass the watertight integrity test.

458-5 Method of Measurement.

The poured joint without backer rod will be incidental to the concrete work and included in the cost of the concrete. Poured joints with backer rod, strip seal joints, and modular expansion joints will be the plan quantity length of each type of joint constructed and accepted.

458-6 Basis of Payment.

458-6.1 Basic Items of Joints. The Contract unit price per foot for joints will be full compensation for all work and materials necessary for the complete installation. Such price and payment will include, but not be limited to, the following specific incidental work:

1. Any work required to clean and prepare the adjacent bridge deck, deck block out or deck joint gap.
2. Any work to replace any rejected joints.
3. Any repairs to the galvanizing on metallic joint components.
4. Any additional work or materials required for non-standardized or special construction or installation techniques.
5. Any cost of erection and removal of any temporary supports which may be necessary for ensuring proper alignment and positioning of the joint relative to the bridge deck.
6. Any sidewalk cover plates required.
7. All costs associated with the manufacturer's installation technician.
8. All work related to performance of the watertight integrity test and any necessary repairs and retesting.

458-6.2 Payment Items: Payment shall be made under:

Item No. 458 - 1- Bridge Deck Expansion Joint - per foot.

SECTION 459
BITUMEN COATING AND POLYETHYLENE SHEETING ON CONCRETE PILES

459-1 Description.

Furnish and apply bituminous coating and primer, or install polyethylene sheeting and lubricant to prestressed concrete piles.

459-2 Materials.

459-2.1 Bituminous Coating: Use an asphalt type bituminous coating meeting the requirements of Section 916, with a minimum viscosity (at 140ºF) of 3,000 poises and a maximum of 1,000 poises. Apply bituminous coating uniformly over an asphalt primer.

459-2.2 Primer: Meet the requirements of ASTM D41.

459-2.3 Polyethylene Sheeting: Use polyethylene sheeting that is 6 mils thick and is clean, new and has a smooth surface.

459-2.4 Lubricant: Use a lubricant between the two layers of sheeting that is either a vegetable oil or other approved environmentally and functionally acceptable lubricant.

459-3 Construction Requirements.

Before surfaces are coated with bitumen, dry and thoroughly clean them of dust and loose materials. Do not apply primer or bitumen in wet weather or when the temperature is below 65ºF.

Apply the primer to the surfaces and allow it to dry completely before applying the bituminous coating. Apply primer uniformly at the quantity of 1 gal/100 ft^2 of surface.

Apply bitumen uniformly at a temperature of not less than 300ºF, or more than 350ºF, and apply either by mopping, brushing, or spraying at the project site. Completely fill all holes or depressions in the concrete surface with bitumen. Apply the bituminous coating to a minimum dry thickness of 1/8 inch, but not less than 8 gal/100 ft^2.

Store bitumen coated piles before driving, and protect piles from sunlight and heat. Ensure that pile coatings are not damaged during storage, hauling, or handling. Take appropriate measures to preserve and maintain the bitumen coating. At the time of pile driving, ensure that the bitumen coating has a minimum dry thickness of 1/8 inch. If necessary, recoat the piles, at no cost to the Department, to comply with the requirements of this Section.

Ensure that all surfaces to be wrapped with polyethylene sheeting are dry and thoroughly cleaned of dust and loose materials.

Place the sheeting on the pile to the limits shown on the Plans. Wrap the pile with a minimum of 2 1/4 wraps of sheeting. Apply a uniform coating of a lubricant between the first and the second layers. Ensure that this coating fully covers the entire surface of the first layer of sheeting. Once the pile has been wrapped with the minimum of two and one-quarter wraps of sheeting, secure the sheeting with tape or other means that does not damage the sheeting or restrict its movement. Do not place any tape or other material other than the lubricant between the first and second layers of sheeting. Protect the sheeting from construction damage. Where sheeting has been damaged, completely remove the damaged sheet of polyethylene and replace it, at no cost to the Department, as directed by the Engineer.

Where the sheeting will not wrap the specified limits of the pile in one sheet, overlap the previous sheet with each subsequent sheet by 12 inches.

459-4 Method of Measurement.

459-4.1 Bitumen Coating: The quantity will be paid for by the square yard of coating in place on concrete pile surfaces.

459-4.2 Polyethylene Sheeting: The quantity will be paid for by the square yard of wrapped concrete pile surfaces.

459-5 Basis of Payment.

459-5.1 Bitumen Coating: Price and payment will be full compensation for all work specified in this Section, including furnishing all labor, materials, tools, equipment, and incidentals, and doing all the work involved in applying the bituminous coating and primer, as specified in the Contract Documents.

459-5.2 Polyethylene Sheeting: Price and payment will be full compensation for furnishing all labor, materials, including primer and lubricant, tools, equipment, and incidentals, and for doing all the work involved in installing the polyethylene sheeting and lubricant, as specified in the Contract Documents.

459-5.3 Payment Items: Payment will be made under:

Item No. 459- 70-	Bitumen Coating on Concrete Piles - per square yard.
Item No. 459- 71-	Polyethylene Sheeting on Concrete Piles - per square yard.

SECTION 460
STRUCTURAL STEEL AND MISCELLANEOUS METALS

460-1 Description.

460-1.1 General: Prepare, fabricate, assemble, erect, and perform all nondestructive testing for structural steel or miscellaneous metal structures, or portions thereof in accordance with the Contract Documents.

Obtain Structural Steel and Miscellaneous Metals from a fabricator that is currently on the Department's Production Facility Listing. Fabricators seeking inclusion on the list shall meet the requirements of Section 105.

As used in this specification, the following terms shall apply:

Main or primary load-carrying member or component: This designation refers to the following;

1. Longitudinal or transverse rolled beams or fabricated girders (I or box, curved or straight)
2. All truss members not designated as cross frames
3. Cross frames, diaphragms and connection plates of horizontally curved beams or girders
4. Rib members of steel arches
5. Bracing members subjected to and specifically designed for traffic live load and/or other loads
6. Cross frames or diaphragms at pier and abutment supports of tub or box girders (trapezoidal members) and their connection plates
7. Attachments and components of the above such as splice, cover, cross frame and diaphragm connection and gusset plates, but not transverse and bearing stiffeners (unless acting as a cross frame or diaphragm)
8. Cables, moment release pins and links, and hangers
9. All steel substructure members except those designated as secondary in the Contract Documents
10. Overhead cantilevers, trusses, spans and gantries
11. Other members as may be identified in the Contract Documents
12. Forgings and castings to be used in bridge machinery

Miscellaneous components - This designation refers to, but is not limited to, the following:

1. Steel modular joints
2. Load plates
3. Bearings
4. Laminated bearing pads
5. Aluminum J-arms
6. Roadway Gratings, inlets, and frames
7. Steel and aluminum railing

460-1.2 Fabrication Categories: As a prerequisite for being on the Department's Production Facility Listing, fabricators must currently be accredited in accordance with one of the programs in Table 460-1, by fabrication category/categories of the products that they are producing.

Fabricators are required to submit their proposed fabrication Quality Control (QC) Plan for review by the Department.

Table 460-1 Fabrication Categories	
Structure Type	Accepted Accreditation Program
Simple Steel Bridge: Pedestrian bridge (prefabricated steel truss pedestrian bridges meeting the Category 1 conditions of FDOT Design Manual 266.4), bridge grid decking	AISC Simple Bridge
Steel Bridge: Vehicular bridge, Pedestrian bridge (all others)	AISC Advanced Bridge Fracture Critical Endorsement
Structural Highway Metal Components, Group I: bridge machinery, bridge bearings, modular joints, load plates, laminated bearing pads, cantilever, truss/span, monotube, gantry, mast arms, steel light poles, aluminum light poles, aluminum j-arms, drainage (welded gratings, frames, inlets)	AISC Components Manufacturer or AWS Welding Fabricator
Structural Highway Metal Components, Group II: bridge forgings, bridge castings, steel railing, aluminum railing, castings (manhole, grating, inlet, frame), guardrail, coated steel fence, elastomeric bearing pads, stay in-place forms	ISO 9001
Notes: An AISC fracture critical (FC) endorsement is required for all FC work. Other accreditations programs may be submitted to the FDOT State Materials Office for review and consideration in addition to the programs listed in the table above.	

460-2 Materials.

Provide the materials specified in the Contract Documents in accordance with Sections 6, 105, ASTM A6, and AASHTO/AWS D1.5, Bridge Welding Code. Fabricate all unpainted steel elements using steels with weathering characteristics as defined in ASTM A709 for grades with a "W" suffix.

Structural components designated as "fracture critical" shall conform to the provisions of the AASHTO/AWS D1.5, Bridge Welding Code, Clause 12-AASHTO/AWS Fracture Critical Control Plan for Non-Redundant Members, in addition to the requirements of the Contract Documents.

Meet the additional following requirements:

Steel and Miscellaneous Metal Items .....Section 962
Material Testing and Certifications .....Section 962
Galvanizing .....Section 962
Structural Coatings.....Section 560
Structural Coating Materials .....Section 975

460-3 Pre-Assembly Requirements.

460-3.1 Shop Drawings: When shop drawings are required, submit such drawings in accordance with Section 5. For drawing presentation format, refer to the AASHTO/NSBA Steel Bridge Collaboration "Guidelines for Shop Detail Drawing Presentation".

460-3.2 Welding Procedures: Submit all shop and field welding procedures to the Engineer. Such procedures shall contain a notation that they have been reviewed by a Certified Welding Inspector, and shall be signed, dated and stamped accordingly.

460-3.3 Pre-Assembly Meeting: Prior to commencing work, a meeting shall be held between the Contractor and the Engineer. Representatives of the Fabricator, Suppliers or subcontractors may attend the meeting if requested by the Engineer or Contractor. During this meeting, the Engineer may review various aspects of the job, including but not limited to, any of the following:

1. Plant and Personnel Certification.
2. Organizational Structure of Contractor personnel.
3. Traceability of Materials to Pre-Qualified Fabricator.
4. Shop Drawing requirements, submittal, review and approval process.
5. Fabrication Procedures, especially shop assembly, welding and painting.
6. Sampling and Testing Procedures.
7. Project specific areas of concern for fabrication, inspection and testing.
8. Handling of Material Test Reports.
9. Work Schedule.
10. Lines of Communication.
11. Availability of Quality Control and Verification Inspectors during specific fabrication/erection operations.
12. Loading and Transporting.
13. Handling of non-conformance and repair issues.
14. Special Requirements.
15. Consistency between fabrication shop drawings and the Erection Plan, specifically between the fabrication shop blocking diagrams and available site locations for temporary support during erection.

460-3.4 Access to Fabrication Facilities: Provide the Engineer full access of facilities or sites where the product is being stored, fabricated, assembled, coated or erected.

Provide and maintain office facilities at the fabrication facility for the Department's inspectors that ensure a reasonable amount of privacy, are clean, properly illuminated, heated or air-conditioned as necessary and are relatively free of noise, dust and odors. Locate the office reasonably close to the work and provide access any time fabrication, assembly or erection operations are in progress. Provide a desk, chair, and a four-drawer locking file cabinet for the use by each inspector and the Engineer. Provide a telephone within the office with an outside line suitable for modem communication. Provide ready access to adequate parking, fax and copy machines, and clean, contractor-maintained restrooms within a reasonable distance to the office.

The Engineer may observe any or all activities and perform nondestructive testing of materials, components and the fabricated product to the extent considered necessary to confirm the conformance with Contract Documents.

460-3.5 Notification Prior to Commencement of Assembly: Notify the Engineer at least one week prior to beginning assembly, when conducted in-state, and at least two weeks prior to beginning assembly, when conducted out-of-state.

460-4 Shop Workmanship and Assembly.

460-4.1 Handling, Transporting and Storage of Materials:

460-4.1.1 General: Handle, transport and store plates, shapes, assemblies, fastener components and other parts in a manner that protects them from damage and facilitates subsequent inspections in a safe manner.

Provide storage which will keep materials, assemblies, other components and parts clean, and free from dirt, grease, other foreign matter, unacceptable corrosion or coating deterioration, and any other adverse environmental conditions.

460-4.1.2 Bulk Materials: Ensure that all bulk materials, such as shear studs, are stored together in individual LOTs and that the outside of each container has a list and description of the contents. Maintain a separate list of the weights of all tools and erection materials.

460-4.1.3 Fastener Assemblies (Bolts, Nuts and Washers): Transport and store fastener assemblies in sealed, watertight containers. Label the side of each container with the supplier's name and LOT identification number, and marked to identify the contents and size of the fastener components. Ensure that all surfaces of the nuts are lubricated prior to their placement in watertight containers. Provide containers for components that are capable of protecting them from moisture and other harmful materials. Maintain containers in their sealed conditions until they are opened for use at their assembly locations.

Do not remove more fastener assemblies from the protected area than can be installed and tightened during a work shift. Leave the containers unopened until needed for assembly. At the end of the work shift, return unused fastener assemblies to the protected storage area for future use. Protect opened storage containers from contamination.

460-4.1.4 Coatings: Store coatings in accordance with Sections 962, and 975 and the manufacturer's recommendations. Notify the Engineer if the manufacturer's recommendations vary from that provided in the Contract Documents.

460-4.1.5 Anchor Rods and Nuts: Ship anchor rods and nuts as an assembly. Washers may be shipped separate from the assembly.

460-4.2 Material Traceability:

460-4.2.1 General: All materials arriving at the shop shall be properly identified in accordance the requirements of ASTM A6. Document all main load-carrying member material, high-strength fastener assemblies, and weld materials incorporated into the work through the entire fabrication process. Document this material traceability in a report type format that correlates heat numbers to their respective locations in the completed members. Submit diagrams and sketches as requested by the Engineer for clarity.

At the fabrication facility, maintain the records of the material testing and certification processes and component/part identification as part of the fabricator's permanent project records for a period of not less than two years as measured from the last shipment of materials from the fabricator's facility. Submit all project-related records to the Engineer.

Mark the weight on members weighing more than three tons, in a visible location.

460-4.2.2 Match Marking of Members and Assemblies: Match mark all connecting members or parts that have been reamed or drilled while assembled. The fabricator shall submit a diagram showing all marks and clearly indicate the location of all the marks on the shop drawings.

Use painted marks, attached metal tags, other durable methods which do not degrade the finish of the piece, including plasma etching or low-stress type steel die stamps to identify and match mark pieces. If steel die stamps are used, they must be blunt nosed or

interrupted dot dies, manufactured to produce impressions that are rounded at the bottom of the impression. Re-mark coated type markings as necessary to maintain continuity in traceability. Plasma etching using robotic equipment may be used to mark the surface of a steel plate when done at 10 amps and at 150 inches per minute. Plasma etching outside of these parameters requires Engineer approval.

Mark splice plates and girders so that upon erection, the mark on the splice plate is located opposite a matching mark on the girder. Place the mark on web splice plates, midway down the long side of the plate, on either the right or left side, to correspond with the girder to which the splice plate will be temporarily attached for shipping to the erection site. Make a matching stamp on the girder web opposite the mark on the splice plate.

Place the mark on top or bottom flange splice plates, on the right or left end of the plate, corresponding to the girder to which the plate will be attached for shipment to the erection site. Place a corresponding mark on the girder flange opposite the mark in the splice plate.

As an alternate location for tub girder bottom flange splice plates, place the mark midway down the long side of the plate, on either the right or left side, to correspond with the girder to which the splice plate will be temporarily attached for shipping to the erection site. Make a matching mark on the girder flange opposite the mark on the splice plate.

Mark girders and beams on the left end, according to the orientation shown in the shop drawings, near the top flange. Mark diaphragms in the middle upper portion of the web. Mark cross-frames in the middle of the top or bottom horizontal member.

When heat numbers and other identification marking are applied by die stamping to fracture critical members, low stress dies shall be used.

Low-stress die stamp markings applied to fracture critical members shall be placed in locations or zones shown or described in the approved shop drawings. Low-stress or compression areas are preferred.

Ensure that during fabrication, the heat number is maintained on each primary load-carrying component by paint until the component is permanently joined into a piece marked member or assembly.

460-4.3 Workmanship:

460-4.3.1 Cutting, Shearing and Machining: Cutting (including burning and sawing), shearing, and machining shall be accomplished in accordance with the AASHTO/AWS 1.5, Bridge Welding Code and the following requirements:

Plane, mill, grind or thermally cut the sheared edges of main load-carrying member plate components greater than 5/8 inch thick to a depth of 1/4 inch.

Cut and fabricate steel plates so that the primary direction of rolling is parallel to the direction of the member or component main stress. For flanges and webs, the direction of rolling is parallel to the flanges unless noted otherwise in the Contract Documents. Web splice plates may be rolled parallel to their length.

460-4.3.2 Bending:

460-4.3.2.1 Cold Bending: Fracture critical and non fracture critical plates and bars shall be cold bent, unless otherwise permitted according to the provisions of Section 460-4.3.2.2.

The minimum bend radii measured to the concave face of the plate, shall be taken as 5.0(t) for all grades and thicknesses of steel conforming to structural steel for bridges, AASHTO M 270M/M 270 (ASTM A709/A709M), where ‘t’ is the thickness of the plate

in inches. For cross-frame or diaphragm connection plates up to 0.75 inches, the minimum bending radii may be taken as 1.5(t). For all other grades of steel the minimum bend radii recommendations from the plate fabricator shall be followed, but the radii shall not be less than the minimums specified herein.

Wherever possible, bend lines shall be oriented perpendicular to the direction of final rolling of the plate. If the bend lines are parallel to the direction of final rolling, the minimum bend radii shall be increased to 7.5(t).

460-4.3.2.2 Hot Bending: Fracture critical and non-fracture critical plates and bars may be bent hot subject to the approval of the Engineer. Heat-shrink methods as described in 460-4.3.4 are also permitted. If hot bending is to be employed, the heating and bending procedure shall be submitted for review and approval by the Engineer. The plates and bars shall be bent hot at a temperature above the blue brittle temperature of steel (700° F), not to exceed the temperature limits in Table 460-2. The minimum radii of the hot bend must satisfy the requirements of 460-4.3.2.1.

460-4.3.3 Straightening: Member components, such as plates, angles or shapes, are to be straightened before the parts are assembled. Perform straightening such that no cracking or other damage occurs in the part. If heat is to be used for straightening, follow the provisions of 460-4.3.4.

460-4.3.4 Heat Application:

460-4.3.4.1 General: At various points during the fabrication of structural steel, applications of heat may be necessary for hot-bending, cambering, curving or straightening. Use the temperature limits and guidelines given in this Section, unless alternate procedures have been approved by the Engineer. Routine straightening of material other than quenched and tempered material shall be done in accordance with the temperature limits and guidelines as specified herein, but do not require a submitted procedure.

Heat curving may be used in conjunction with a cut-curve procedure, in which a portion of the curvature is obtained by cutting the plates to all or part of the required radius, except as limited by 460-4.3.4.4.

460-4.3.4.2 Heating Process and Equipment:

460-4.3.4.2.1 Maximum Temperatures: The maximum allowable temperature to which the material can be heated is given in Table 460-2, Maximum Temperature Limits for Heat Applications.

Table 460-2
Maximum Temperature Limits for Heat Applications

ASTM A709 Grade	Maximum Temperature, °F
36, 50, 50S, 50W & HPS 50W	1,200
HPS 70W & HPS 100W	1,100

460-4.3.4.2.2 Timing of Heat Applications: Conduct heating operations prior to the application of coatings.

460-4.3.4.2.3 Allowable Preload Stresses: Preload compressive stresses will be permitted up to 0.5 times the minimum specified yield strength (Fy) of the material. This stress limit is applicable to all steels covered by this specification as listed in Table 460-2. If jacks are used, energize and lock off prior to the application of heat.

460-4.3.4.2.4 Heating Tips: Apply heat using orifice tips only. Select tip sizes proportional to the thickness of the heated material.

460-4.3.4.2.5 Torches: Manipulate the heating torches to guard against general and surface overheating. In addition, place heat reflective sheet material against the web before applying heat to the inside flange surface. When heating the inside flange surface, point the torches to prevent applying heat directly to the web.

460-4.3.4.2.6 Heating Patterns: Fundamental heating patterns (such as vee, line, edge, spot, and strip) may be used separately or in combination. Mark vee and strip heat patterns on the material surfaces prior to heating. When heating, bring the steel within the planned pattern to the specified heating temperature as rapidly as possible without overheating the steel. Apply heat in accordance with the approved procedure.

460-4.3.4.2.7 Thin Wide Plates: Prevent buckling of thin wide plates by not applying excessive heat.

460-4.3.4.2.8 Verification of Temperatures: Use temperature-sensitive crayons, pyrometers, or infrared non-contact thermometers for verifying temperatures during heating operations. When heating patterns are used, make regular verifications of the temperatures throughout the pattern. Remove the heating flame from the material before taking measurements.

460-4.3.4.2.9 Cooling: Prior to the use of any artificial cooling, allow steel to cool below 600°F. Use only dry compressed air. Do not quench with water or a water and air mixture.

460-4.3.4.2.10 Reheating: Reheat only after the material has cooled below 250°F.

460-4.3.4.2.11 Over Heating: The Engineer may reject the product, if any portion of the material is exposed to heating higher than the allowable temperature.

460-4.3.4.3 Heat-Curving of Bridge Members (Weak Axis Shaping):

460-4.3.4.3.1 General: Rolled beams and girders may be heat-curved at the job site, provided that the heating is performed in accordance with the Engineer's approval.

460-4.3.4.3.2 Sequence of Operations: Heat curve members prior to the attachment of longitudinal stiffeners.

460-4.3.4.3.3 Web Position: When the radius is less than 1,000 feet, heat curve members with the web in the horizontal position or preloaded to induce stress prior to heating. Otherwise, members may be heat-curved with the web in either the vertical or horizontal position.

460-4.3.4.3.4 Subsequent Heats: If multiple locations are to be heated, do not reheat the same location until after at least three heats at other locations.

460-4.3.4.3.5 Locating Heating Patterns: Space the heating patterns along the full length of each flange to produce a circular (not parabolic) curvature. Adjust the heating patterns to produce the necessary curvature. Compensate for differences in flange thickness and width as necessary. Use enough heating patterns in each piece to eliminate chording effects.

460-4.3.4.4 Minimum Radius for Heat-Curving: Heat-curving of beams and girders is allowed when the horizontal radius of curvature measured to the centerline of the member web is greater than both values calculated by Equations 4.1 and 4.2 below, and greater

than 150 feet at any and all cross sections throughout the length of the member. Do not heat curve steels with a minimum specified yield strength greater than 50 ksi, other than ASTM A709, Grade HPS 70W.

$$R = \frac{14bD}{\sqrt{F_y \psi t}} \text{ in.} \qquad \text{(Equation 4.1)}$$

$$R = \frac{7500\,b}{F_y \psi} \text{ in.} \qquad \text{(Equation 4.2)}$$

where:

Fy = specified minimum yield point of member web, ksi;
ψ = ratio of the total cross section area to the cross-sectional area of both flanges;
b = width of the widest flange, inch;
D = clear distance between flanges, inch;
t = web thickness, inch;
R = radius, inch.

In addition to the above requirements, do not heat curve if the radius is less than 1,000 feet when the flange thickness exceeds 3 inches or the flange width exceeds 30 inches.

460-4.3.4.5 Heat-Cambering (Strong Axis Shaping):

460-4.3.4.5.1 General: Procedures for cambering of built-up plate girders shall be submitted as a part of the Producer Quality Control (QC) Plan. In the procedures, address any proposed preloading and heat application and control. Minor heat adjustments in camber at the finishing stage of the girder do not require approval if the patterns and temperatures are followed in accordance with the approved procedures.

Do not utilize heat-cambering as the primary source of vertical camber in horizontally curved main load-carrying members; cut the web plate to the required position. Only use heat-cambering on horizontally curved main members to adjust cut cambering with the approval of the Engineer.

460-4.3.4.5.2 Web Position: Support members to be heat-cambered with the web vertical. Space supports to take maximum advantage of dead load in the member prior to the application of heat.

460-4.3.4.5.3 Subsequent Heats: If multiple locations are to be heated, do not reheat the same location until after at least three heats at other locations.

460-4.3.4.5.4 Rolled Beams: Rolled beams may be heat-cambered to provide the required curvature at the producing mill. Attach all detail material, such as connection plates, bearing stiffeners and gusset plates, after the beam has been heat-cambered.

460-4.3.4.6 Heat-Straightening Damaged Structural Steel:

460-4.3.4.6.1 General: Submit procedures for heat-straightening for the Engineer's review prior to beginning the work. Describe in detail the distortion to be corrected and all details for preloading, heating, cooling, verifying final dimensions, and nondestructive testing.

460-4.3.4.6.2 Cracking: As a minimum, visually examine all heat-straightened areas. Notify the Engineer when suspected areas of cracking are found. Examine these areas by one or more of the following methods, as directed by the Engineer:

1. Visual examination;
2. Liquid penetrant examination
3. Magnetic particle examination
4. Ultrasonic examination
5. Radiographic examination

460-4.3.4.6.3 Restraining Forces: Restraining forces (usually jacks) shall be set to restrain the steel during heating, but allow free contraction during cooling. In addition, apply the restraining forces in a direction tending to restore the member and limit the magnitude so that the material is not overstressed during heating.

460-4.3.4.6.4 Heating: Heat the steel in a single pass following the specified pattern and allow it to cool to below 250°F prior to reheating. Select heating patterns and sequences appropriate for the type of damage and shape of the cross section. Simultaneous vee heats may be used provided the clear spacing between vees is greater than the width of the plate element.

460-4.3.4.6.5 Subsequent Repair: Heat cambered members damaged after cambering may be repaired. However, do not repair previously heat-straightened members in the same region of damage without the approval of the Engineer.

460-4.3.4.7 Heat Treatment:

460-4.3.4.7.1 General: When any special form of heat treatment is required, it will be described in the Contract Documents. Perform heat treatments prior to any boring, machining or straightening operations.

460-4.3.4.7.2 Stress Relief: Where required, perform thermal stress relief in accordance with the procedure outlined in the AASHTO/AWS D1.5, Bridge Welding Code. Provide welding materials consistent with the stress relieving process utilized.

460-4.3.4.7.3 Normalizing and Annealing: Where required by the Contract Documents, perform normalizing and annealing as defined in ASTM A941. Maintain temperatures uniformly throughout the furnace during heating and cooling so that the temperatures at any points on the member do not differ by more than 130°F.

460-4.3.4.8 Contact and Bearing Surfaces: Provide surface finishes of bearings, base plates, and other contact surfaces in accordance with the ANSI surface roughness requirements as defined in ANSI B46.1, Surface Roughness, Waviness and Lay, Part I, given in Table 460-3, ANSI Surface Roughness Requirements.

Table 460-3
ANSI Surface Roughness Requirements

Steel slabs	ANSI 2000 micro-inch
Heavy plates in contact with shoes to be welded	ANSI 1000 micro-inch
Milled ends to compression members, milled or ground ends of stiffeners or rockers	ANSI 500 micro-inch
Bridge rollers and rockers	ANSI 250 micro-inch
Sliding bearings	ANSI 125 micro-inch
Pins and pin holes	ANSI 125 micro-inch

460-4.3.4.9 Cleaning and Coating (Including Galvanizing):

460-4.3.4.9.1 General: Clean and coat the work in accordance with 460-2 and/or 460-7.2 and Sections 560, and 562.

460-4.3.4.9.2 Removal of Lubricants: Remove lubricants from the exposed surfaces of installed fastener assemblies and other surfaces in accordance with the approved Producer QC Plan or the paint manufacturer's recommendations prior to painting. Demonstrate the procedures to the Engineer prior to preparations for painting. Bring to the Engineer's attention any manufacturer's processes or procedures that conflict with those specified in the Contract Documents.

460-4.3.5 Bolt Holes:

460-4.3.5.1 General: Unless shown otherwise in the Contract Documents, the bolt hole geometry is to be as shown in Table 460-4, Bolt Hole Geometry.

Table 460-4
Bolt Hole Geometry

Bolt Diameter (d), inch	Standard (Diameter, inch)	Oversize (Diameter, inch)	Short-Slotted (Width, inch by Length, inch)	Long-Slotted (Width, inch by Length, inch)
1/2	9/16	5/8	9/16 x 11/16	9/16 x 1 1/4
5/8	11/16	13/16	11/16 x 7/8	11/16 x 1 9/16
3/4	13/16	15/16	13/16 x 1	13/16 x 1 7/8
7/8	15/16	1 1/16	15/16 x 1 1/8	15/16 x 2 3/16
1	1 1/16	1 1/4	1 1/16 x 1 5/16	1 1/16 x 2 1/2
> 1 1/8	d + 1/16	D + 5/16	(d + 1/16) x (d + 3/8)	(d + 1/16) x (2.5 x d)

Note: Except as shown elsewhere in the Contract Documents, bolt holes in the connections of primary members are to be standard size.

460-4.3.5.2 Holes, Tolerances and Quality: Make bolt (and anchor rod) holes using any method suitable to the Fabricator and as specified below; except holes for high strength fasteners in main or primary load-carrying members which are not to be punched full size, but may be thermally cut in accordance with 460-4.3.5.4 and ground smooth with the approval of the Engineer.

The misalignment of holes in a bolt group relative to the same holes in the component or components it is joined to in a connection, shall not exceed 1/32 inch for 85% of the bolt holes in that group. Bolt holes are to be normal to the work and have no tears, cracks, fins, dirt, loose rust, burrs or other anomalies, and the surface is to be flat within a slope of 1/20. Bolt holes are to be round within plus or minus 1/32 inch and within plus or minus 1/32 inch of the specified size. For subsize holes, a pin 1/8 inch smaller than the subsize holes must be able to pass through all assembled plies in at least 75% of the locations prior to reaming. Holes inclined more than 3 degrees to a surface in any direction must have a hardened beveled washer provided at that face. Unless specified elsewhere in the Contract Documents, it is not required to coat the inside of the bolt holes.

460-4.3.5.3 Slotted Holes: Slots may be made by a single punch, or by joining two adjacent drilled or punched holes when punching is permitted. When joining holes, thermal cutting is to follow the common tangent to the two holes, and this cut is to be ground. Do

not make slotted holes more than 1/32 inch in width nor 1/16 inch greater in length than specified. Grind smooth any flame cut portions of the slot to ANSI 1000 micro-inches.

460-4.3.5.4 Holes in Plates Not Subjected to Tensile Stress: Large diameter holes in heavy plates not subjected to tensile stress (such as bearing plates) and slotted holes in materials not subject to tensile stress may be thermally cut, followed by appropriate grinding to smooth the periphery. Stop the practice if gouges or other defects occur, or if directed by the Engineer. These holes are to meet the following criteria:

Do not thermally cut holes in ASTM A709, GradeHPS 100W steel. Provide hole centerlines aligned within plus or minus 1/16 inch of theoretical. The inside (cut) faces of the hole are to be perpendicular to the plane of the plate. Eighty-five percent of the (open) hole diameter is not to exceed that specified in the Contract Documents, plus or minus 1/16 inch. Local notches, gouges or the maximum diameter shall not exceed that specified in the Contract Documents plus or minus 3/32 inch.

460-4.3.5.5 Punching: Material forming parts of a member composed of five thicknesses or less of metal may be punched full-size. When more than five thicknesses of material are joined, material shall be subdrilled or subpunched and then reamed full-size, or drilled full-size while in assembly. Subpunched or subdrilled holes, when required, must be at least 3/16 inches smaller than the finished hole size.

Holes in cross frames, lateral bracing components, and the corresponding holes in connection plates between girders and cross frames or lateral components may be punched full size. Holes in longitudinal main load-carrying members, transverse floorbeams, and any components designated as fracture critical (FCMs) shall not be punched full-size.

460-4.3.5.6 Edge Distance: Provide minimum as-fabricated distance from the center of a bolt hole to an edge as given in Table 460-5, Edge Distances, unless otherwise shown in the Contract Documents.

Table 460-5
Edge Distances

Fastener Size, Inch	Sheared Edge, Inch	Rolled Edges of Plates or Shapes or Gas Cut Edges Inch
5/8	1-1/8	7/8
3/4	1-1/4	1
7/8	1-1/2	1-1/8
1	1-3/4	1-1/4

460-4.3.5.7 Bolted Splice Gaps: Unless shown elsewhere in the Contract Documents, the tolerance for bolted splice gaps (open distance face-of-web/flange to face-of-web/flange) shall be from zero (no gap between faces) to a maximum of 1/8 inch greater than the gap shown on the Plans. If no gap is shown in the Plans, assume that a nominal gap of 3/8 inch is required. In addition, meet the edge distance requirements, provided above.

460-4.3.5.8 Maximum Edge Distance: Unless otherwise specified in the Contract Documents, the maximum fabricated distance from any edge to the center of the hole shall be 8 times the thickness of the thinnest outside plate, not to exceed 5 inches with no additional tolerance allowed.

460-4.3.5.9 Spacing of Bolt Holes: Space bolt holes within plus or minus 3/16 inch of that shown in the Contract Documents.

460-4.3.5.10 Holding of Plies: When drilling or reaming is accomplished through multiple plies of material, do not hold the materials together by welds not specified in the Contract Drawings.

460-4.4 Member Geometry:

460-4.4.1 General:

460-4.4.1.1 Tolerances: Provide dimensional tolerances as follows:

1. Rolled shapes, plates, bars, wide flange sections and miscellaneous steel in accordance with ASTM A6;

2. Fabricate girders in accordance with the AASHTO/AWS D1.5, Bridge Welding Code and as described below;

3. For built-up members not specifically covered by AASHTO/AWS D1.5, apply AASHTO/AWS D1.5, Bridge Welding Code, except as noted below or as directed by the Engineer.

460-4.4.1.2 Camber and Sweep: Tolerances for camber and sweep of continuous and simply supported girders of any shape shall be as described in the AASHTO/AWS D1.5, Bridge Welding Code. The camber and sweep tolerances for steel pier caps shall be the same as those specified for girders. Measure sweep for horizontally curved members from the theoretical centerline for comparison to the aforementioned requirements.

460-4.4.1.3 Alternate Sections: Rolled sections or fabricated sections of equal or slightly greater dimensions than the section specified may be proposed for the Engineer's approval. Changes that reduce fatigue resistance or significantly affect splice design or deflection will require complete design calculations.

460-4.4.1.4 Web Flatness: Maximum deviation from flatness for webs of curved and/or cambered sections shall be the same as for straight built-up girders. Measure curved girder web flatness using a straightedge oriented perpendicular to the flanges ("vertical", flange to flange).

460-4.4.1.5 Girder Length: If measuring girder length with a device that is free of thermal effects, appropriately adjust the measurements to the reference temperature shown in the Contract Documents. Measure the length of horizontally curved girders along the arc.

460-4.4.2 Specialty Structures:

460-4.4.2.1 Box Members as Bent Caps:

460-4.4.2.1.1 Tolerances: Unless otherwise shown in the Contract Documents, submit tolerances for bearing planes and box twist to the Engineer for review and approval. Prior to submitting these tolerance values for approval, coordinate between the Erector and the Fabricator.

460-4.4.2.1.2 Bearings: Unless otherwise specified in the Contract Documents, each bearing is to be true to a tolerance of 1/32 inch across its entire width in either direction.

460-4.4.2.1.3 Beam Trueness: Unless otherwise specified in the Contract Documents, the plane of beam supports on the box girder (the bearing area specifically attached to the box girder) is to be true to the box girder bearing within 1/16 inch in the short direction and true to the vertical axis of the nesting girders (those girders attached to or resting on the box girder) within 1/16 inch.

460-4.4.2.2 Trapezoidal Bridge Members: As a minimum, trapezoidal bridge members (tub or box girders) shall meet AASHTO/AWS D1.5, Bridge Welding Code dimensional tolerances. Camber may be verified with the girder in its upright position, supported to avoid dead load deflections.

460-4.4.2.3 Pinholes: Unless shown elsewhere in the Contract Documents, bore pinholes:

1. True to the specified diameter;
2. Smooth to ANSI 3 (125 micro-inches);
3. At right angles with the axis of the member;
4. Parallel with each other; and
5. With a diameter of the pinhole not exceeding that of the pin by more than 0.015 inch for pins 5 inches or less in diameter, or 1/32 inch for larger pins.

460-4.4.2.4 Truss Chord Joints: Abutting joints in truss chords not specified to be mill-to-bear shall have openings of 1/4 inch, plus or minus 1/8 inch.

Abutting joints in truss chords specified to be mill-to-bear shall be faced and brought into bearing. When assembled, provide 85% or more of the abutting surfaces in full contact. Allowable visible gaps shall not exceed 1/64 inch.

460-4.4.2.5 Horizontally Curved Beams and Skewed Steel Girders: Account for torsion induced deflections for horizontally curved beams and skewed steel girders. Unless otherwise defined in the Contract Documents, a horizontally curved beam or girder is a longitudinal or transverse bridge component with a radius less than 10,000 feet anywhere along its continuous length.

460-4.5 Shop Assembly:

460-4.5.1 General: Ensure the fit of all connections and the geometry of all components. Unless specified elsewhere in the Contract Documents, check the fit of all longitudinal girder/beam lines in accordance with 460-4.5.1.1. Perform this prior to transporting the pieces in question to the site for erection.

460-4.5.1.1 Progressive Girder or Truss Assembly: Assemble the structure for a minimum of three spans, panels, field sections, segments or longitudinal chords of the structure. Successive assemblies shall consist of at least one longitudinal segment of the previous assembly, repositioned as necessary for accurate alignment, plus two or more longitudinal segments added at the advancing end. For entire structures less than 150 feet in length or less than three segments, assemble the entire longitudinal line. Meet the requirements of 460-4.5.1.4 when utilizing computer-numerically-controlled drilling equipment.

When a transverse structural steel member or members is required for the continuation of the uninterrupted girder or beam line, truss, arch rib, bent tower face or rigid frame, and is designated elsewhere in the Contract Documents to be shop assembled, the Fabricator may include this member or component in a separate subassembly and not the three segment longitudinal assembly (discussed above). If combined in a different subassembly, include the longitudinal member(s) or component(s), as designated elsewhere in the Contract Documents to be shop assembled, that frame directly into the transverse structural member. Do not include the transverse member(s) in the longitudinal assembly unless directed so elsewhere in the Contract Documents or by the Engineer. Account for end rotations and deflections as necessary, and submit the procedure to the Engineer for review.

460-4.5.1.2 Progressive Chord Assembly: When specified elsewhere in the Contract Documents, assemble the truss chords for a minimum of three panels or longitudinal

segments of the structure. Successive assemblies shall consist of at least one longitudinal segment of the previous assembly, repositioned as necessary for accurate alignment, plus two or more longitudinal segments added at the advancing end. For entire structures less than 150 feet in length or less than three segments, assemble the entire longitudinal line. Meet the requirements of 460-4.5.1.4 when using computer-numerically-controlled drilling equipment.

Account for transverse members indicted elsewhere in the Contract Documents to be included in the shop assembly as in 460-4.5.1.1.

When assembled in accordance with this subsection, the holes of the connections will be so located that they will be drilled to the final geometric angles. This will require that the truss members, when erected under the no load (or practically no load or stress) condition, must be bent and forced to fit the end conditions. This condition will introduce an initial reverse secondary stress that will theoretically wane when the structure assumes the loading for which it is cambered. Submit the procedure to the Engineer for review.

460-4.5.1.3 Special Complete Structure Assembly: When specified elsewhere in the Contract Documents, this type of shop assembly will include assembling the entire structure including the diaphragms, cross frames, integral steel substructure and floor components. Miscellaneous components are not included unless directed elsewhere in the Contract Documents. Establish procedures for each structure or structure type including consideration of incremental erection, temporary field support locations, stage construction and final tightening of field connections. Submit the procedures for review by the Engineer.

460-4.5.1.4 Computer-Numerically-Controlled (CNC) Drilling Associated with Progressive Girder, Truss or Chord Assembly: If the Fabricator chooses to drill the holes in all plies of all connections of the continuous main girder or beam line, truss, arch rib, bent, tower face or rigid frame and any intersecting (transverse) members utilizing computer-controlled-numerical drilling procedures, piece-wise assembly of the entire continuous girder or beam line, truss, arch rib, bent, tower face or rigid frame is not required if the following requirements are met:

Prior to transporting to the site, perform a check fit of the first three spans, panels, field sections, segments or longitudinal chords; or entire first bent, tower face or rigid frame of the structure to ensure the accuracy of the CNC procedures and equipment.

As selected by and at the discretion of the Engineer and prior to transporting to the site, perform another check fit of a different assembly of three spans, panels, field sections, segments or longitudinal chords; or another entire bent, tower face or rigid frame of the structure to ensure that the accuracy of the CNC procedures and equipment is maintained. If either of the above fails to meet the Contract requirements, assemble the entire girder or beam line, truss, arch rib, bent, tower face or rigid frame as originally prescribed in 460-4.5.1.1 or 460-4.5.1.2 as prescribed elsewhere in the Contract Documents. Account for transverse members indicated elsewhere in the Contract Documents to be included in the shop assembly as in 460-4.5.1.1.

460-4.6 Evaluation of Work: The Engineer will evaluate and accept materials and work conforming to the Contract Documents. These evaluations may take place prior to or following delivery of the materials to the site of the structure. Materials or work that fails to meet Contract requirements will be rejected.

The Engineer may, at his sole discretion, permit further inspections and testing of materials or work that fail to meet Contract requirements for acceptance. The cost of such inspections and tests shall be borne by the Contractor.

Bring to the attention of the Engineer, all nonconforming work and or materials that cannot be brought into conformance with the Contract Documents using pre-established procedures as outlined in the Department approved Producer QC Plan. Submit the following information to the Engineer:

A cover letter prepared on the Contractor's letterhead and addressed to the Engineer briefly describing the nonconforming work and the proposed credit to the Contract proportionate to the nonconformance. For each fabricating facility and for each project within that fabrication facility, submittals must be numbered consecutively beginning with the number 1, at the start of each project. Erectors will start with one for each individual project.

A completed Department Nonconforming Structural Steel and Miscellaneous Metal Component Data Sheet prepared by the Contractor and countersigned by the Engineer's designated representative to indicate agreement between the Contractor and the Department regarding the nonconformance, not any solution, resolution or credit. If the Contractor and the Engineer's designated representative are not in agreement regarding the nonconformance, the Engineer's designated representative will either reject the submittal indicating the reason(s) for the rejection or modify the submittal and forward to the Engineer. In the event of modification, the Contractor will initial the submittal before being forwarded to the Engineer, thereby indicating the Contractor's concurrence with the modification.

A list of supporting information such as sketches, documentation, calculations, pictures, etc., must be included in the appropriate space on the Nonconforming Component Data Sheet. Supporting information regarding Contract Document noncompliance in the form of separate documents is only necessary when space on the Department Nonconforming Structural Steel and Miscellaneous Metal Component Data Sheet is inadequate for the required data. All of the supporting information required for the form must be prepared by, or under the supervision of, the Specialty Engineer who will sign and seal the supporting information.

If requested by the Engineer, submit a structural and durability evaluation of the proposed repair and/or remediation. This evaluation must be conducted under the supervision of a Specialty Engineer and the submittal is to bear the Specialty Engineer's signature and seal.

460-4.7 Member or Component Certification: Coordinate with the Engineer to schedule final inspection of the completed work within two weeks prior to shipment or erection to verify that all Contract Document requirements have been met. After verification that all Contract Document requirements have been met and all necessary repairs have been satisfactorily completed, the Quality Control Manager shall certify, by initials and/or signature, such materials, components or members. The record shall include certification for:

1.Items being shipped or stored prior to final assembly. Affix a certification in the form of a stamp or tag in accordance with 460-4.2 and as indicated in the Producer Q C Plan, and with a copy of the certification placed in the Contractor's permanent project records,

2. Work being placed into its final position. Document in the Contractor's permanent project records.

Submit a summary certification at the least once a month or with each payment request that includes the following or similar wording. "The undersigned, being a responsible official of (insert Contractor identification) certifies that the materials, components or members listed herein have been produced under strict quality control and meet the requirements of the Contract Documents" Include a positive identification in the certification such that the applicable materials, components and/or members can be uniquely identified utilizing just the summary certification document. The Quality Control Manager shall sign this summary certification.

460-5 Bolted Connections.

460-5.1 General: High strength bolts are described as follows:

1. ASTM F3125 Grade A325 or as Grade A325
2. ASTM F3125 Grade A490 or as Grade A490

Use bolts as follows:

1. Use galvanized Grade A325 Type 1 bolts in all field installed bolted structural steel connections for painted steel.
2. Use either black or galvanized Grade A325 Type 1 bolts in all shop installed bolted structural steel connections that will be shop painted.
3. Use black Grade A325 Type 3 bolts in all bolted structural steel connections for weathering steel that is to remain unpainted.
4. Use the bolts as specified for connected assemblies or parts that are designated as miscellaneous components where the fastener type is specified elsewhere in the Contract Documents.

Tighten Grade A325 bolts in accordance with the procedures specified below for turn-of-nut or direct-tension-indicator (DTI) tightening.

Lubricate and maintain consistency in lubrication of fastener assembly during Rotational Capacity (RC) testing and installation. Assemblies that exhibit a loss of lubrication, as determined by the Engineer, may be re-lubricated and retested prior to installation.

Use Grade A490 bolts only with the approval of the Engineer. Submit procedures in accordance with ASTM F3125 Grade A490 for the handling, lubrication, installation, tightening and testing of such bolts. Do not install Grade A490 bolts without prior approval of the procedures by the Engineer.

When the Engineer approves ASTM A307 bolts for use in miscellaneous components, tighten them such that the plies of the joint are in firm contact. Use three to five impacts of an impact wrench or the full effort of a person using an ordinary spud wrench to obtain a snug connection.

Fasten aluminum, other materials or assemblies of dissimilar materials in accordance with the Contract Documents.

Install ordinary rough or machine bolts and nuts in accordance with the Contract Documents.

460-5.2 Testing:

460-5.2.1 Rotational Capacity (RC) Tests: At the location of and prior to installation of permanent high-strength fasteners in main or primary load-carrying member connections, perform RC tests in accordance with FM 5-581 (for long bolts) or FM 5-582 (for short bolts) to ensure that the fasteners are capable of developing the specified strength and that the fasteners are properly lubricated. As a minimum, test two assemblies per LOT designation. The bolt, nut and washer shall come from the same LOT and be packed in the same container (or group of containers assigned the same LOT), except in special cases where nuts and washers have only one production LOT number for each size.

Short bolts may also be tested using FM 5-583 with DTIs calibrated with long bolts installed in a Tension Measuring Device.

Washers are required for RC tests even though they may not be required for jobsite installation. Where washers are not required for jobsite installation, LOT identification is not required. The washer coating shall be the same as that for the bolt and nut.

If any of the required tests fails, the entire LOT will be rejected.

460-5.2.2 Verification of Direct Tension Indicator (DTI) Device Performance: On a daily basis (when DTI devices are being installed) and at the location of installation, perform DTI Verification tests in accordance with FM 5-583. Perform this test on a minimum of two high-strength fastener assemblies from each fastener assembly LOT and position of the DTI prior to production installation. If either assembly fails, test additional fastener assembly LOT/DTI combinations as requested by the Engineer to verify that the Requirements of the Contract Documents have been satisfied. These two tests are in addition to the RC tests required in 460-5.2.1. If, after additional testing, the DTI fails to meet the requirements of FM 5-583, the LOT will be rejected by the Engineer.

460-5.3 Reuse and Retightening: Do not reuse Grade A490 bolts or galvanized Grade A325 bolts. Black Grade A325 bolts with free spinning nuts may be reused one time with the Engineer's approval. Previously tightened bolts that may have been loosened by the tightening of adjacent bolts can be further tightened from the original position. Ensure proper lubrication prior to retightening. Discard and replace fractured or damaged bolts.

460-5.4 Assembly of Bolted Connections:

460-5.4.1 General: Verify that the faying surfaces are in accordance with the Contract Documents, are free of dirt or other foreign materials, and that the geometry of the bolt holes and the connection meets the requirements of 460-4.3.5.

Install fastener assembly components of the same LOT and of the size and quality specified in the Contract Documents. Provide final bolts, cylindrical erection pins or other fit-up bolts as indicated in the Erection Plan.

When it is impractical to turn the nut, tighten the fastener by turning the bolt while preventing the nut from rotating. During this tightening operation, do not allow the rotation of the part of the fastener assembly not turned by the wrench.

460-5.4.2 Preparation of Faying Surfaces: Provide coated and non-coated faying surfaces in accordance with the Contract Documents. Faying surfaces specified as blast-cleaned must satisfy SSPC SP-10 'Near-White Blast Cleaning.'

When painting of the slip-critical faying surface of bolted connections is required, use only the prime coat. Prepare and coat the faying surfaces prior to installation of the fasteners. Provide certification of the slip critical classification required in the Contract Documents.

Submit certification to the Engineer that galvanized faying surfaces meet or exceed a Class C slip critical classification, unless a different classification is required elsewhere in the Contract Documents. Mechanically roughen galvanized faying surfaces in accordance with the galvanizer's recommendations.

460-5.4.3 Reaming: Do not over size bolt holes by reaming (or any other method) without the approval of the Engineer.

460-5.4.4 Drifting: Do not over size, stretch or otherwise damage bolt holes by improper and excessive drifting.

460-5.4.5 Splice Plate Filler Material: Unless otherwise specified in the Contract Documents, provide filler material edges within 1/8 inch of the adjacent splice material edge. Where required for proper alignment at a bolted flange splice, additional filler material may be added provided that the total thickness of filler plates is less than 1/4 inch.

460-5.4.6 Installation of Fastener Assemblies: Unless shown otherwise in the Erection Plan, install the bolts of the connection by progressing systematically from the most rigid part of the connection to the free edges. Install bolts in all holes of the connection and bring

them to a “snug tight” condition. Following the sequence indicated in the Erection Plan, further tighten all the bolts in the connection.

For Grade A325 bolts, obtain the required bolt tension as shown in Table 460-6, Minimum Required Fastener Tension in accordance with the turn-of-nut method specified in 460-5.4.8, or when DTIs are used, the DTI tightening method specified in 460-5.4.9.

For connections (such as large main load-carrying members or truss joints) in which previously tightened high strength bolts become loose and require retightening upon the tensioning of others, install into a minimum of ten percent of the holes fully tensioned bolts prior to final tensioning of the permanent bolts. Distribute these first bolts randomly throughout the connection. If directed by the Engineer, remove the initial bolts and install permanent bolts at each location, otherwise retighten in accordance with 460-5.3.

Table 460-6
Minimum Required Fastener Tension

Bolt Size, inch	Tension Grade A325 bolts, kips
5/8	19
3/4	28
7/8	39
1	51
1-1/8	64
1-1/4	81
1-3/8	97
1-1/2	118

460-5.4.7 Bolt Tension: Provide a Skidmore-Wilhelm Calibrator, or other equivalent bolt tension measuring device, wherever final connections are being made. Confirm the accuracy of the tension measuring device by having it calibrated by an approved testing agency once a year.

460-5.4.8 Turn-of-Nut Tightening: For each work shift, perform tests utilizing a representative sample of five fastener assemblies, from each LOT to be installed that shift. Perform the tests using the tension measuring device, following the same procedure to be used for actual installation of the fastener assemblies, to a snug-tight tension and corresponding torque, which, when the additional turns required in Table 460-7, Nut Rotation from the Snug-Tight Condition are added, will result in at least 1.05 times the minimum required fastener installation tension as shown in Table 460-6. Place a washer under the part turned in the tightening of the bolt. Consider the job inspection snug-tight torque as the average of three test values determined after rejecting the high and low-test values.

For fastener assemblies too short to fit in the tension measuring device, modify the determination of the job inspection snug-tight torque in accordance with FM 5-582.

460-5.4.8.1 Snug-Tight Condition: In the turn-of-nut method, first bring all the fastener assemblies of the connection to a “snug-tight” condition to ensure that all parts of the connection are in firm contact with each other. For the purposes of this specification, “firm contact” shall mean the condition that exists on a faying surface when the plies are solidly seated against each other, but not necessarily in continuous contact. Regard snug-tight as the tightness

required to produce the bolt tension, which following the final applied rotation, produces at least 1.05 times the minimum required bolt tension in accordance with Table 460-6, Minimum Required Fastener Tension. In the presence of the Engineer, and on a daily basis, determine the job inspection snug-tight torque as specified herein.

460-5.4.8.2 Final Tightening: After verification of the snug-tight condition in accordance with 460-5.4.11 by the Engineer, tighten all fastener assemblies in the joint by applying the applicable amount of nut rotation specified in Table 460-7, Nut Rotation from the Snug-Tight Condition. Once snug-tight, bring all fasteners to the required tension within the same work shift.

Table 460-7
Nut Rotation from the Snug-Tight Condition

Bolt Length Measured from Underside of Head to End of Bolt	Both Faces Normal to Bolt Axis	One Face Normal to Bolt Axis and Other Face Sloped Not More than 20:1. Bevel Washer not Used.	Both Faces Sloped Not More than 20:1 from Normal to Bolt Axis. Bevel Washers not Used.
Up to and Including Four (4) Diameters	1/3 turn	1/2 turn	2/3 turn
Over Four (4) Diameters but not Exceeding Eight (8) Diameters	1/2 turn	2/3 turn	5/6 turn
Over Eight (8) Diameters but Not Exceeding Twelve (12) Diameters	2/3 turn	5/6 turn	1 turn

Notes:
1. Nut rotation is relative to the bolt, regardless of the element being turned.
2. Tolerance for bolts installed by 1/2 turn or less is ± 30 degrees. For bolts installed by 2/3 turn or more, the tolerance is ± 45 degrees.
3. Nut rotations given are only applicable to connections in which all material within the grip of the bolt is steel.
4. For bolt lengths exceeding 12 diameters, establish the required rotation by performing actual tests in a suitable tension device simulating the actual conditions. Submit procedures to the Engineer for review.

460-5.4.9 Direct-Tension-Indicator (DTI) Tightening: After complying with the requirements of 460-5.2.2, install and tighten DTI devices following the procedures described in the DTI Verification Test. Do not permit the DTI to turn during installation and tightening. Provide washers in accordance with 460-5.4.10.

460-5.4.9.1 Snug-Tight Condition: Install the bolts as specified through Step 3 (Snug-Tight Condition) of the DTI Verification test. If the 0.005 inch feeler gage is refused in more gaps than shown in the table in Step 3.5 of the test, or the DTI device becomes loose and can be spun by hand, remove the bolt and DTI device, discarding the DTI device. Provide a new DTI device and reinstall the assembly and bring to the snug-tight condition.

460-5.4.9.2 Final Tightening: After verification by the Engineer that the snug-tight condition for all bolts has been met, tighten all fastener assemblies in the joint such that the number of spaces in which the 0.005 inch thickness gauge is refused is equal to or greater than the number shown in Table 460-8, DTI Device Tightening Criteria. Once snug-tight, bring all fasteners to the required tension within the same work shift.

Table 460-8 DTI Device Tightening Criteria						
Number of Spaces in DTI	4	5	6	7	8	9
Minimum Spaces in which Gage is Refused	2	3	3	4	4	5

Do not tighten the assembly beyond the smallest gap permitted in Step 3.5 of FM 5-583. Remove and replace bolts, discarding the DTI, which have a DTI with a smaller gap or no gap.

460-5.4.10 Washers:

460-5.4.10.1 General: Provide ASTM F436 hardened steel washers as follows:

1. For connections (and all associated testing) using Grade A490 bolts, use a hardened washer under each element.
2. For connections using Grade A325 bolts, use hardened washers under the turned element.
3. Use hardened steel washers as part of the Rotational Capacity tests.
4. Where the outer face of the bolted parts has a slope of greater than 20:1 with respect to a plane normal to the bolt axis, use a hardened, beveled washer to compensate for the lack of parallelism.
5. Where bolts are to be installed in a oversized or slotted hole in an outer ply, provide a single washer satisfying ASTM F436, or continuous bar satisfying ASTM A709: for Grade A325 bolts, provide a thickness of at least 5/16 inch; and for Grade A490 bolts, provide a thickness of 3/8 inch. Provide these washers or bars to completely cover the slot after installation. Provide a finish consistent with the bolt specified.
6. In non-Direct-Tension-Indicator (DTI) applications, clip washers on one side to a point not closer than 7/8 of the bolt diameter from the center of the washer, if necessary.

460-5.4.10.2 Use of Washers with Direct-Tension-Indicators (DTIs) Devices: When DTIs are used; use ASTM F436 hardened washers as follows:

1. When the nut is turned and the DTI is located under the bolt head, a hardened washer is to be located under the nut.
2. When the nut is turned and the DTI is located under the nut, a hardened washer is to be located between the nut and the DTI.
3. When the bolt head is turned and the DTI is located under the nut, a hardened washer is to be located under the bolt head.
4. When the bolt head is turned and the DTI is located under the bolt head, a hardened washer is to be located between the bolt head and the DTI.

460-5.4.11 Inspection:

460-5.4.11.1 Turn-of-Nut Tightening:

1. Once the snug-tight condition is achieved for all of the fastener assemblies of the connection, within 24 hours of snugging the first bolt in the connection and in the presence of the Engineer, verify for a minimum of three (3) bolts [two (2) for two bolt connections] or 10% of the fastener assemblies, that the job inspection snug-tight torque has been attained. These fasteners are to have a snug-tight torque equal to or exceeding that specified

in 460-5.4.8. Perform this check using the same torque wrench used in 460-5.4.8. For bolts tested in accordance with FM 5-583 or when multiple torque wrenches are required, provide a calibrated torque wrench or wrenches.

2. If the tested fasteners do not obtain the job inspection snug-tight torque, test all remaining untested fastener assemblies using the torque wrench in the connection in question. Following testing of all assemblies, bring to snug-tight all assemblies and retest as stated above. Re-snug and retest as necessary using the calibrated torque wrench until the minimum testing stated above is performed favorably.

3. Following confirmation of the snug-tight condition as performed by the Contractor, and in the presence of the Engineer, match mark the fastener assemblies on the end of the bolt thread and on the nut, and then tighten the nut the amount of rotation specified in Table 460-7, Nut Rotation from the Snug-Tight Condition. The Engineer will accept the connection as fully tightened when all of the following conditions are met:

a. the rotation specified in Table 460-7 has been achieved,
b. there are no loose assemblies in the connection,
c. all plies of the connection are in firm contact,
d. there are no indications that excessive stretching or yielding has occurred in the fastener assembly,
e. bolt stick-through is consistent per LOT.

460-5.4.11.2 Direct-Tension-Indicator (DTI) Tightening: Prior to bringing the connection to a snug-tight condition, verify in the presence of the Engineer that the 'dimples' of the DTI are not deformed or damaged. Bring the connection to a snug-tight condition and tighten in accordance with the requirements of 460-5.4.9. The Engineer will accept the connection as fully tightened when all of the following conditions are met:

1. The requirements of 460-5.4.9 have been achieved,
2. There are no loose assemblies in the connection,
3. All plies of the connection are in firm contact,
4. There are no indications that excessive stretching or yielding has occurred in the fastener assembly,
5. Bolt stick-through is consistent per LOT.

460-6 Welding.

460-6.1 General: Perform all shop and field welding in accordance with the applicable AWS Welding Code. This requirement includes the use of qualified welders, qualified weld procedures, and qualified inspection personnel.

460-6.2 Welding on Non-Dynamically Loaded Elements: Perform welding on miscellaneous components and other statically (non-dynamically, non-cyclically, etc.) loaded structural elements in accordance with the AWS D1.1, Structural Welding Code, or the AASHTO/AWS D1.5, Bridge Welding Code.

460-6.3 Electroslag Welding: Perform NGI-ESW welding in accordance with the AASHTO/AWS D1.5, Bridge Welding Code.

460-6.4 Welding of Hollow Structural Steel Sections (Pipes and Tubes): Except as noted in the Contract Documents, perform all shop and field welding of Hollow Structural Shapes in accordance with the AWS D1.1, Structural Welding Code as amended herein.

460-6.4.1 Highway Sign, Lighting and Traffic Signal Support Structures: For structural steel supports for signs, lighting, and traffic signals, comply with the AWS D1.1 Structural Welding Code as amended by the following.

Unless otherwise shown in the Plans, perform ultrasonic testing (UT) or radiographic testing (RT) on complete joint penetration welds at the following frequency (use the AWS D1.1 Tubular Connections Class R Criteria for UT and Cyclically Loaded Criteria for RT.

One hundred percent of each joint subject to tension or reversal of stress.

Twenty-five percent of each joint subject to only compression or shear. If discontinuities are found in the joint, the remainder of the joint shall be tested.

Perform Magnetic Particle Testing at the following frequencies:

A minimum of 25% of all fillet or partial penetration groove welds in main members (Use the AWS D1.1 Tubular Connections Criteria). If discontinuities are found, the remainder of the welds on the members shall be tested.

460-6.4.2 Tubular Bridge: Comply with the requirements of the AWS D1.1 Structural Welding Code as amended by the following:

Unless otherwise shown in the Plans, perform ultrasonic testing (UT) or radiographic testing (RT) on complete joint penetration welds at the following frequency (use the AWS D1.1 Tubular Connections Class R Criteria for UT and Cyclically Loaded Criteria for RT).

One hundred percent of each joint subject to tension or reversal of stress.

Twenty-five percent of each joint subject to only compression or shear. If unacceptable discontinuities are found in the joint, the remainder of the joint shall be tested.

Perform Magnetic Particle Testing at the following frequencies:

A minimum of 25% of all fillet or partial penetration groove welds in main members (Use the AWS D1.1 Tubular Connections Criteria). If unacceptable discontinuities are found, the remainder of the welds on the members shall be tested.

460-6.4.3 Overhead Sign Structures and Toll Gantries: Comply with the requirements of the AWS D1.1 Structural Welding Code as amended by the following:

Unless otherwise shown in the Plans, perform 100 percent ultrasonic testing (UT) or radiographic testing (RT) on all complete joint penetration welds.

Prior to galvanizing, perform Magnetic Particle Testing (MT) at the following frequencies:

One hundred percent of all fillet or partial penetration groove welds in the upright columns. A minimum of 25% of all other fillet or partial penetration groove welds in main members other than upright columns. If unacceptable discontinuities are found, the remainder of the welds on the member shall be tested.

After members are galvanized, perform one hundred percent MT of all fillet welds in the upright columns.

For acceptance, use AWS D1.1 Tubular Connection Criteria for MT, Tubular Connection Class R Criteria for UT, and Cyclically Loaded Criteria for RT.

460-6.5 Field Welding: Field weld only with the approval of the Engineer or as shown in the Plans. All field welding operations must be conducted in accordance with AWS D1.5 and in the presence of a Certified Welding Inspector.

460-6.6 Tack Welds: Do not weld or tack any fill plates, brackets, clips, shipping devices, or other materials not required by the Contract Documents or allowed by the AASHTO/AWS D1.5 Bridge Welding Code.

460-7 Erection.

460-7.1 Pre-erection Requirements:

460-7.1.1 Erection Quality Control (QC) Plan: Submit an Erection QC Plan for review and approval of the Engineer.

460-7.1.2 Submittals: Meet the requirements of Sections 5 and 103 for any required submittals. Provide submittals to the Engineer for review by the Department in accordance with Section 5 and the Contract Documents.

460-7.1.3 Erection Plan: Submit, for the Engineer's review, an Erection Plan locating all primary members, lifting equipment and temporary supports or braces, and bolting pattern tightening procedures not considered routine. Ensure that the plan includes the Specialty Engineer's signature and stamp. Include supporting calculations indicating that the design unit stresses indicated in the Contract Documents have not been exceeded. Submit this plan or plans to the Engineer three weeks before erecting the piece or pieces.

Include the following information in the Erection Plan:

1. A plan of the work area showing all substructure units and foundations; surface roads and railroads; all streams, creeks and rivers; all overhead utilities; and any underground utilities that could possibly impact, or be adversely affected by, erection operations as determined by the Specialty Engineer.
2. The erection sequence for all primary load-carrying members and all primary load-carrying member bracing. Note any and all permanent or temporary support and/or bracing locations, including crane-holding positions.
3. The center of gravity locations, pick weight and delivery orientation for all primary load-carrying members.
4. Identify any bolting requirements not considered routine.
5. Locate all pick crane work points.
6. Identify all temporary works and staging areas such as barges, mats and temporary excavation support.
7. Include capacity charts on the drawings for each crane configuration and boom extension utilized.
8. Details of all temporary bracing, falsework, towers and shoring.
9. Submit any procedures requested by the Engineer and not contained in the Erection Plan.

460-7.2 Special Requirements for Uncoated Weathering Steel:

460-7.2.1 General: Do not use marking materials (grease sticks, crayons) that leave behind a residual film that may affect the weathering process of the steel. Store the girders as required for non-weathering steels.

460-7.2.2 Steel Preparations: Prior to erection, perform the following as appropriate:

Blast clean the exposed fascia of the exterior girders (both I and box) to meet SSPC-SP10 criteria; blast clean the remaining exposed surfaces of steel trapezoidal girders, not required to be prepared otherwise, to meet SSPC-SP6 criteria; for steel I-girders, if a non-uniform mill scale finish has developed, as determined by the Engineer, blast clean all remaining exposed surfaces, not required to be prepared otherwise, to SSPC-SP6 criteria; coat the inside of box members including, but not limited to, all bracing members, cross frames and diaphragms in accordance with Section 560. Coat the exterior face of box girder end diaphragms and all interior

surfaces of box girders extending beyond the end diaphragm with an inorganic zinc coating system in accordance with Section 560.

460-7.2.3 Concrete Substructure Preparations:

460-7.2.3.1 Substructure Areas Not Receiving Class 5 Finish: Prior to erection of the girders, cover all exposed substructure concrete surfaces to protect them against staining from the weathering steel components. Leave the covering in place until after placement of the concrete deck. As directed by the Engineer, clean all visible stains on concrete in areas not receiving a Class 5 Finish by sandblasting and follow-on cleaning using a stain remover or commercial cleaner after completion of the structure in accordance with Section 400.

460-7.2.3.2 Substructure Areas Receiving a Class 5 Finish: If the Class 5 Finish is to be applied prior to the placement of the concrete deck, cover all finish concrete surfaces after application and curing of the Class 5 Finish to protect them from staining from the weathering steel components. Leave the covering in place until after placement of the concrete deck. Upon removal of the covering, reapply the Class 5 Finish to cover any stains which may be present.

If the Class 5 Finish is to be applied after placement of the concrete deck, no substructure covering will be required.

460-7.2.4 Structure and Site Clean Up: Upon the completion of construction, remove all oil, dirt, grease or other foreign material, including excessive or uneven mill scale from the steel. Remove lubricants from the exposed surfaces of installed fastener assemblies and other surfaces in accordance with the manufacturer's recommendations. Follow procedures specified in Section 560 as appropriate. Final surface finish is to be an even mill scale as approved by the Engineer.

460-7.3 Coordination with Substructure: Prior to the erection of primary load-carrying members, conduct a survey to document the vertical, longitudinal and transverse position of all substructure units and anchor rod locations. Appropriately account for ambient temperature in the survey.

Should a discrepancy be identified with the Contract Documents, submit the necessary details to the Engineer for resolution.

460-7.4 Placing Anchor Rods: Locate and place anchor rods within the tolerance shown in the Contract Documents or within 1/4 inch of the theoretical location shown. If anchor rods cannot be located to the specified tolerance, place only with the approval of the Engineer. Unless shown otherwise in the Contract Documents, provide galvanized anchor rods, nuts and washers as follows:

1. Set the anchor rods in preformed holes vertical to the plane of the bridge seat.
2. Provide 4 inch diameter holes.
3. Provide non-shrink grout/mortar of a strength greater than or equal to that of the substructure concrete strength, or as shown elsewhere in the Contract Documents.
4. Install the rods in accordance with the grout/mortar manufacturer's recommendations.
5. Clean the threads of the anchor rods as necessary without damaging the coating.

460-7.5 Preparation of Bearing Areas and Setting of Bearings: Prior to placing superstructure bearing units (including but not limited to neoprene pads and masonry plates), prepare the top of concrete pad (bearing area) in accordance with Section 400. If a discrepancy is identified, report it to the Engineer for resolution.

For expansion bearings with slotted holes for anchor rods, which allow movement of the superstructure with respect to the substructure, vary the location of the slotted plate in relation to the anchor rods, in accordance with the prevailing temperature at the time of setting.

For fixed bearings at multiple adjacent piers, if necessary, horizontally jack the substructure units to correctly set the centerline of bearing. Adequately account for temperature.

Unless specified elsewhere in the Contract Documents, locate the theoretical centerline of bearings to within 1/16 inch transverse to longitudinal girder lines; and in the direction parallel to the longitudinal girder line locate the theoretical centerline of bearing within 1/4 inch of the theoretical centerline of bearing.

After setting the bearings and installing anchor rod nuts, washers and any other associated hardware specified in the Contract Documents, clean the protruding/exposed surfaces of the assembly of all deleterious material. Finish-coat metal parts in accordance with 460-4.3.4.9.

460-7.6 Tightening of Anchor Bolt/Rod Nuts:

460-7.6.1 Fixed and Expansion Pot Bearing: Tighten anchor bolts or rod nuts to a 'snug tight' condition such that the different mating surfaces (such as the top of concrete, neoprene and steel) are in firm contact. The nut or bolt is to be tight enough to develop friction between surfaces to prevent sliding, but not over-tightened that bulging or damage occurs in any of the mating materials.

460-7.6.2 Fixed and Expansion Bearings with Elastomeric Bearing Pads: Draw down the lower nut such that a total gap of 1/2 inch exists between the nut and bearing plate. Tighten a second nut of the same specification to a snug tight condition against the lower nut maintaining the required gap.

460-7.7 Bolted Connections: For splice connections of primary members, as well as connections of diaphragms or crossframes, fill at least 50% of the holes prior to crane release. The 50% may be either erection bolts in a snug tight condition or full size erection pins, but at least half (25% of all holes) shall be bolts, and sufficient pins shall be used near outside corners of splice plates and at member ends near splice plate edges to ensure alignment. Filled holes should be uniformly distributed between the web and flange connections for primary members such that approximately 50% of the web connections are filled and approximately 50% of the flange connections are filled. For diaphragms or cross-frames, the filled holes should be uniformly distributed between all the bolt groups connecting the diaphragm or crossframe to the primary member. The 50% requirement may be waived if a reduced percentage is calculated as sufficient and shown on the approved Erection Plan. Primary member splice connections that are made up on the ground (prior to erection) shall be 100 percent complete prior to any lifting operation. Fully tighten all bolts prior to installation of deck forming for each unit.

460-7.8 Final Position of Girder Webs: Unless shown elsewhere in the Contract Documents, detail the girders and cross frames as directed by the Engineer. The final condition is to be defined as with the deck and parapets cast, but without any future wearing surface. A web will be considered plumb if it is within a tolerance horizontally between the top and bottom of the web of 3/32 inch per foot of web depth compared against the theoretical position as required in the Contract Documents. Measure the out-of-plumb perpendicular to the face of the web. Erect trapezoidal girders to the geometry shown in the Contract Documents to the same 3/32 inch per foot of web depth tolerance.

460-7.9 Inspection and Final Acceptance:

460-7.9.1 General: Perform Quality Control inspections of all phases of the work. The inspection frequency and depth shall be sufficient to ensure that all materials and workmanship incorporated into the work meet the requirements of the Contract Documents and that the processes are controlled to ensure that the final finished product(s) conform to the physical characteristics and dimensions required by the Contract Documents. The Quality Control Manager shall be responsible for all inspection operations. An adequate number of Quality Control Inspectors shall be available to ensure review of all materials and fabrication processes are preformed in accordance with the Producer QC Plan. Weekly meetings shall be held with the Engineer to review inspection findings. The review of this information is to identify any refinements and/or improvements in the process being utilized in the work. The frequency of the meetings may be altered by the Engineer.

460-7.9.2 Inspection/Final Acceptance: Ensure the final alignment, profile and fastening of the erected steel is in accordance with the Contract Documents.

460-8 Method of Measurement.

460-8.1 General: The quantities to be paid for will be the items covered by this Section, following acceptance by the Engineer. Partial payments may be made for fabricated components yet to be assembled into larger components, members and assemblies as allowed for elsewhere in the Contract Documents.

460-8.2 Deductions and Allowances: No deductions from the computed weight of rolled or fabricated structural steel or miscellaneous components will be made for sheared edges, punchings, holes, milling, plaining or other items of waste associated with the finished components or parts.

460-8.3 Weights of Structural Steel and Miscellaneous Materials: The weights of structural steel will be taken as nominal weights as reported in the AASHTO LRFD Bridge Construction Specifications and ASTM Specifications, in that order of precedence, using the dimensions shown in the Contract Documents.

460-8.4 Structural Steel and Miscellaneous Metals: The quantity of structural steel and miscellaneous metals becoming part of the completed structure and accepted by the Engineer will be paid for at the plan quantity shown in the Contract Documents, or as modified by the Engineer, measured in pounds, or by the Contract lump sum price for Structural Steel.

460-8.5 High-Strength Fastener Assemblies: The weight of high-strength fastener assemblies (including nuts and washers) installed by the Contractor and accepted by the Engineer will be computed on the basis of an average length in accordance with Table 460-9:

Table 460-9
Weights of High-Strength Fastener Assemblies

Diameter of High-Strength Fasteners, inch	3/4 inch	7/8 inch	1 inch	1-1/8 inches	1-1/4 inches
Weight per 100, pounds	52	100	135	182	238

The weight of high-strength fastener assemblies will be included in the determination of the weight of the completed structure in determining the quantity paid when

payment is not by Lump Sum. The Engineer will determine values for sizes of high-strength fastener assemblies not shown.

460-8.6 Welding and Welds; Fasteners Not Designated as High-Strength; Anchor Rods, Nuts, Bolts and Associated Washers; Transporting; Handling; and Erection: Welding and welds; fastener assemblies not designated as high-strength; anchor rods, nuts, bolts and associated washers; transporting; handling; and erection are considered incidental to the work and will not be paid for separately.

460-8.7 Shims and Fill Plates: The quantity of shims and fill plates will be included in the determination of the weight of the completed structure in determining the quantity paid when payment is not by Lump Sum.

460-8.8 Coatings: The preparation, application, clean-up and the consumables used in the coatings process are considered incidental to the work and will not be paid for separately.

460-8.9 Weathering Steel Preparation, Handling and/or Clean-up: The preparation, handling, and/or clean-up of weathering steel or the “rust" marks on other items (concrete units, etc.) caused by the development of the patina are considered incidental to the work and will not be paid for separately.

460-8.10 Shear Connectors: Shear connectors are considered incidental to the work and will not be paid for separately.

460-8.11 Span Jacking (Fixed Bridge): Jacking of substructure units of adjacent fixed piers required to set bearing in accordance with the Contract Documents is considered incidental to the work and will not be paid for separately.

460-9 Basis of Payment.

460-9.1 General: Prices and payments will be for full compensation for all work specified in this Section completed and accepted, including but not limited to testing, bolting, welding, cleaning and coating, temporary works and erection. No separate payment will be made for falsework or other erection expense.

460-9.2 Payment Items: Payment will be made under:

Item No. 460- 1-	Structural Steel - Rehab - per pound.
Item No. 460- 2-	Structural Steel - New/Widening - lump sum.
Item No. 460- 6-	Ladders & Platforms - lump sum or per pound.
Item No. 460- 71-	Metal Traffic Railing - per linear foot.
Item No. 460- 81-	Rivet or High-Strength Bolt Replacement - each.
Item No. 460- 95-	Structural Steel Repair - per pound.
Item No. 460- 98-	Pipe Hanger - each.
Item No. 460-112-	Anchor Bolt Replacement - each.

SECTION 461
MULTIROTATIONAL BEARINGS

461-1 Description.

Furnish and install multirotational bearings in accordance with the recommendations of the manufacturer and details shown in the Plans. Obtain all multirotational bearings from a fabricator that is currently on the Department's Production Facility Listing. Provide bearings on each bridge from the same manufacturer. This Section covers the following types of multirotational bearings:

1. pot bearings.
2. disc bearings.

461-2 Materials.

Provide materials in accordance with the AASHTO LRFD Bridge Design Specifications and as follows.

461-2.1 Structural Steel:

Furnish structural steel conforming to ASTM A709 Grade 50W.

461-2.2 Stainless Steel:

Furnish stainless steel conforming to ASTM A240, Type 316, 16 gage minimum thickness.

461-2.3 Metalizing Wire:

Furnish metalizing wire in accordance with ASTM B833, having an 85% zinc/15% aluminum (Z30700) composition.

461-2.4 Anchor Rods, Nuts and Washers:

Furnish galvanized anchor rods, nuts and washers in accordance with Section 962.

461-3 Design.

Design bearings in accordance with the AASHTO LRFD Bridge Design Specifications. Design bearing connections to allow for bearing replacement without having to remove the masonry plate or sole plate. Detail all steel bearing components with sliding surfaces (e.g., stainless-steel plates or PTFE plates), masonry plates and elastomeric components to be replaceable. Welded attachments are not considered a replaceable connection.

Design guided bearings for the lateral load shown in the Plans or 10% of the vertical load capacity of the bearing shown in the Plans, whichever is greater.

For disc bearings, provide steel limiting rings around the top and bottom of the polyether urethane disc except if using the following: a minimum 62 Type (Shore) D durometer disc, a shear restraint device, and surface friction between the disc and steel plates.

461-4 Shop Drawings.

Submit shop drawings in accordance with Section 5. Include design calculations, signed and sealed by a Specialty Engineer, confirming that all components are in conformance with the requirements of this Section. Include the following information on the shop drawings:

1. Items listed in AASHTO LRFD Bridge Construction Specifications Article 18.1.1.
2. The bearing manufacturer's instructions for proper installation, including the proper positioning settings for a minimum 100°F temperature range.
3. Items required in 461-6.1.

461-5 Fabrication.

Fabricate bearings in accordance with the AASHTO LRFD Bridge Construction Specifications and the following requirements.

Shop metalize and seal all steel surfaces, except PTFE-stainless steel sliding surfaces, the insides of pots and the bottoms of pistons in accordance with SSPC-CS23.00/AWS C2.23M/NACE No. 12, “Specification for the Application of Thermal Spray Coatings (Metalizing) of Aluminum, Zinc, and Their Alloys and Composites for the Corrosion Protection of Steel”. Prepare surfaces prior to metalizing to a "near white" metal condition in accordance with SSPC-SP10 using abrasives meeting the requirements of 560-2. Achieve a sharp angular blast anchor profile meeting the requirements of ASTM D4417, Method C, 3 mils plus or minus 1 mil (75 µm plus or minus 25 µm). Provide a metalizing thickness of 10 mils minimum and 20 mils maximum. Prepare a sample coupon using the same processes used to prepare the surfaces and apply the coating to the bearing. Test the coating bond strength on the coupon in accordance with ASTM D4541. The bond strength must be a minimum of 700 psi. If the bond strength of the coating on the coupon is deficient, test the coating on the bearing. If the required bond strength is achieved, repair the coating on the bearing.

Prior to shipment, bearings shall be packaged in such a manner to ensure that during shipment and storage the bearings will be protected against damage from handling, weather, or any normal hazard. Secure bearing assemblies in the fabrication plant with temporary metal bolts or straps to avoid separation during transport and installation.

461-6 Testing and Certification.

461-6.1 General:

Test the materials used to fabricate the bearings and the completed bearings themselves in accordance with the AASHTO LRFD Bridge Construction Specifications. Submit all test results including visual documentation of the bearing both during testing and upon disassembly after testing to the Engineer.

461-6.2 Long-Term Proof Load Test: Conduct long-term proof load testing on full-size bearings on a per LOT basis using the reactions, rotations and movements shown in the Plans for each type of bearing.

461-6.3 Long-Term Deterioration Test: Long-term deterioration testing requirements will be considered satisfied by either of the following:

1. Testing of full-size bearings on a per LOT basis.
2. Prequalification in accordance with Materials Manual Chapter 11.1. The capacity of successfully tested bearings must be within 25% of the required demand specified in the Plans (reactions and resultant compressive stresses, rotations, and movements) for prequalification testing to be considered satisfied for a project. Test results for bearings of a given type and configuration are valid for five years from the original date of testing.

Production bearings must be manufactured using the same materials, methods, and quality control procedures as those used for testing.

461-7 Installation.

Store multirotational bearings delivered to the bridge site under cover on a platform above the ground surface. Protect bearings at all times from damage and ensure they are clean, dry and free from dirt, oil, grease or other foreign substances before placement. Install the bearings in accordance with the recommendations of the manufacturer, contract drawings, and as may be directed by the Engineer. If there is any discrepancy between the recommendations of the

manufacturer, these Specifications, and Contract Drawings, the Engineer will be the sole judge in reconciling any such discrepancy.

Obtain the services of a qualified technical representative, employed by the manufacturer of the bearings, to supervise the first installation of each type of bearing (expansion pot, fixed pot, expansion disc, fixed disc or other type as defined by the Engineer) but for only one size of each type. Submit to the Engineer a certified statement from the manufacturer that its representative has the necessary technical experience and knowledge to supervise bearing installations and to train Contractor personnel about proper bearing installation procedures and methods. Do not install the bearings before the Engineer receives the certification and the representative is on the job site. Assume this responsibility at no further expense to the Department.

Perform any required touchup repair and field metalizing as directed by the Engineer.

461-8 Method of Measurement.

Quantities for fixed and expansion bearings will be the plan quantity number of each type of bearing constructed and accepted.

461-9 Basis of Payment.

461-9.1 Basic Items of Bearings: The Contract unit price per each for bearings will be full compensation for all work and materials necessary for the complete installation. Such price and payment will include, but not limited to, the following specific incidental items:

1. testing,
2. tools and equipment required for installation,
3. any work to replace rejected bearings,
4. any repairs to the metalized coating on the bearings,
5. all costs associated with the manufacturer's installation technician,
6. sole plate, masonry plate, high strength bolt assemblies, and anchor rod assemblies.

461-9.2 Payment Items:

Payment will be made under:

Item No. 461-113- Multirotational Bearing Assembly - Fixed - each.

Item No. 461-114- Multirotational Bearing Assembly - Expansion - each.

SECTION 462
POST-TENSIONING

462-1 Description.

1. Furnish, test, transport, store, handle, and install all components of Post-Tensioning (PT) systems, in accordance with the requirements of this Section and the component manufacturer's recommendations. Constituent components of PT systems include, but are not limited to, anchorage assemblies, filler containment assemblies, filler material, and related steel reinforcement. Use the most stringent requirements, as determined by the Engineer, of those specified in this Section or the component manufacturer's recommendations for protecting components from damage due to environmental exposure, improper handling, or improper installation.

2. With the exception of mild reinforcing and prestressing steel, furnish all PT system components from a single supplier (vendor).

3. Submit PT system shop drawings in accordance with Section 5. Perform PT system testing in accordance with Section 960. Include in the PT system testing all possible combinations of components to be incorporated into the structure.

4. Use only PT systems meeting the requirements of Section 960 and approved by the Engineer in accordance with Section 5.

a. Use only PT systems of appropriate type and size required to construct tendons shown in the Contract Documents.

b. Use only the exact manufacturer and/or model of major components, as defined in 960-2, that were used in system testing and as listed on the approved PT system shop drawings.

c. With the exception of local zone reinforcement, do not substitute, modify, or delete any major components, as defined in 960-2, of a PT system approved by the Engineer for use on the project.

5. Provide a mockup test in accordance with this Section. PT system acceptance testing may be performed concurrent with mockup testing if performed prior to installation of any PT system hardware.

6. Just prior to PT tendon installation, blow oil-free dry compressed air meeting ASTM D4285 through the duct. Provide visual confirmation that the duct is free of water and moisture.

7. Install the PT tendon (e.g., strands, wires, or bars) in duct. Stress the PT tendon to a predetermined load, anchor ends directly against hardened concrete and install permanent anchorage caps.

8. Just prior to wax filler injection, blow oil-free dry compressed air meeting ASTM D4285 through the duct. Provide visual confirmation that the duct and tendon are free of water and moisture.

9. Inject ducts with filler to completely fill voids and install protection at anchorages.

10. Submit all required documents in accordance with this Section and Section 5 to the Engineer for review and written approval.

11. Arches, cable supported and extradosed bridges are not covered by this Specification.

12. Install duct filler. Provide fully filled duct and anchorage assemblies free from leaks, blockages, and voids. Submit test data to the Engineer to verify that the work meets the requirements of this Section. Perform filler injection operations in accordance with 462-7.4.

462-2 Materials.

462-2.1 General:

Approval of any material by the Engineer will not preclude subsequent rejection if material is damaged or otherwise found to not meet the requirements of this Section or Section 960.

462-2.2 Steel Reinforcing:

462-2.2.1 Mild Steel:

1. Provide reinforcing steel per Section 931.

2. Final design and details of local zone reinforcement are system specific and are the responsibility of PT system supplier (vendor). Design system specific local zone reinforcement for the number of strands or wires a particular PT system can accommodate at maximum allowable strand or wire force; do not design project specific local zone reinforcement for a reduced system capacity.

3. Submit signed and sealed project specific local zone reinforcement details to the Engineer for review and written approval.

462-2.2.2 Prestressing:

462-2.2.2.1 Strand:

1. Provide prestressing strands per Section 960.
2. Strand couplers are not permitted.

462-2.2.2.2 Bar:

1. Provide prestressing bars per Section 960.
2. For permanent applications, use and location of bar couplers is subject to written approval by the Engineer.

462-2.2.2.3 Parallel Wire:

1. Provide prestressing parallel wire assemblies per Section 960.
2. Wire couplers are not permitted.

462-2.3 Duct Filler: Use only grout and flexible filler meeting the requirements of Section 938 and are listed on the Department's Approved Product List (APL).

462-2.3.1 Grout:

1. Select grout for use in PT system by application: repair, horizontal, or vertical.

2. Mix grout per manufacturer's instructions with potable water meeting requirements of Section 923.

3. Do not combine different grout products.

462-2.3.2 Flexible Filler: Prepare flexible filler for installation in accordance with the manufacturer's instructions. Do not combine different flexible filler products.

462-2.4 Other Material References:

Meet the requirements of this Section, as well as the following:

Class 5 Applied Coating* .....Section 975
Elastomeric Coating System* .....Section 975
Epoxy Compound* .....Section 926
Magnesium Ammonium Phosphate Concrete* .....Section 930
Methacrylate* .....Section 413
Water.....Section 923

*Use products listed on the Department's Approved Product List (APL).

462-2.5 Component Samples:

462-2.5.1 Prestressing Steel:

1. Furnish samples per Section 933 from each manufacturer of prestressing strand, wire, and bar to be used on project.

2. The Engineer will collect sample materials from prestressing steel used for PT operations on the Project.

3. Samples, properly identified and tagged per 462-6, will be stored by the Engineer.

462-2.5.2 Grout:

1. The Engineer may sample grout packages at random, not to exceed a total quantity of one bag per LOT or shipment. A LOT is defined as a quantity of material from a single production batch or shipment

2. Grout sample may be virgin package mix, liquefied state, or solid state; Engineer will determine at what frequency, interval, sample phase (powder, liquid or solid) and location those samples will be recovered from the project.

3. Sample, properly identified and tagged per 462-6, will be stored by the Engineer.

4. Submit the following samples from each manufacturer per each production LOT of grout to be used on the project. These samples will be used by the State Materials Office for product testing.

a) Submit three 2" x2" x2" hardened grout cube samples from a trial batch using the same water source and grout to be used for production grouting.

b) One bag of grout.

Submit samples a minimum of four weeks prior to initial production grouting. Do not commence grouting operations until grout test results are available and approved by the Engineer. Mock-up testing per section 462-7.4.1.1 (5) may proceed prior to grout approval.

462-2.5.3 Flexible Filler:

1. The Engineer may sample flexible filler at random, not to exceed a total quantity of one gallon per LOT. A LOT is defined as a quantity of material from a single production batch or shipment not to exceed 1,000 gallons.

2. Sample may be virgin product in liquefied state or solid state. The Engineer will determine at what frequency, interval, sample phase (liquid or solid) and location those samples will be recovered from the project.

3. Sample, properly identified and tagged per 462-6, will be stored by the Engineer.

462-3 Alternate PT System Designs.

Designs using a PT scheme different from that shown in the Contract Documents may be submitted for the Engineer's approval provided proposed scheme fulfills the design requirements, and the Contractor demonstrates compliance with these requirements:

1. PT system type and size meets all requirements of this Section.

2. Net compressive stress in the concrete after all prestress losses is equivalent to or greater than that provided by the PT scheme shown in original Contract Documents.

3. Distribution of individual tendons at each cross section generally conform to the distribution shown in original Contract Documents.

4. Proposed PT scheme meets the ultimate strength requirements of the American Association of State Highway and Transportation Officials Load and Resistance Factor Design,

AASHTO LRFD Bridge Design Specifications Section 5, and is equivalent to or greater than service and strength limit states provided in original Contract Documents.

5. Stresses in concrete and PT steel at all sections and at all stages of construction meet requirements of the Design Criteria shown in original Contract Documents.

6. All Design Criteria provisions noted in original Contract Documents are satisfied.

7. Show complete design and detail of all elements for proposed locations of alternate PT scheme.

8. Submit the following for the Engineer's approval:

a. design calculations including short and long term prestress losses

b. complete shop drawings including PT scheme and system, reinforcing steel, and concrete cover

9. Any alternate PT system approved by the Engineer resulting in a change in quantity from that shown in the Contract Documents is paid based on comparison of the following:

a. quantity actually used and accepted or original plan quantity, whichever is less, and

b. unit bid price.

If approved alternate PT scheme or system is under a Cost Savings Initiative Proposal (CSIP), method of payment will be in compliance with CSIP agreement.

10. Submit alternate PT scheme signed and sealed by the Contractor's Engineer of Record.

462-4 Qualifications.

Provide all project personnel and crew foreman in accordance with Section 105.

462-5 Submittals.

1. Submit to the Engineer all necessary information, Plans, shop and working drawings, and manuals in accordance with this Section and Section 5. Submit to the Engineer signed and sealed PT related shop drawings designed by the Contractor's Engineer of Record.

2. Prepare shop drawings addressing all requirements stated in the Contract Documents and requirements of this Section. Show details of PT hardware components, tendon geometry and locations complying with the Contract Documents and limitations of selected PT system. Include all inlets, outlets, high point inspection port details, anchorage inspection details, permanent anchorage caps, protection system materials, and application limits. If applicable, include details of the duct dehumidification system.

462-6 Transport, Handling and Storage.

462-6.1 General:

Store all materials in a weatherproof building, shed, covering, or container until time of use.

462-6.2 LOT Identification:

1. Assign an individual LOT number and tag items shipped to project in a manner that allows each LOT to be clearly identified at project site for all PT system components, filler, bars of each size from each mill heat of steel, and all strands from each manufactured reel.

2. Submit records to the Engineer identifying assigned LOT numbers with heat or reel of material represented if applicable.

3. All unidentified prestressing components, strands, wires, bars, or filler received at the site will be rejected.

4. Loss of positive identification of these items at any time will be cause for rejection.

5. Submit filler Quality Control Data Sheets from the manufacturer, to the Engineer for each LOT of filler on the project.

462-6.3 Prestressing Steel:

1. Protect all prestressing steel against physical damage and corrosion at all times.

a. Package prestressing steel in containers for protection against physical damage and corrosion during shipping and storage.

b. Place a corrosion inhibitor, which prevents rust, in package or incorporate it into a corrosion inhibitor carrier type packaging material.

c. Corrosion inhibitor must have no deleterious effect on steel, filler, concrete, or bond strength of steel to concrete.

d. Inhibitor carrier type packaging material must conform to provisions of Federal Specification MIL-P-3420.

e. Immediately replace or restore damaged packaging to original condition.

f. Clearly mark shipping package with a statement that package contains high-strength prestressing steel, care to be used in handling, include type, kind, and amount of corrosion inhibitor used, date when placed, safety orders, and instructions for use.

2. The Engineer will reject prestressing steel that has sustained physical damage.

3. Remove and discard lengths of strand found to contain broken wires.

4. Wire must be bright and uniformly colored, with no foreign matter or pitting on its surface.

462-6.4 Filler:

1. Maintain filler in environmental exposure conditions (e.g., temperature, humidity) in strict conformance with manufacturer's recommendations at all times from manufacture to installation.

2. Storage in the open must be on a raised platform with adequate waterproof covering to protect the filler.

3. On site storage of grout filler on a raised and covered platform is limited to a maximum period of one week. The allowable on site storage time may be extended by the Engineer if the grout filler is in a climate-controlled structure. Grout filler material with a total time from manufacturer in excess of six months must be removed from the jobsite and replaced with new material.

4. Flexible filler may be stored on site on a raised and covered platform up to the manufacturer's expiration date. Do not use flexible filler that has exceeded the manufacturer's recommended usage date. Remove all such filler from the jobsite and replace with new material.

462-6.5 Duct and Pipe:

1. Protect ducts against ultraviolet degradation, crushing, excessive bending, dirt contamination, corrosive elements, or any other damage or contamination during transport, storage, and handling.

2. Furnish ducts with end caps to prevent contamination inside duct. Do not remove duct end caps until duct is incorporated into the bridge component.

3. Ship capped duct in bundles that are covered during transport and storage.

4. Store on a raised platform and completely covered to prevent contamination.

5. If contamination is discovered, immediately flush duct with potable water per 462-7.2.4 before use.

462-7 Construction.

462-7.1 General:

1. Prior to installing any PT system hardware:

a. Submit to the Engineer a list of all PT systems chosen for the project.

b. For each PT system, submit a package to the Engineer meeting the requirements of Section 960-3.6.

c. For each PT system, submit to the Engineer written certification that all major components, as defined in 960-2, furnished to the project and shown on the approved PT system shop drawings exactly match the major components used in PT system testing.

2. Use methods to place and consolidate concrete that will not displace or damage any PT ducts, anchorage assemblies, splices and connections, reinforcement, or other embedded items.

3. Conduct all stressing and filler injection operations in the presence of the Engineer.

462-7.2 System Installation:

Accurately and securely fasten all PT anchorages, ducts, inlet and outlet pipes, miscellaneous hardware, reinforcing bars, and other embedded items at locations shown in the Contract Documents or on approved shop or working drawings or as otherwise approved by the Engineer in writing.

If the anchorage caps will be fastened to the anchorage bearing plates, install the anchorages such that the top and bottom holes of the anchorage cap will form a vertical axis oriented 90 degrees from horizontal as required by 462-7.3.3.2.

462-7.2.1 Ducts:

1. Construct tendon ducts using the minimum number of splices as practical.

2. Accurately position and align ducts at locations shown in the Contract Documents, or according to approved shop or working drawings, or as approved in writing by the Engineer.

3. Securely fasten all internal ducts at regular intervals not exceeding 30 inches for steel pipes, 24 inches for round plastic ducts, and 12 inches for flat ducts to prevent movement, displacement, or damage from concrete placement and consolidation operations.

4. Show method and spacing of duct supports on appropriate shop drawings.

5. Ensure external tendon ducts are straight between connections to internal ducts at anchorages, diaphragms, and deviation saddles and are supported at intermediate locations according to the Contract Documents including approved shop drawings.

6. Ensure all alignments, including curves and straight portions, are smooth and continuous with no lips, kinks, or dents. This also applies to curves in pre-bent steel pipe.

7. Check and repair all ducts in accordance with 462-7.5 as necessary before placing any concrete.

8. Ensure ducts at end connections to anchorages, splices, inlets, outlets, drains, and all other duct openings are sealed at all times after installing ducts and until tendon installation is complete.

9. Provide an absolute seal of anchorage and duct termination locations per the approved system drawings.

10. Use of tape, caulking, epoxy or other sealants is not permitted to make connections or sealing for any reason.

11. Use heat welding techniques, in accordance with duct manufacturer's instructions, to make splices between sections of smooth plastic duct or make connection with electrofusion duct coupler as shown on the approved PT system shop drawings.

12. When connecting steel pipe to plastic pipe with a boot, use a 3/8 inches wide power seated band and clamps in accordance with 960-2.2 on each end of a duct boot to seal against filler leakage. Install band per manufacturer's instructions.

13. Ducts for prestressing used exclusively for temporary erection where PT will be removed from structure are not required to be coupled across segment joints.

14. Briefly open low point drains to allow for drainage of any water that may be present within the duct.

462-7.2.1.1 Installation Tolerances:

1. Ensure final position of PT ducts is within the tolerances in the following table:

Table 462-1
Duct Installation Tolerances

Type	Vertical Position (inches)	Horizontal Position (inches)
Horizontal tendons in slabs or in slab regions of larger members	±1/4	±1/2
Longitudinal draped superstructure tendons in webs: Tendon over supports or in middle third of span	±1/4	±1/4
Tendon in middle half of web depth	±1/2	±1/4
Longitudinal, generally horizontal, superstructure tendons usually in top or bottom of member	±1/4	±1/4
Horizontal tendons in substructures and foundations	±1/2	±1/2
Vertical tendons in web	Longitudinal Position ±1	Transverse Position ±1/4
Vertical tendons in pier shafts	±1/2	±1/4
All other cases	±1/4	±1/4

2. Ensure entrance and exit angles of tendon paths at anchorages, duct joints, and/or at faces of concrete are within plus or minus 3 degrees of desired angle measured in any direction.

3. Accomplish any deviations in alignment with smooth unkinked transitions.

4. Locate anchorages within plus or minus 1/4 inch of desired position laterally and plus or minus 1 inch along tendon except that minimum cover requirements must be maintained.

5. Position local zone anchorage confinement reinforcement in the form of spirals, multiple U-shaped bars, or links centered around duct and anchorage (±1/4 inch tolerance) and starting within 1/2 inch of the back of the main anchorage plate.

6. If conflicts exist between reinforcement and a PT duct/anchorage and other non-local zone reinforcement, the position of duct prevails. Adjust the non-local zone reinforcement with the Engineer's written approval.

462-7.2.2 Splices and Joints:

1. All splices, joints, couplings, connections (inlet and outlet), and valves are part of approved PT system.

2. Fabricate all duct splices to prevent duct kinks during concrete placement.

3. Use mandrels as needed to maintain duct alignment and shape.

462-7.2.3 Inlets, Outlets, Drains and Ports:

1. Place filler inlets, outlets, drains and ports at locations shown in the Contract Documents including approved shop drawings.

2. Equip all filler inlets, outlets, drains and ports with approved positive shut-off devices (e.g., valves).

3. At a minimum, place filler inlets, outlets or ports in the following positions and those shown in Standard Plans, Index 462-001:

a. Top of tendon anchorage;

b. Top and bottom of anchorage cap;

c. At high points of duct profile when vertical distance between highest and lowest point is more than 2 feet;

d. At major change in duct cross section; and,

e. At other locations required by the Engineer.

4. For all tendons other than grouted top slab transverse tendons in box girders, place drains at the geometric low points of all duct profiles, or as close as is practical to the geometric low points of all duct profiles, except where an inlet, outlet or anchorage that can serve as a drain is located at a low point. Locate drains, and inlets and outlets serving as drains, at the bottom of the duct cross section. Do not locate drains within the limits of diabolos.

5. Extend filler and drain tubes a sufficient distance out of concrete member to allow for proper closing of valves.

6. Direct inlets, outlets, drains and ports exiting on vertical or predominantly vertical surfaces of box and I-girders toward the inside face of exterior I-girders or toward the interior of box girders.

462-7.2.4 Tendons:

1. Store the PT tendon in such a way that it remains completely dry and free of moisture prior to installation within the duct.

2. Do not exceed 14 calendar days between first installation of PT strand within duct and completion of the stressing and filler injection operation.

3. Do not exceed 21 calendar days between the first installation of PT bars within duct and completion of the stressing and filler injection operations.

4. With written approval of the Engineer, the maximum number of calendars days allowed between the first installation of the PT tendon within the duct and completion of the stressing and filler injection operations is 30 for PT strand and 45 for PT bars by monitoring and continuously maintaining the relative humidity of air within the duct below 40%. Use a closed dehumidification system or other means approved by the Engineer. The dehumidification system must be installed and operational within 24 hours of first installation of the PT tendon within the duct and remain operational until just prior to filler injection.

5. The use of temporary corrosion inhibitor powder is not permitted as a method to increase the allowed number of calendar days between the first installation of the PT tendon within the duct and completion of the stressing and filler injection operations.

6. Any light surface corrosion forming during the period of time described in (1), (2), (3) or (4) of this Article will not be cause for rejection of the PT tendon.

7. Failure to inject filler into duct within the number of calendar days specified, will result in stoppage of work, except when waived by the Engineer in writing.

8. Just prior to PT tendon installation, briefly open low point drains to allow for drainage of any water that may be present within the duct. Close all low point drains and ports except the inlet and outlet ports at the anchorage caps. Blow oil-free dry compressed air meeting ASTM D4285 through one of the anchorage cap ports until the relative humidity measured at the inlet and outlet ends are less than 40% and continuing blowing for an additional 30 minutes. Stop blowing, wait a minimum of 15 minutes, and take humidity measurements at the inlet and outlet ends of blowing. Further blowing is not required if both humidity readings are less than 40%. If the humidity readings are 40% or greater, then repeat the process of blowing and waiting for 15 minutes until the humidity measurements at the inlet and outlet end of blowing are less than 40%. Take humidity measurements of air within the duct at the inlet end and outlet end of blowing using separate humidity meters. Use humidity meters approved by the Engineer.

9. Provide visual confirmation that the duct is free of water, moisture, and debris at the anchorages and low points of the tendon profile before installing the PT tendon within the duct.

10. Flushing of filler is not permitted without written approval of the Engineer and is only permitted as defined in this Article.

11. For grouted operations, vacuum injection is required to repair all voids and blockages as subject to provisions of 462-8.3.2. For flexible filler operations, use the repair procedure described in the approved Wax Injection Operations Plan.

12. For tendon ducts subjected to contamination with chlorides (e.g., uncapped ducts that have been subjected to salt spray), flush duct with potable water containing slack lime (i.e., calcium hydroxide) or quicklime (i.e., calcium oxide) in the amount of 0.17 pounds per gallon.

a. Test for presence of chlorides and oils in discharged water before placing tendon.

b. If chloride levels in flush water outflow exceed 300 ppm, continue to flush duct until chloride level in flush water outflow is below 250 ppm.

c. After the chloride level of flush water is below 250 ppm, open low point drains to allow for drainage of flush water within the duct. Perform the blowing process described in (8) of this Article. Provide visual confirmation that the duct is free of water and moisture for its entire length before installing the PT tendon within the duct.

13. Push or pull strands and wires through ducts to make up a tendon using methods that will not snag on any lips or joints in ducts.

14. Round off end of strands and wires that are pushed or fit advancing end with smooth protective cap.

15. Do not intentionally rotate strands or wires by any mechanical means during installation of PT strand into duct.

16. For superstructure tendons, provide sufficient strand and wire length beyond dead end anchorages to allow for second end stressing as needed for reconciliation of jacking force versus measured elongation.

17. Alternatively, tendons may be pulled through duct using a special steel wire sock or other device attached to advancing end. Strands may be brazed together for pulling as long as one foot of strand from the brazed end is removed by cutting after installation. Do not electric arc weld strand ends together for this purpose.

18. Cut tendons in accordance with 462-7.3.2.7.

19. Strand installation aids (i.e. wire/nylon ties around strand bundle, strand spacers, etc.) must be removed prior to stressing

20. Do not install permanent tendons before completion of testing as required by this Section or the Contract Documents. The only two exceptions are:

a. Tendon to be tested by "Theoretical Elongation Verification" may be installed for test; and,

b. Transverse tendons may be pre-installed in precast segmental boxes prior to concrete casting such that they meet 462-8.3.1.

462-7.3 Post-Tensioning Operations:

1. Do not apply PT forces until concrete has attained compressive strength specified in the Contract Documents.

2. Conduct all stressing operations in presence of the Engineer.

3. With the written approval of the Engineer, revise PT operations so final tendon force is in agreement with the Contract Documents.

462-7.3.1 Stressing Equipment:

Only use equipment furnished by supplier of PT system.

462-7.3.1.1 Jacks and Gauges:

Equip each jack with pressure gauge for determining jacking pressure that has a minimum dial diameter of six inches.

462-7.3.1.2 Calibration:

1. Calibrate each jack and its gauges as a unit.

2. Calibration must consist of three test cycles with cylinder extension of jack in various positions (e.g., two-inch, four-inch, eight-inch stroke).

3. At each pressure increment, average forces from each test cycle to obtain an average force.

4. Perform calibration with equipment (e.g., jack, pump, hoses, etc.) setup in same configuration intended for use on Project.

5. Jack and gauge calibration is to be initially performed by PT supplier or an independent laboratory.

6. Use load cells calibrated within the past 12 months to calibrate stressing equipment.

7. Supply documentation denoting the load cells calibration date and tractability to National Institute of Standards and Technology (NIST) along with jack/gauge calibration.

8. Submit to the Engineer certified calibration charts and curves for each jack and gauge unit used on the project prior to start of work and every six months thereafter or as requested by the Engineer.

9. Calibrations subsequent to initial calibration with a load cell may be accomplished with use of a master gauge. Supply master gauge to the Engineer in a protective waterproof container capable of protecting calibration of gauge during shipment to a laboratory. Provide a quick-attach hydraulic manifold to enable quick and easy installation of master gauge to verify permanent readings. Master gauge will remain in the possession of the Engineer for duration of project and will be returned to the Contractor after final acceptance of project by the Engineer.

10. Any jack repair, such as replacing seals or changing length of hydraulic lines, requires recalibration using a load cell.

11. No extra compensation will be allowed for initial or any subsequent calibrations or use of master gauge required by the Engineer.

462-7.3.2 Stressing Tendons:

1. Tension all PT steel so PT force is not less than that required by the Contract Documents or as otherwise approved by the Engineer in writing.

2. Do not use monostrand jacks to stress straight tendons with five or more strands or wires, or for curved tendons with two or more strands or wires.

3. 4-strand curved top slab transverse tendons in box girders are permitted to use a monostrand jack.

4. Use of curved stressing noses or chairs is not permitted.

5. If the anchorage caps will be fastened to the wedge plates, maintain the position of both the stressing end and dead end wedge plates throughout the jacking process such that the top and bottom holes of the anchorage cap will form a vertical axis oriented 90 degrees from horizontal as required by 462-7.3.3.2.

462-7.3.2.1 Jacking Maximum Stress:

Maximum temporary stress (i.e., jacking stress) in PT steel must not exceed 80% and 75% of Guaranteed Ultimate Tensile Strength (GUTS) for PT strands and bars, respectively. The maximum temporary jacking stress must not exceed 50% of GUTS for PT bars that will be reused.

462-7.3.2.2 Initial and Permanent Stresses:

1. PT steel must be anchored at initial stresses resulting in long term retention of permanent stresses or forces of no less than those shown in the Contract Documents.

2. Unless otherwise approved by the Engineer in writing, initial stress after anchor set must not exceed 70% of GUTS at anchorages and 74% of GUTS at all other locations between anchorages.

3. Permanent stress and permanent force are stress and force remaining in PT steel after all losses, including long term creep and shrinkage of concrete, elastic shortening of concrete, relaxation of steel, losses in PT steel from sequence of stressing, friction, and unintended wobble of ducts, anchor set, friction in anchorages, and all other losses particular to the specific PT system.

462-7.3.2.3 Stressing Sequence:

1. Permanent PT tendons must be stressed from both ends, except as noted in the Contract Documents.

2. Required force may be applied at one end and subsequently at other end or simultaneously at both ends.

462-7.3.2.4 Elongation:

1. Ensure forces being applied to tendon and resulting elongation of tendon can be measured at all times.

2. Measure elongations to nearest 1/16 inch.

3. For required tendon force, observed elongation must agree within 7% of theoretical elongation or entire operation must be halted, checked, and source of error determined and remedied to satisfaction of the Engineer before proceeding.

4. Do not overstress tendon to achieve theoretical elongation.

5. If agreement between observed and theoretical elongations at the required force falls outside acceptable tolerances, additional tests may be required, at the Engineer's discretion and without additional compensation to the Contractor, for Tendon Modulus of Elasticity and/or In Place Wobble and Friction Test, or Lift-Off Test.

462-7.3.2.5 Friction:

1. Provide actual expected friction and wobble coefficients and anchor set in the shop drawings; submit calculations and show a typical tendon force diagram on shop drawings based upon expected actual coefficients and values for the PT system to be used.

2. Graphite may be used as a lubricant when friction must be reduced, subject to written approval of the Engineer.

462-7.3.2.6 Tendon Wire Failure:

1. Multi-strand PT tendons with wires which fail by breaking or slipping during stressing may be accepted provided these conditions are met:

a. Completed structure has a final PT force of at least 98% of original total design PT force;

b. PT force across a mating joint is at least 98% of PT force required by the Contract Documents for that mating joint for that stage of construction for precast or cast-in-place segmental construction. This 98% minimum PT force requirement applies to segmental construction, or any similar construction, that has members post-tensioned together across a common joint face at any stage of construction; and,

c. Any single tendon must have no more than a 5% reduction in cross-sectional area of PT steel due to wire failure.

2. When conditions permit the Contractor to propose acceptable alternative means of restoring PT force lost due to wire failure, any of the above conditions may be waived at discretion of and with approval of the Engineer in writing.

462-7.3.2.7 Cutting of PT Steel:

1. Cut PT steel using an abrasive saw or plasma torch within 3/4 inches to 1-1/2 inches away from the anchorage.

2. Flame cutting of PT steel is not permitted.

3. Do not cut tendon to final length prior to acceptance.

462-7.3.2.8 Post-Tensioning Operations Record:

1. Keep a record of these PT operations for each tendon installed:

a. Project name, Financial Project ID (FPID);

b. Contractor and/or subcontractor;
c. Tendon location, size, and type;
d. Date tendon was first installed in duct;
e. Reel number for strands and wires and heat number for bars;
f. Tendon cross-sectional area;
g. Modulus of elasticity;
h. Date stressed;
i. Jack and Gauge numbers per tendon end;
j. Required jacking force;
k. Gauge pressures at the pump and at the inlet;
l. Elongations (theoretical and actual);
m. Anchor sets (anticipated and actual);
n. Stressing sequence (i.e., sequential order of tendon stressing by number);
o. Stressing mode (single-end, dual-end, simultaneous);
p. Witnesses to stressing operations (Contractor and Inspector);
q. Any other relevant information.

2. Submit to the Engineer a complete set of stressing operation records within five days of completed tendon installation.

462-7.3.3 System Protection:

462-7.3.3.1 Tendon:

1. Seal all other duct openings other than installing anchorage caps within four hours after tendon stressing.

2. Install anchorage caps after tendon has been accepted. If acceptance of tendon will be delayed more than four hours after stressing, immediately provide temporary weatherproofing of tendons at open ends of anchorages. If tendons and anchorages are temporarily weatherproofed, install anchorage caps within 1 day of tendon being accepted.

3. If tendon contamination occurs and if directed by the Engineer, remove tendon, flush duct with potable water per 462-7.2.4, and replace with new tendon.

462-7.3.3.2 Anchorage:

1. Install the anchorage cap such that the top and bottom holes form a vertical axis oriented 90 degrees from horizontal.

2. Provide the following at anchorages as shown on Standard Plans, Index 462-002:

a. Temporary drain holes at the bottom of open top blockouts.

b. Temporary weatherproof plugs for upwardly oriented access or vent holes.

3. Cap all filler inlets/outlets with plugs meeting the requirements of Section 960.

4. Construct anchorage pour-backs and place elastomeric coatings at anchorages as indicated in the Contract Documents and as shown on Standard Plans, Index 462-002 within seven days of completing filler injection operations (see 462-7.4 for filler injection operations). For anchorages which require acrylic aliphatic polyurethane top coating,

apply the acrylic aliphatic polyurethane top coating after the elastomeric coating has fully cured. See Standard Plans Index 462-002 and the Contract Documents for details on anchorages which require acrylic aliphatic polyurethane top coating. Construct anchorage pour-backs using reinforced concrete, magnesium ammonium phosphate concrete, or a Type Q epoxy grout meeting the requirements of Section 926.

a. Remove all laitance, grease, curing compounds, surface treatments, coatings, and oils by grit blasting or water blasting. Flush surface with water and blow dry. Surfaces must be clean, sound, and without any standing water. Test substrate at all pour-back locations using ACI 503 and develop a minimum of 175 psi tension (e.g., pull-off value). Testing frequency may be reduced, as determined by the Engineer, after the Contractor has demonstrated an ability to prepare substrate surfaces for bonding as indicated by the result of the ACI 503 test.

b. Mix and apply epoxy grout and magnesium ammonium phosphate concrete in accordance with the manufacturer's current standard technical guidelines. Construct all pour-backs in leak proof forms creating neat lines. Epoxy grout may require pumping for proper installation. Construct forms to maintain a liquid head to ensure intimate contact with concrete surface. Use vents as needed to provide for escape of air to ensure complete filling of forms.

5. Coat exposed surfaces of pour-backs and anchorage caps as shown on Standard Plans, Index 462-002 with an elastomeric coating system meeting the requirements of Section 975 and having a thickness of 30 mils to 45 mils. Apply the acrylic aliphatic polyurethane top coating to a dry film thickness of 5 to 6 mils. Ensure concrete, anchorage caps, or other substrates are structurally sound, clean, and dry. Concrete must be a minimum of 28 days old. Remove all laitance, grease, curing compounds, surface treatments, coatings, and oils by grit blasting or water blasting using a minimum 3,000 psi nozzle pressure. Blow surface with compressed air to remove dust or water. Apply the elastomeric coating within 90 days of filler injection. Apply the acrylic aliphatic polyurethane top coat and the manufacturer's approved primer over the elastomeric coating before applying Class 5 coating, if required.

6. Prior to application of elastomeric coating, construct a 2 foot x 4 foot concrete test block with a similar surface texture to surfaces to be coated. Coat a vertical face with chosen elastomeric coating system. Determine number of coats required to achieve the specified thickness without runs and drips. Mix and apply elastomeric coating as per manufacturer's current standard technical specifications. Spray application is preferred; roller application is permitted. Have coating manufacturer representative on site to supervise and comment on application of elastomeric coating onto test block. Apply coating using approved and experienced personnel with a minimum of three years experience applying similar polyurethane systems. Submit credentials of these persons to the Engineer for review and consideration for approval.

462-7.4 Filler Injection Operations:

462-7.4.1 Grouting Operations: Conduct all grouting operations in the presence of the Engineer.

462-7.4.1.1 Grout Injection Operations Plan:

1. Submit a Grouting Operations Plan to the Engineer for approval at least six weeks in advance of any scheduled grouting operation.

2. Written approval of Grouting Operations Plan by the Engineer is required before any grouting of permanent structure takes place.

3. At minimum, Grouting Operations Plan will address and provide:

a. Names and proof of training for grouting crew and crew supervisor in conformance with this Specification;

b. Type, quantity, and brand of materials to be used in grouting, including all required certifications;

c. Type of equipment to be used, including capacity in relation to demand and working conditions, as well as, standby equipment and spare parts;

d. General grouting procedure;

f. If applicable, procedures for monitoring and continuously maintaining less than 40% relative humidity of air within the duct;

g. Method to be used to control rate of flow within ducts;

h. Theoretical grout volume calculations;

i. Mixing and pumping procedures in accordance with the manufacturer's recommendations;

j. Direction of grouting accounting for grade and/or slope of tendon;

k. Sequence of inlet and outlet pipes use;

l. Procedures for handling blockages;

m. Procedures for possible post grouting repair.

4. Conduct a joint meeting of the Contractor, grouting crew, and the Engineer before grouting operations begin. Discuss Grouting Operations Plan, required testing, corrective procedures, and any other relevant issues at the meeting.

5. Prior to production grouting, demonstrate to the Engineer's satisfaction successful grout injection by injecting full-scale mockups that are constructed with all associated PT system components using the mockup tendon profiles shown in the Plans and the proposed Grouting Operations Plan. Utilize smooth duct and associated couplers and fittings meeting the requirements of Section 960 for all mockups. Utilize smooth duct for the mockups which has an inside diameter required for a given mockup tendon size. If the mockup is also being used to perform PT system acceptance testing, use the duct type appropriate for the PT system location. Place the mockup tendons specified in the Plans inside the ducts to simulate the in-place PT tendons. Stress mockup tendons to the minimum values shown in the Plans by using jacks or other methods approved by the Engineer. Perform pressure tests on the mockups in accordance with 462-8.2.1 prior to grout injection. For the grout injection operations, utilize the same grout material and types and sizes of grout injection equipment that will be used on the project including but not limited to mixers, pumps, hoses, valves and pressure gauges. Inject grout into the mockups using the proposed Grouting Operations Plan. Allow the grout to harden a minimum of 24 hours after injection before inspecting the mockup. Inspect the mockup in accordance with the requirements of 462-8.3.2.1 and then carefully cut open the duct at all high points and other locations as directed by the Engineer to check for voids. Prepare a report documenting the findings and submit it to the Engineer. If voids are found, determine the cause and revise the proposed Grouting Operations Plan accordingly. If directed by the Engineer, construct additional mockups and repeat the grout injection operation using the revised Grouting Operations Plan as many times as are required until the results are acceptable.

462-7.4.1.2 Inlets and Outlets:

1. Ensure connections from grout pump hose to inlets are free of dirt and are air-tight.

2. Inspect valves to ensure they can open and close properly.

462-7.4.1.3 Supplies:

Provide an adequate supply of water and compressed air for clearing and testing ducts, as well as, mixing and pumping grout before grouting operations start.

462-7.4.1.4 Equipment:

1. Provide grouting equipment consisting of measuring devices for water, a high-speed shear colloidal mixer, a storage hopper (e.g., holding reservoir) and pump with all necessary connecting hoses, valves, and pressure gauge.

2. Provide pumping equipment with sufficient capacity to ensure PT ducts can be filled and vented in not more than 30 minutes without interruption.

3. Provide an air compressor and hoses with sufficient output to perform required functions.

4. Have vacuum grouting equipment (i.e., volumetric measuring type) and experienced operators available to meet the timeframe requirements of 462-8.3.2.1-6.

462-7.4.1.4.1 Mixer and Storage Hopper:

1. Provide colloidal grout machinery with a charging tank for blending and a holding tank. Blending tank must be equipped with a high speed shear colloidal mixer capable of continuous mechanical mixing producing a homogeneous and stable grout free of lumps and un-dispersed cement. Holding tank must be kept agitated and at least 10% full at all times during pumping operations to prevent air from being drawn into duct.

2. Add water during primary mixing phase in the colloidal mixer by use of a flow meter or calibrated water reservoir with measuring accuracy equal to 1% of total water volume.

462-7.4.1.4.2 Pumps:

1. Provide pumping equipment capable of:

a. continuous operation which includes a system for circulating and agitating grout when actual grouting is not in progress,

b. maintaining pressure on grouted ducts,

c. fitted with a valve that can be closed off without loss of pressure in duct.

2. Grout pumps will:

a. be positive displacement type,

b. provide a continuous grout flow

c. be able to maintain a discharge pressure of at least 145 psi.

3. Use pumps constructed with seals to prevent oil, air, or other foreign substances from contaminating grout and prevent loss of grout or water.

4. Specify pump capacity adequate to maintain the specified grouting rate.

5. Place pressure gauges with full scale reading of no more than 300 psi at the pump and at the duct inlet.

6. Grout hoses to be compatible with pump output (diameter and pressure rating).

462-7.4.1.4.3 Vacuum Grouting: Provide vacuum grouting equipment meeting these minimum requirements:

1. Volumeter for measurement of void volume;
2. Vacuum pump with a minimum capacity of ten cubic feet per minute and equipped with a flow-meter, graduated hopper, or other acceptable means approved by the Engineer capable of measuring the amount of grout being injected.
3. Manual colloidal mixers, manual high speed shear mixers, or other mixing methods recommended and approved by the grout manufacturer, in writing, for the specific project covered by this Section for voids less than 5.5 gallons in volume. However, mix a minimum of one full bag of grout regardless of the size void to be grouted.
4. Standard colloidal mixers for voids 5.5 gallons and greater in volume.

462-7.4.1.4.4 Standby Equipment: Provide a standby colloidal grout mixer and pump during grouting operations.

462-7.4.1.5 Grouting:

1. Maintain grout fluidity in strict compliance with grout manufacturer's recommendations.
2. In the presence of the Engineer, perform a test to confirm accuracy of grouting equipment volume-measuring components each day of use before performing any grouting operations. Testing in a warehouse or similar condition is acceptable. Use either water or grout for testing using standard testing devices with volumes of 0.5 gallon and 6.5 gallon and an accuracy of equal to or less than four ounces. Perform one test with each device. Results must verify accuracy of grouting equipment void volume-measuring component within 5% of test device volume and must verify accuracy of grouting equipment grout volume component within 10% of test device volume for the 0.5 gallon test device. When testing the 6.5 gallon device, ensure an accuracy of 3% (test device volume) and 6% (grout volume).
3. Do not use grout that tests outside allowable flow rates.
4. Perform grouting in accordance with procedures set forth in approved Grouting Operations Plan.
5. Grout all ducts.

462-7.4.1.5.1 Temperature:

1. At inlet end of grout hose, the maximum limit for grout temperature is 90°F for normal grouting procedures and 85°F when performing repair operations with vacuum grouting.
2. Condition grout material to maintain mixed grout temperature below maximum limit.
3. Grouting operations are not permitted when ambient temperature is below 40°F or is expected to fall below 40°F within one day subsequent to grouting.
4. Postpone grouting operations if freezing temperatures are forecasted within two days subsequent to grouting.

462-7.4.1.5.2 Mixing and Pumping:

1. Mix grout with a metered amount of water.
2. Mix materials to produce a homogeneous grout.
3. Continuously agitate grout until grouting operations are complete.

4. Reject bags of grout containing clumps.

462-7.4.1.5.3 Production Test:

1. Test grout fluidity to verify it is within limits established by grout manufacturer during grouting operations. Target fluidity rate is established by manufacturer's representative based on ambient weather conditions.

2. Determine grout fluidity in accordance with Section 938.

a. Perform a fluidity test using flow cone on grout discharged from anchorage cap outlet immediately after uncontaminated uniform consistency discharge begins for each tendon greater than 50 feet in length. For tendons 50 feet or less, perform a fluidity test on a per batch basis. For fluidity tests done on a per batch basis, perform test after new batch has been transferred from mixing tank to holding tank and thoroughly mixed with remains of the previous batch to produce a new homogenous mixture. During mixing process, continually re-circulate grout from hose into holding tank. Ensure measured grout efflux time is not less than efflux time measured at injection end of grout hose.

b. Additionally, check grout fluidity using Wet Density method contained in Section 938. Density at discharge outlet must not be less than grout density at inlet. Continuously discharge grout until density requirements are met. Discard grout used for testing fluidity.

3. Perform fluidity test for each tendon to be grouted without modifying water-cement ratio.

4. Check temperature of grout at inlet end of grout hose hourly to verify conformance to this Section.

5. Obtain a sample from first production batch of grout and perform a wick induced bleed test on this sample in accordance with Section 938 at beginning of each day's grouting operation. Begin grouting operations after sample is obtained.

6. Once grouting has begun, if zero bleed requirement is found to not have been achieved in the wick induced bleed test at any time during required test time period, complete grouting of any partially grouted tendons currently being grouted but do not begin grouting any new or additional tendons. Immediately inform the Engineer when grouting operations have ceased due to non-compliance of the wick induced bleed test.

7. Do not re-start grouting operations until such time that testing shows grout meets specified requirements.

462-7.4.1.5.4 Grout Injection Operations:

1. Briefly open low point drains to allow for drainage of any water that may be present within the duct. If water is present:

a. Capture and measure the water removed from the duct and retain for further testing as directed by the Engineer; blow the duct with oil free dry compressed air meeting the ASTM D4285 with the end vent port open.

b. Obtain written authorization from the Engineer to proceed with grouting injection operations.

2. Open all grout outlets before starting grouting operation.

3. Inject grout into duct in accordance with approved Grouting Operations Plan.

4. Pump grout at the lowest possible pressure practical.

5. Conduct normal grouting operations at a pressure range of 10 psi to 50 psi measured at grout inlet.

6. Do not exceed a pumping pressure of 145 psi anywhere within the system. Do not exceed a pumping pressure of 75 psi at the grout inlet for flat ducts.

7. Use grout pumping methods that ensure complete filling of ducts and complete encasement of steel.

8. Grout must flow from first and subsequent outlets until any residual water or entrapped air has been removed prior to closing outlet.

9. Pump grout through duct and continuously discharge it at anchorage and anchorage cap outlets until all free water and air are discharged and consistency of grout is equivalent to that of grout being pumped into inlet. Close anchorage outlet and discharge a minimum of two gallons of grout from anchorage cap into a clean receptacle. Close anchorage cap outlet.

10. Elevate grout pressure to the equivalent realized pumping pressure while grouting the duct, seal inlet valve, and wait two minutes to determine if any leaks exist after all outlets have been bled and sealed. If leaks are present repair all identified leaks using methods pre-approved by the Engineer and repeat steps until no leaks are present. Bleed pressure to 5 psi and wait a minimum of ten minutes for any entrapped air to flow to high points if no leaks are present. Increase pumping pressure not to exceed actual realized pumping pressure of duct and discharge grout at each high point outlet to eliminate any entrapped air or water after specified ten minute period has expired. Complete process by locking a pressure of 30 psi into tendon duct.

11. If actual grouting pressure exceeds maximum allowed, close inlet and pump grout at next outlet which has just been closed or is ready to be closed as long as a one-way flow is maintained. Do not pump grout into a succeeding outlet from which grout has not yet flowed. Fit outlet/inlet to be used for pumping with a positive shut-off valve as shown in the approved system drawings and pressure gauge if this procedure is used.

12. Stop grouting operation if complete grouting of tendon cannot be achieved by the steps stated and in compliance with the approved Grouting Operations Plan. After waiting 48 hours, vacuum grout duct in accordance with this Section.

462-7.4.1.5.5 Vertical Grouting:

1. Provide a reservoir, equivalent to a minimum of 2% of the total anticipated grout volume used on a particular tendon, at upper end of tendon to store bleed water and grout; maintain grout level above level of prestressing plate and anchorage for all vertical tendons. Design and size this device to maintain level grout at an elevation that ensures potential bleed will not drop below the highest point of upper anchorage device. Design reservoir to allow all bleed water, if any, to rise into reservoir.

2. Discharge grout and check grout fluidity as described in this Section. Immediately add grout if level of grout begins to drop, potentially allowing bleed water into the upper anchorage device and tendon duct. Remove reservoir after grout has hardened. Visually inspect for voids using a borescope or probe in presence of the Engineer. Fill all voids found in duct using volumetric measuring vacuum grouting process in accordance with this Section.

3. Allow grout to flow from each outlet until all air and water have been purged prior to using a higher elevation outlet for pumping. Pump grout at increasingly higher outlets which have been or are ready to be closed, as long as one-way grout flow is maintained for vertical tendons within allowable grouting pressures.

462-7.4.1.5.6 Grouting Operations Report:

1. Submit grouting report signed by the grouting Contractor within five days of each grouting operation for review by the Engineer.

2. Record theoretical quantity of grout anticipated as compared to actual quantity of grout used to fill duct. Notify the Engineer immediately of shortages or overages.

3. Information to be noted in this report must include at a minimum, but not necessarily be limited to:

a. identification of tendon;
b. date grouted;
c. number of days from tendon installation to grouting;
d. type of grout;
e. injection end;
f. verification that water or moisture is not present within the duct;
g. daily duct humidity readings if applicable;
h. Pressure gauge readings at the pump and at the inlet;
i. Ratio of actual to theoretical grout quantity;
j. Number of grout bags mixed;
k. Total quantity of water used to mix grout;
l. Summary of any problems encountered; and,
m. corrective action taken,
n. description and results of the post grouting operations and inspection.

462-7.4.2 Flexible Filler Operations:

1. Inject flexible filler with or without using vacuum assistance for tendons with vertical or predominately vertical profiles as shown on Standard Plans, Index 462-001.

2. Inject flexible filler using vacuum assistance for all other tendon profiles shown on Standard Plans, Index 462-001.

462-7.4.2.1 Microcrystalline Wax: Conduct all wax injection operations, repairs, and inspections in the presence of the Filler Injection Foreman, Filler Injection QC Inspector and the Engineer.

462-7.4.2.1.1 Wax Injection Operations Plan:

1. Prepare a Wax Injection Operations Plan in cooperation with the PT system vendor and the PT wax manufacturer.

2. Submit the Wax Injection Operations Plan to the Engineer for approval at least six weeks in advance of any scheduled injection operation.

3. Written approval of the Wax Injection Operations Plan by the Engineer is required before any injection of permanent structure can begin.

4. At a minimum, the Wax Injection Operations Plan will address and provide the following:

a. Names and qualifications for wax injection crew and crew supervisor in conformance with this Specification;

b. Type, quantity, and brand of materials to be used in wax injection including all required certifications;

c. Type of equipment to be used, including capacity in relation to demand and working conditions, as well as, standby equipment and spare parts;

d. Personal Protective Equipment (PPE);

e. Communication equipment to be used during injection;

f. Location and sequence of ducts to be injected;

g. Calculation of temporary elongation of tendons due to wax injection temperature;

h. Procedures for checking the presence of water or moisture in the duct, blowing oil-free dry compressed air, and measuring humidity of air within the duct;

i. If applicable, procedures for monitoring and continuously maintaining less than 40% humidity of air within the duct;

j. General wax injection procedure for all duct geometries and types;

k. Duct pressure test and repair procedures;

l. Method to be used to control rate of flow within ducts and anchorage assembly;

m. Theoretical wax volume calculations;

n. Injection rate;

o. Maximum injection pressure during injection and locking pressure;

p. Vacuum (gauge) pressure requirements, vacuum tests and repair procedures;

q. Heating, mixing and pumping procedures in accordance with the manufacturer's recommendations;

r. Direction of wax injection accounting for grade and/or slope of tendon;

s. Location of all high points and all low points accounting for grade and/or slope of tendon;

t. Sequence of valve operations at PT system inlets and outlets, including minimum wax discharge quantities;

u. Procedures for handling blockages;

v. Procedure for sealing duct after wax injection;

w. Procedure for inspecting the PT system after wax injection, filling voids created by inspection procedures, and sealing duct after PT system inspection;

x. Procedures for possible post injection repair;

y. Method(s) and material(s) that will be used to protect concrete surfaces from wax spills, leaks, etc. during wax injection, post injection inspection and post injection repair;

z. Safety and clean-up procedures;

5. Conduct a joint meeting of the Contractor, wax injection crew, and the Engineer before wax injection operations begin. Discuss Wax Injection Operations Plan, required testing, corrective procedures, and any other relevant issues at the meeting.

6. Prior to production wax injection, demonstrate to the Engineer's satisfaction successful wax injection by injecting full-scale mockups that are constructed with all associated PT system components using the mockup tendon profiles shown in the Plans and the proposed Wax Injection Operations Plan. Utilize smooth duct and associated couplers and fittings meeting the requirements of Section 960 for all mockups. Utilize smooth duct for the mockups which has an inside diameter required for a given mockup tendon size. If the mockup is also being used to perform PT system acceptance testing, use the duct type appropriate for the PT system location. Place the mockup tendons specified in the Plans inside the ducts to simulate the in-place PT tendons. Stress mockup tendons to the minimum values shown in the Plans by using jacks or other methods approved by the Engineer. Perform pressure tests on the mockups in accordance with 462-8.2.1 prior to wax injection. If vacuum assisted wax injection is required to be used, perform vacuum tests on the mockups in accordance with 462-8.2.1 prior to wax injection. For the wax injection operations, utilize the same wax material and types and sizes of wax injection equipment that will be used on the project including but not limited to heaters, pumps, hoses, valves and pressure gauges. Inject wax into the mockups using the proposed Wax Injection Operations Plan. Allow the wax to cool a minimum of 24 hours after injection before inspecting the mockup. Inspect the mockup in accordance with the requirements of 462-8.3.2.2.1 and then carefully cut open the duct at all high points and other locations as directed by the Engineer to check for voids. Prepare a report documenting the findings and submit it to the Engineer. If voids are found, determine the cause and revise the proposed Wax Injection Operations Plan accordingly. If directed by the Engineer, construct additional mockups and repeat the wax injection operation using the revised Wax Injection Operations Plan as many times as are required until the results are acceptable.

462-7.4.2.1.2 Inlets and Outlets:

1. Ensure connections from wax pump hose to inlets are free of dirt and are air-tight.

2. Inspect valves to ensure they can open and close properly.

3. Provide clear hose and connections to outlet valves compatible with heated wax injection for discharging excess wax. Kinks and clogs in the vent hoses are not permitted during pumping operations.

462-7.4.2.1.3 Supplies:

1. Provide an adequate supply of compressed air for clearing and testing ducts before wax injection operations start.

2. Provide clean receptacles for collecting excess wax at outlet locations.

3. Provide supplies for stopping wax leaks including rags and buckets of cold water.

462-7.4.2.1.4 Equipment:

1. Provide equipment consisting of measuring devices for wax, wax melting unit(s), wax mixer for maintaining uniform temperature, a storage holding reservoir, pump, and volumetric flow rate and displacement volumetric meters with all necessary connecting hoses, valves, pressure gauges, timer, and temperature gauge.

2. Provide pumping equipment with sufficient capacity to ensure PT ducts can be filled and vented in not more than time specified by the wax manufacturer and this Specification.

3. Provide an air compressor and hoses with sufficient output to perform required functions.

4. For filling of air voids in an incomplete wax injection, have the required equipment and personnel as stated in the approved Wax Injection Operations plan available to meet the timeframe requirements of 462-8.3.2.2.1-6.

5. For vacuum assisted injection, provide vacuum pump equipment able to measure and have sufficient capacity to ensure a minimum of 90% vacuum in the PT system prior to filler injection. Provide a continuously running vacuum pump or vacuum reservoir capable of maintaining vacuum during the wax injection process.

6. Ensure that all injection and inspection equipment is maintained in accordance with equipment manufacturer's instructions and is calibrated and in good working condition.

7. Provide equipment for dislodging congealed wax blockages.

8. Provide standby pumping and vacuum equipment on the project site during injection operations.

462-7.4.2.1.4.1 Storage Reservoir and Mixing:

1. Provide heated holding tanks for wax injection.

a. Holding tanks must be equipped with a heating system capable of producing a melted wax free of lumps within the temperature limits specified by the manufacturer.

b. Holding tanks must be kept at least 10% full at all times during pumping operations to prevent clogs and air from being drawn into duct

c. Holding tanks must have at time of injection a quantity of heated wax required to inject the PT system. The quantity of heated wax required to inject the PT system is calculated as 25% more than the total quantity to fill the duct and anchorages, to discharge wax at outlets, to fill pumping equipment and hoses, and to maintain the minimum amount of wax in the holding tanks during pumping operations.

2. Provide equipment to ensure uniform temperature of heated wax, either by mixing or other methods.

462-7.4.2.1.4.2 Pumps:

1. Provide pumping equipment capable of the following:

a. continuous operation which includes a system for heating pump components when wax injection is not in progress;

b. maintaining pressure on wax injected ducts;

c. fitted with a valve that can be closed off without loss of pressure in duct.

2. Wax pumps will:

a. be positive displacement type;

b. provide a continuous wax flow;

c. be able to maintain a discharge pressure of at least 75 psi;

d. provide an injection of filler into duct in a velocity range of 40-70 ft/min.

3. Use pumps constructed with seals to prevent oil, air, or other foreign substances from contaminating wax and prevent loss of wax.

4. Pumps with hoppers are not permitted.

5. Specify pump capacity adequate to maintain the wax injection rate.

6. Place pressure gauge with full scale reading of no more than 300 psi at pump and duct inlets.

7. Wax injection hoses to be compatible with pump output (diameter, pressure rating and temperature).

462-7.4.2.1.4.3 Vacuum Wax Injection:

1. If vacuum wax injection is to be used for filling voids in incomplete wax filling operations, provide vacuum wax injection equipment meeting these minimum requirements:

a. Volumeter for measurement of void volume;

b. Vacuum pump with a minimum capacity of ten cubic feet of air per minute and equipped with a flow-meter, graduated reservoir, or other acceptable means approved by the Engineer capable of measuring the amount of wax being injected.

c. Mixers and heaters, or other mixing and heating methods recommended and approved by the wax manufacturer, in writing, for the specific project covered by this Section.

2. For vacuum assisted injection, provide vacuum wax injection equipment meeting these minimum requirements:

a. Vacuum pump with a minimum capacity of ten cubic feet of air per minute (free air) with the capability of removing 90% of standard atmospheric pressure within the PT system and equipped with a vacuum pressure gauge;

b. Hoses, vacuum reservoirs, and connections required for attachment to the PT system.

462-7.4.2.1.4.4 Heaters: Use a heater and temperature monitoring system capable of liquefying the entire mass of PT wax to be used for a given injection operation within the temperature limits specified by the PT wax manufacturer. The heater systems must apply a uniform heat to the PT wax and avoid locally high temperatures that may damage the PT wax or container. Use a heater and temperature monitoring system which complies with the recommendations of the PT wax manufacturer.

462-7.4.2.1.5 Wax Injection:

1. Maintain wax temperature in strict compliance with the wax manufacturer's published product data sheet and within the limits of this Section.

2. Perform wax injection in accordance with procedures set forth in approved Wax Injection Operations Plan.

3. Inject hot wax into specified duct inlet.

462-7.4.2.1.5.1 Temperature:

1. Condition wax to maintain its temperature during injection between 212°F and 240°F.

2. Wax injection operations are not permitted when ambient temperature is below minimum temperatures specified by the wax manufacturer.

462-7.4.2.1.5.2 Production Test:

1. Check wax temperature to verify it is within established limits during operations.

2. Do not start operations until such time that testing shows wax meets specified requirements.

462-7.4.2.1.5.3 Wax Injection Operations:

1. Briefly open low point drains to allow for drainage of any water that may be present within the duct. If water is present:

a. Capture and measure the water removed from the duct and retain for further testing as directed by the Engineer;

b. Obtain written authorization from the Engineer to proceed with blowing of compressed air.

2. Just prior to wax injection, close all low point drains and ports except the inlet and outlet ports at the anchorage caps. Blow oil-free dry compressed air meeting ASTM D4285 through one of the anchorage cap ports until the humidity measured at the inlet and outlet ends are less than 40% and continuing blowing for an additional 30 minutes. Stop blowing, wait a minimum of 15 minutes, and take humidity measurements at the inlet and outlet ends of blowing. Further blowing is not required if both humidity readings are less than 40%. If the humidity readings are 40% or greater, then repeat the process of blowing and waiting for 15 minutes until the humidity measurements at the inlet and outlet end of blowing are less than 40%. Take humidity measurements of air within the duct at the inlet end and outlet end of blowing using separate humidity meters. Use humidity meters approved by the Engineer.

4. Provide visual confirmation that the duct and tendon are free of water, moisture and debris at the anchorages and low points of the tendon profile.

5. Protect concrete surfaces from wax spills, leaks, etc.

6. Inject wax in accordance with approved Wax Injection Operations Plan.

7. Use pumping methods that ensure complete filling of ducts and anchorage assembly with wax.

8. Ensure the entire mass of wax is fully liquefied prior to and throughout injection operations. Establish a non-turbulent, laminar system circulation by continuously recirculating the wax between the pump and the storage container prior to injecting the wax into the duct. Pump components must be at wax injection temperature prior to wax injection into duct. Do not allow wax to free fall during recirculation or injection operations. Maintain a positive head of liquid wax above all withdrawal and recirculation ports and do not allow air intrusion into the pumping system. Do not pour liquid wax into an open pump or hopper.

9. Inject PT wax at a continuous and steady rate in accordance with the approved Wax Injection Operations Plan at a flow rate through duct at a velocity between 40 and 70 feet per minute and pressure limited to 75 psi at the duct inlet and 145 psi at the pump.

10. For tendons in which vacuum assisted injection is used, provide a minimum of 90% vacuum in the duct prior to injection. Connect both the

anchorage outlet and the cap outlet to the vacuum system. After the vacuum is established, lock off the air supply to the duct and monitor the vacuum for 1 minute. If the loss of vacuum after 1 minute exceeds 10%, repair leaks as directed by the Engineer and retest the duct. If the results are acceptable, reestablish and maintain a minimum 90% vacuum using the outlets at the higher end anchorage shown on Standard Plans, Index 462-001 while injecting wax using the inlet at the lower end anchorage shown on the same Standard. Close all outlets, inlets, and ports other than at injection and vacuum locations during injection procedure. Pump wax into inlet and continuously vacuum air at the outlet. After the duct is fully injected with wax and the wax reaches the vacuum end, close the outlet valve, turn off the vacuum pump and continue the injection pump. Bleed all outlets starting at the anchorage cap at the injection end and proceed to bleed every valve thereafter from injection end to vacuum end, ending with the anchorage cap at the vacuum end. When bleeding each valve, collect a minimum of two gallons of continuously flowing wax free from air before closing the valve. After all outlet valves are closed, close inlet valve with locking pressure between 30 psi and 45 psi. Do not reuse discharged wax.

11. For tendons in which vacuum assisted injection is not used, inject wax under pressure at locations shown on Standard Plans, Index 462-001. Allow wax to flow from duct and anchorage discharge points until a steady flow of wax free from air is continuously discharged. Collect a minimum of two gallons of continuously flowing wax free from air at discharge point before closing outlet valve. Do not reuse discharged wax. After all outlets are closed, close the inlet valve at locking pressure between 30 and 45 psi.

12. Record the total volume of wax injected into the system.

13. Upon completion of wax injection, seal the duct in accordance with the approved PT system drawings. Remove all excess wax from exposed surfaces.

462-7.4.2.1.5.4 Wax Injection Operations Report:

1. Submit the wax injection report signed by the wax injection Contractor within five days of each wax injection operation for review by the Engineer.

2. Record theoretical quantity of wax anticipated as compared to actual quantity of wax used to fill duct. Notify the Engineer immediately of shortages or overages.

3. Information to be noted in this report must include at a minimum, but not necessarily be limited to:

a. Identification of duct;
b. Date of duct pressure test;
c. Date wax injected;
d. Number of days from tendon installation to wax injection;
e. Wax product identification;
f. Daily duct humidity readings if applicable;
g. Humidity readings from blowing compressed air through duct;
h. Verification that water or moisture is not present within the duct prior to wax injection;

i. Pressure gauge readings at the pump and at the inlet;

j. Final locking pressure of wax in PT system;

k. Reservoir temperature at time of initiation of wax injection;

l. Theoretical volume of wax required to completely fill the duct;

m. Volume of wax injected into duct;

n. Volume of wax collected at discharge points;

o. Injection rate including timing of duct inlet opening and closing;

p. Ambient temperature;

q. Summary of any problems encountered and any deviations from the Wax Injection Operations Plan;

r. Corrective action taken;

s. Description and results of the post wax injection operations and inspection;

t. Vacuum gauge pressure and percent vacuum in duct prior to injection;

4. Maintain daily wax injection operations reports at the job site for review by the Engineer. Submit all daily reports to the Engineer on a weekly basis or as directed by the Engineer.

462-7.4.2.1.6 Manufacturer's Installation Technician: Provide for a PT system vendor installation technician, certified by the vendor as having sufficient knowledge and expertise to oversee the wax injection personnel. The vendor's technician shall be under the direct employ of the vendor and shall be present for all wax injection activities for a minimum of the first two days of wax injection for each of the Contractor's wax injection crews. The vendor's technician shall submit written certification to the Engineer that the Contractor's installation process is in conformance with the approved Wax Injection Operations Plan.

462-7.5 Repair: Perform no remedial or repair work without the Engineer's approval in writing.

462-7.5.1 Lifting and Access Holes:

1. Repair all holes with magnesium ammonium phosphate concrete meeting requirements of Section 930 or Type Q epoxy grout meeting requirements of Section 926. Immediately before casting concrete (i.e., within 24 hours), mechanically clean and roughen the mating concrete surfaces to remove any laitance and expose small aggregate. Use grit blasting or water blasting using a minimum 10,000 psi nozzle pressure. Flush surface with water and blow dry. Form, mix, place, and cure material in strict compliance with manufacturer's recommendations.

2. Upon completion of deck grooving, coat repaired holes, block-outs, and an area extending six inches outside perimeter of repair with a high molecular weight methacrylate (HMWM) meeting the requirements of Section 413. Prepare surface to be coated

and apply HMWM in accordance with Section 413. Friction (skid) tests per Section 413 are not required.

462-7.5.2 Inlets, Outlets, Drains and Ports:

1. Place threaded plastic plugs in all inlet, outlet, drain and port locations required in the Contract Documents.

2. Fill inlet, outlet, drain and port recesses as shown in the Contract Documents using a Type Q epoxy compound, Type E epoxy compound, or Type F-1 epoxy compound meeting requirements of Section 926.

3. Prepare surface to receive epoxy compounds in compliance with manufacturer's recommendations.

462-7.5.3 Duct:

1. Repair the following ducts using heat-shrink wrap material designed for duct repair:

a. Smooth plastic ducts that will be encased in concrete;

b. Corrugated plastic ducts;

c. External smooth plastic ducts after the flexible filler injection procedure has been completed.

Install heat-shrink wrap in accordance with manufacturer's instructions.

2. Repair external smooth plastic ducts before the flexible filler injection procedure has been completed using elastomer sleeves and stainless steel band clamps.

462-8 Acceptance and Testing.

462-8.1 Contractor Material Testing:

1. The following tests are not required on post-tensioned, precast flat slab bridges, and double-tee bridges, but are required on all other PT applications.

2. Include cost for Contractor Tendon Modulus of Elasticity Test and In-Place Wobble and Friction Test in price of PT system.

462-8.1.1 Tendon Modulus of Elasticity Test:

Perform a tendon modulus of elasticity test in accordance with the following procedure if required in the Contract Documents or ordered by the Engineer.

1. Bench test two samples of each size tendon prior to stressing tendons to determine modulus of elasticity for purpose of accurately determining tendon elongations while stressing.

2. Bench length between anchorages must be at least 40 feet and tendon duct at least two inches clear of tendon all around for purpose of this test.

3. Test procedure must consist of stressing tendon at an anchorage assembly with a load cell at dead end.

4. Tension test specimen 80% of GUTS in ten increments and then detention from 80% of GUTS to zero in ten decrements.

5. Record gauge pressure, elongations, and load cell forces for each increment and decrement.

6. Note elongations of tendon for both ends and the central 30 feet, measured to an accuracy of plus or minus 1/32 inches.

7. Correct elongations for actual anchor set of dead end.

8. Calculate modulus of elasticity as follows:

$$E = PL/Adl$$

where,

P = force in tendon

L = distance between pulling wedges and dead end wedges or exact length in the center 30 feet of tendon

A = cross sectional area of tendon

dl = tendon elongation within length, L, for load, P

9. Submit revisions to theoretical elongations to the Engineer for approval if bench test varies from modulus of elasticity used for shop or working drawings by more than 1%.

10. Additional Tendon Modulus of Elasticity Tests may be required when observed tendon elongations in erected structure fall outside acceptable tolerances or to otherwise settle disputes to the satisfaction of the Engineer.

11. Additional test series of substantiation from previous projects, not to exceed two per source, will be required if source of prestressing steel changes during project.

12. Apparatus and methods used to perform the test must be submitted to the Engineer for approval in writing.

13. Tests must be conducted in the Engineer's presence.

462-8.1.2 In-Place Wobble and Friction Test:

1. Test in-place a minimum of one tendon per tendon group performing the same function for tendons in excess of 100 feet long.

2. Functional tendon groups are cantilever tendons, continuity tendons, draped external tendons, or continuous profiled tendons passing through one or more spans.

3. Selected tendon will represent the size and length of tendon group being tested.

4. In-place test is not required on projects with straight tendons used in flat slabs or precast voided slabs.

5. Test procedure consists of stressing tendon at an anchorage assembly with a load cell or a second certified jack at dead end.

6. Stress test specimen to 80% of GUTS in eight equal increments.

7. For each increment, record gauge pressure, elongations, and load cell force (if a load cell is used).

8. Take into account any wedge seating in both live end (i.e., back of jack) and dead end (i.e., back of load cell) and any friction within anchorages, wedge plates, and jack as a result of slight deviations of strands or wires through these assemblies.

9. Keep an accurate account of elongation at jacking end allowing for intermediate wedge seating and slip of the jack's wedges for long tendons requiring multiple jack pulls with intermediate temporary anchoring.

10. If elongations fall outside the plus or minus 7% range compared to anticipated elongations, investigate reason and make detailed calculations confirming final tendon forces are in agreement with requirements of the approved Contract Documents.

11. Do not vary value of expected friction and wobble coefficients by more than plus or minus 10% in reconciling theoretical and actual elongations.

12. Submit for written approval by the Engineer a plan to correct or compensate for elongation discrepancies if necessary.

13. The Engineer will require one successful test for each tendon group for the project.

14. The Engineer may require additional in-place tests if there are irreconcilable differences between forces and elongations or other difficulties during the course of routine stressing operations.

15. Submit apparatus and methods used to perform test to the Engineer for approval in writing.

16. Conduct all in-place tests in the Engineer's presence.

462-8.1.3 Required Reports:

1. Submit the test report for "Tendon Modulus of Elasticity Test" to the Engineer at least 30 days before installing tendon.

2. Submit the test report for "In-Place Wobble and Friction Test" to the Engineer within two weeks after successful installation of tested tendon.

462-8.1.4 Test Results Application:

1. Reevaluate theoretical elongations shown on PT shop or working drawings using results of "Tendon Modulus of Elasticity Test" and "In-Place Wobble and Friction Test," as appropriate, and correct calculations as necessary.

2. Submit revisions to theoretical elongations to the Engineer for approval in writing.

462-8.2 Contractor Field Tests:

462-8.2.1 Prior to Concrete Placement:

462-8.2.1.1 All Tendons Except as Noted:

1. Test all PT system components utilized on the project, except those used for internal longitudinal tendons in precast box-girder segments in the casting cell (e.g., cantilever tendons).

2. In the formwork, pressure test each duct with all assemblies used in a single structural component (e.g. segment, beam, etc.).

3. Test assemblies in their final position just prior to concrete placement by sealing them at their anchorages or construction joint termini and then applying compressed air in accordance with this Section to determine if assembly connections are pressure tight.

4. In presence of the Engineer, pressurize duct to 7.5 psi and lock-off outside air source. Record pressure loss for one minute. If pressure loss exceeds 0.75 psi, or 10%, find and repair leaks in duct assembly using repair methods approved by the Engineer and retest.

462-8.2.1.2 Tendons for Which Vacuum Assisted Filler Injection Will Be Used:

1. Test all PT system components utilized on the project except those used for internal longitudinal tendons in box-girder segments.

2. In the formwork, perform a vacuum test for each duct with all assemblies used in a single structural component (e.g. segment, beam, etc.).

3. Test assemblies in their final position just prior to concrete placement by sealing them at their anchorages or construction joint termini and then applying a vacuum in accordance with this Section to determine if assembly connections are pressure tight.

4. In presence of the Engineer, apply a 90% vacuum and lock-off outside air source. Record vacuum loss for five minutes. If vacuum loss exceeds 10%, find and repair leaks in duct assembly using repair methods approved by the Engineer and retest.

462-8.2.2 Post Concrete Placement:

1. After stressing and before injecting filler into duct, install all anchorage caps, inlets and outlets and test the duct with compressed air in accordance with this Section to determine if duct connections require repair.

2. In the presence of the Engineer, pressurize duct to 50 psi and lock-off outside air source. Record pressure loss for one minute. A pressure loss less than 25 psi, or 50%, is acceptable for ducts with a length of equal to or less than 150 feet and a pressure loss less than 15 psi is acceptable for ducts longer than 150 feet.

3. If the pressure loss exceeds allowable, repair leaking connections using methods approved by the Engineer and retest.

462-8.3 Contractor Inspections:

462-8.3.1 Post Concrete Placement/Prior to Filler Injection Operations:

1. Upon completion of concrete placement and except as otherwise described, prove PT ducts are free and clear of any obstructions or damage and are able to accept intended PT tendons by passing a torpedo through ducts.

2. Use a torpedo having same cross-sectional shape as duct that is 1/4 inches smaller all around than clear, nominal inside dimensions of duct. Make no deductions to torpedo section dimensions for tolerances allowed in manufacture or fixing of ducts. For straight ducts, use a torpedo at least two feet long. For curved ducts, determine length so that when both ends touch outermost wall of duct, torpedo is 1/4 inches clear of innermost wall. The Engineer will reject member if torpedo will not travel completely through duct and workable repair cannot be made to clear duct. Torpedo must pass through duct easily when pushed through by hand, without resorting to excessive effort or mechanical assistance.

3. Alternatively, four strand tendons in flat ducts used for transverse PT of segmental box-girders may be preplaced prior to concrete casting. Prove PT ducts are free and clear of any obstructions or damage by moving the group of strands back and forth in duct for a minimum distance of one foot in each direction. Move strands easily, by hand, without resorting to excessive effort or mechanical assistance.

462-8.3.2 Post Filler Injection Operations:

462-8.3.2.1 Post Grouting Operations:

1. Inspect all tendons. Complete the inspection of a given tendon within 96 hours after grouting of that tendon.

2. Do not open or remove inlets, outlets, drains or ports until grout has cured for a minimum of 24 hours.

3. Perform inspections within one hour after removal of all inlets and outlets and drains located at anchorages and points along the tendon.

4. Drill into grout ports at all high points along tendon as well as inlets or outlets located at anchorages for inspection. Drill through hardened grout to penetrate full-length of grout port access piping to top of trumpet or duct. If drilling of inlets or outlets is not feasible with conventional equipment, propose an alternative method of tendon inspection for approval by the Engineer in writing. Use drilling equipment that will automatically shut-off when steel is encountered. Do not drill into anchorage cap unless anchorage caps are determined to have voids by sounding.

5. Perform all inspections using borescopes or probes and in presence of the Engineer.

6. Fill voids using volumetric measuring vacuum grouting process within 4 days from grouting.

7. Seal and repair all anchorage and inlet/outlet voids that are produced by drilling for inspection purposes as specified within four hours of completion of inspections if no additional voids are detected in tendon ducts or anchorages.

8. Remove inlet/outlet to a minimum depth of two inches below face of concrete and seal the surface as specified within 4 hours of inlet/outlet removal. Use an injection tube to extend to bottom of holes for backfilling with epoxy grout.

9. Drill into duct and explore voided areas with a borescope if grouting operations were prematurely terminated prior to completely filling duct. Probing is not allowed. Determine location and extent of all voided areas. Fill voids using volumetric measuring vacuum grouting equipment in accordance with this Section.

462-8.3.2.2 Post Flexible Filler Injection Operations:

462-8.3.2.2.1 Microcrystalline Wax:

1. Inspect all tendons. Complete the inspection of a given tendon within 96 hours after injecting that tendon with wax.

2. Do not open or remove inlets, outlets, drains or ports until wax has cooled for a minimum of 24 hours.

3. Perform inspections within one hour after removal of all inlets/outlets located at anchorages and high points along the tendon.

4. Visually inspect existing ports at all high and low points along tendon as well as all ports located at anchorages. Repair wax leaks according to the Wax Injection Operations Plan.

5. Between 24 and 48 hours following wax injection, perform the following inspection operations for each tendon:

a. Sound external ducts with a rubber mallet to ensure the system is free from voids,

b. Remove all inspection port caps and visually inspect to ensure the system is free from voids,

c. If a void is detected and the void is deeper than 1/2 inch or if the strands are exposed and uncoated, address the void using this section and methods described in the approved Wax Injection Operations Plan;

d. Fill voids created by inspection procedures and replace all inspection port caps and seal in accordance with the approved Wax Injection Operations Plan.

6. Fill voids using the methods described in the approved Wax Injection Operations Plan within 4 days from filler injection.

7. Seal and repair all anchorage and inlet, outlet and port voids that are produced for inspection purposes as described in the approved Wax Injection Operations Plan within four hours of completion of inspections if no additional voids are detected in tendon ducts or anchorages.

8. Inspect duct and explore voided areas with a borescope if wax injection operation was prematurely terminated prior to completely filling duct. Determine

location and extent of all voided areas. Fill voids using gravity feed or injection, do not use vacuum repair injection unless proven by a mockup and approved by the Engineer.

462-9 Method of Measurement.

1. Quantity of PT tendons to be paid for under this Section will be computed weight, in pounds, of permanent PT steel tendons installed in the completed structure and accepted.

2. Quantity is determined by theoretical plan length measured from anchorage to anchorage (measured from front face of bearing plate) with no allowance made for waste or extension past bearing faces.

3. No measurement will be made for temporary PT which is considered incidental to Pay Item 462-2, Post Tensioning Tendons.

4. Use these unit weights for quantity determination:

Table 462-2 PT
Strand and Bar Weight per Unit Length

Prestressing System	Weight per Unit Length, Lb/Ft
1/2 inch diameter 7-wire strand	0.52
0.6 inch diameter 7-wire strand	0.74
5/8 inch high strength deformed bar	0.98
3/4 inch high strength deformed bar	1.49
1 inch high strength deformed bar	3.01
1-1/4 inch high strength deformed bar	4.39
1-3/8 inch high strength deformed bar	5.56
1-3/4 inch high strength deformed bar	9.10
2-1/2 inch high strength deformed bar	18.20
3 inch high strength deformed bar	24.09

Note: Weight per unit length of high strength deformed bars is based on values given in ASTM A722.

462-10 Basis of Payment.

462-10.1 General:

1. PT tendons will be paid for at the Contract unit price per pound of steel tendon, completed and accepted.

2. Payment will be full compensation for furnishing, installing, stressing, and filler injection of all temporary and permanent, internal and external ducts. Payment also includes anchorage assemblies and associated supplemental reinforcing steel required by supplier, PT system hardware not embedded in concrete, ducts, grout and grouting operations, flexible filler and filler injection operations, all testing, including construction of and filler injection into mockups, Tendon Modulus of Elasticity Test and In-Place Wobble and Friction Test, protection of PT anchorages, inlets, outlets, drains, and all labor, materials, tools, equipment, and incidentals necessary for completing the work in accordance with the Contract Documents. This payment also includes lubricants in tendon ducts for friction control and flushing lubricants or contaminants from ducts.

3. Anchorage components, ducts, and similar items of PT system hardware embedded within precast components or cast-in-place concrete will be deemed to be included in cost of precast component or cast-in-place concrete in which it is embedded.

4. Payment is based on unit price bid extended by either quantities shown in the Contract Documents or actual quantities used and accepted, whichever is less, if the Contractor constructs structure with an accepted alternate not detailed in the Contract Documents.

5. Permanent PT strand, wire, or bar tendons which are an integral part of individual precast concrete segments or units will be measured and paid for under this item and will not be considered incidental to cost of those precast concrete segments or units.

6. Payment for PT will be made following successful placement, stressing, filler injection, inspection, repair, protection, and written approval by the Engineer.

7. Full payment for PT tendons within precast segmental concrete structure units may occur prior to erection of segments into final position when ducts have been injected and anchorage protection system applied and the segmental unit otherwise approved in writing for placement by the Engineer.

462-10.2 Pay Items:

Payment will be made under:

Item No. 462- 2- Post-Tensioning Tendons - per pound.

SECTION 470
TIMBER STRUCTURES

470-1 Description.

Furnish and erect treated timber into various structures.

470-2 Materials.

Meet the following requirements:

Timber.....Section 952
Preservative.....Section 955

Use timber as specified in the Plans.

470-3 Timber Handling.

Handle treated timber with rope slings, without sudden dropping, breaking of outer fibers, bruising, or penetration of the surface with tools. Do not use cant dogs, hooks, or pike poles.

470-4 Cutting and Framing.

Before treatment, cut and frame all timbers which are shown by the Plans to be furnished in special lengths or framed to detailed dimensions. Limit the cutting of treated timber to minor fitting which might be necessary and that is authorized by the Engineer. For all places where the surface is broken, by cutting or otherwise, thoroughly coat with the preservatives and by the methods specified in AWPA M4.

470-5 Bolt Holes.

The Contractor may drill holes in the field. For timbers originally treated with pentachlorophenol, creosote, creosote solutions, or waterborne preservatives, field treat all cuts, abrasions, bolt holes, and recesses that occur after treatment with two liberal applications of a compatible preservative in accordance with the requirements specified in AWPA Standard M4, Standard for the Care of Pressure-Treated Wood Products.

470-6 Pile Caps.

Ensure that pile caps have full even bearing on all piles in the bent, and secure them to each pile by a 3/4 inch diameter drift bolt extending at least 9 inches into the pile. Where so shown in the Plans, cover the tops and ends of pile caps with 10 ounce, minimum weight, copper sheet meeting the requirements of ASTM B370.

470-7 Floors.

Attach the planks to each joist or nailing strip with at least two 8 inch nails for 3 inch planks, or two 10 inch nails for 4 inch planks. Use nails that are at least 1/4 inch in diameter. For treated timber floors where a bituminous wearing surface is to be applied, lay the planks with the best side up and with adjacent edges in contact. Grade the planks as to thickness before laying, and lay the planks so that no two adjacent planks vary in thickness more than 1/8 inch. Cut the floor to straight lines along the side of the roadway and walkway.

470-8 Framing.

Cut and frame truss and bent timbers to a close fit in such manner that they will have even bearing over the entire contact surface of the joint. Do not perform blocking or shimming of any kind in making the joints. The Engineer will not accept open joints.

470-9 Holes for Bolts, Dowels, Rods, and Lag Screws.

Bore holes to the diameters shown in the following table:

Table 470-1	
Hole use	Hole diameter
Drift Bolts and Dowels	1/16 inch less in diameter than the bolt or dowel to be used
Machine Bolts	same diameter as the bolt
Rods	1/16 inch greater in diameter than the rod
Lag Screws	not larger than the body of the screw at the base of the thread

470-10 Stringers.

The Contractor may use butt joints for outside stringers, but shall frame interior stringers to bear over the full width of floor beam or cap at each end. Separate the ends at least 1/2 inch to allow circulation of air, and securely fasten the ends to the timber on which they rest.

470-11 Railings.

Construct railings of treated dressed lumber.

470-12 Hardware.

470-12.1 General: Use hardware, including bolts, drift pins, dowels, rods, nuts, washers, spikes, nails and all similar incidental metal items, necessary to complete the work in accordance with the details shown in the Plans. Use common wire nails as commercially manufactured. Use ogee washers of cast or malleable iron. The Contractor may use other hardware of steel, iron, or any similar material ordinarily used in the manufacture of such articles.

470-12.2 CCA, ACQ-D, and CA-C, Treated Timber Structures: Use the fasteners and connectors as described in the following table:

Table 470-2 Hardware Requirements for Treated Timber		
Environmental condition where structure will be located	Fasteners	Connectors
Permanent wood foundations and/or where salt spray if prevalent	304 or 316 Stainless Steel	304 or 316 Stainless Steel
Structures that will be exposed to standing water or rainwater	304 or 316 Stainless Steel	304 or 316 Stainless Steel
Structures that will be situated indoors and remain dry in service	304 or 316 Stainless Steel Hot-dipped galvanized fasteners meeting ASTM A-153 requirements	304 or 316 Stainless Steel Hot-dipped galvanized connectors meeting the requirements of ASTM A-653 Class G185 sheet or better
Do not use aluminum in direct contact with treated wood.		

470-12.3 Bolts: Use bolts of the sizes shown in the Plans with square heads and nuts and with screw threads that make close fits in the nuts. Upon completion of the installation, check all nuts for tightness, and cut off protruding bolt ends so that not more than 1/4 inch extends beyond the nut.

470-12.4 Inspection: The Engineer will inspect the hardware for quality of manufacture and accuracy of size prior to use on wood structures.

470-13 Countersinking.

Perform countersinking wherever the heads of screws or bolts would otherwise interfere with the assembly of the work. Fill recesses formed by countersinking with hot asphalt.

470-14 Method of Measurement.

470-14.1 General: The quantity to be paid for will be the plan quantity, in feet board measure, of such timber actually incorporated in and forming a part of the completed structure.

470-14.2 Method of Calculation: For calculating the quantity of timber, the width and thickness will be taken as the actual sizes shown in the Plans or ordered by the Engineer. Where special sizing is required, the width and thickness to be used will be that of the smallest commercial size from which the special piece could be cut. Lengths to be used in the calculations will be the overall lengths of the pieces as shown in the Plans, except that, where the lengths actually incorporated in the structure are less than the lengths shown in the Plans, the lengths actually incorporated will be used in the calculations. Deductions will not be made for copes, scarfs, or crownings.

470-15 Basis of Payment.

Prices and payments will be full compensation for all the work specified in this Section, including all copper covering over pile heads, caps, etc., as shown in the Plans, all hardware except such plates, lag screws, and other metal parts as may be shown in the Plans to be paid for as structural steel and all paint materials and all excavation, painting, and incidentals necessary to complete the work.

Payment will be made under:

Item No. 470- 1- Treated Structural Timber - per Thousand Board Measure.

SECTION 471
FIBER REINFORCED POLYMER FENDER SYSTEMS

471-1 Description.

Construct fiber reinforced polymer (FRP) fender systems using components in accordance with this Section and the Plans.

Submit design calculations, shop drawings, and test reports for the FRP fender system in accordance with the Plans, the FDOT Structures Manual noted in the Plans and this Specification.

471-2 Materials.

Meet the following requirements:

Fiber reinforced polymer composites (Piles, Wales, Spacer-blocks, Decking & Splice Plates) ..... Section 973
Concrete used to fill hollow piles ..... Section 347

Use only SAE Type 316 stainless steel metallic fastening and connection hardware.

471-3 Product Acceptance.

Obtain fender system components from a producer that is currently on the list of Producers with Accepted Quality Control Program for Fiber Reinforced Polymer Composites. Producers seeking inclusion on the list shall meet the requirements of 105-3.

Submit to the Engineer the manufacturer's certification in accordance with Section 6 that the FRP components meet the material requirements of Section 973.

471-4 Shop Drawings and Design Calculations.

471-4.1 Shop Drawings: Submit shop drawings in accordance with Section 5. Include the following, as a minimum, in the shop drawings:

1. General notes.
2. Energy absorption capacity (EAC) of the fender system (in units of kip-ft).
3. Fender system deflection (in units of feet).
4. Minimum pile tip elevation.
5. The name and address of the manufacturer for each component, including the physical address where the fabrication is performed.
6. Pile configuration and layout based on, and compatible with, the geometry shown in the Plans.
7. Pile and wale material properties including fill material used for hollow piles and required admixtures. If the material properties are defined in the Standard Specifications, a reference to the applicable Sections.
8. Pile and wale section properties used in the design.
9. Flexural and shear resistance of the pile and wale components.
10. Pile-to-wale and pile-to-pile connection details.
11. Sections, views, details, and dimensions required to successfully complete the construction of the fender system.
12. Any supplier required limitations regarding pile installation techniques or other typical construction practices permitted by Section 455 (e.g., full length pile driving versus jetting/driving combination).

471-4.2 Design Calculations: Submit design calculations. Design fender system piles, wales, and connections in accordance with the Plans, this Specification, and the FDOT Structures Manual edition noted in the Plans.

471-5 Performance and Testing Requirements.

An independent laboratory must perform all testing and produce the test report. Submit a test report with the following information:

1. Written certification that the fender system components meet the requirements of this Section.
2. Verification of the flexural properties of the pilings and wales as derived from ASTM D6109 using characteristic values in accordance with ASTM D7290 with the following modifications:
    a. Supports shall be located to provide a minimum span-to-depth ratio of 16:1 and a maximum span to depth ratio of 20:1.
    b. Three-point bending tests are acceptable.
    c. Test a minimum of 5 of the same sample of the FRP piling(s) and FRP wale(s) shown on the Shop Drawings.
    d. Do not include adhesive bonding of individual components within a system during verification testing.
3. For hollow FRP sections, verification of shear properties as derived from ASTM D2344. Test a minimum of 5 of the same sample of the hollow FRP sections shown in the Shop Drawings.
4. Detailed material specifications showing material type, quality, certifications, acceptance and rejection criteria and placement procedures.
5. Other information pertinent to the design and performance of the fender system as necessary.

471-6 Design Criteria.

471-6.1 Wales: Wales must meet the following minimum design criteria:

1. Be structurally continuous across a minimum of two spans.
2. Recess all hardware a minimum of 1/2-inch from the front face of wales.
3. Provide fasteners and connection hardware that prevent loosening over time.
4. Provide adequate stiffness to distribute vessel impact loading to meet the minimum required energy absorption capacity (EAC) of the system.
5. Use wales that meet or exceed the flexural and shear demands of the minimum EAC. The minimum flexural resistance must not be less than 40 ft-kip.
6. Meet the following criteria for hollow wale sections:
    a. Provide a minimum of 1/4-inch wall thickness.
    b. Provide a minimum bolt pull-through and crushing resistance greater than or equal to the maximum connection reaction force. Pull-through and crushing resistance is defined at the point of first yield and/or the load at which an audible crack occurs.
    c. Must be capable of resisting crushing loads perpendicular to the axis of the member as required for the impact force applied to the fender in the analysis used to determine the associated EAC of the system. This impact force may be equally distributed between two lines of wales and over a longitudinal distance of five feet.
    d. The minimum shear resistance must not be less than 40 kip.
7. Provide black wales unless otherwise shown in the Plans.

8. Wales, other than RTSS as defined in Section 973, must include minimum 1-1/2" thick UHMW-PE wearing surface.

471-6.2 Piles: Piles must meet the following minimum design criteria:

1. Provide fasteners and connection hardware that prevent loosening over time.

2. For hollow pile sections, provide a minimum bolt pull-through and crushing resistance greater than or equal to the maximum connection reaction force. Pull-through and crushing resistance is defined at the point of first yield and/or the load at which an audible crack occurs.

3. Provide black piles unless otherwise shown in the Plans.

471-7 Storage, Handling and Installation.

Unless otherwise shown in the manufacturer's approved field construction manual, use the following construction details.

Protect materials at all times against exposure to extreme heat or impact. Transport products in a manner that will minimize scratching or damage to the outer surfaces, stack on dunnage above ground so that it may be easily inspected and store in a manner that will avoid damage. Handle and lift products with nylon slings. Do not use sharp instruments in handling the product. Products damaged in shipping or handling will be rejected.

Products containing cracks in the reinforcing rods, or cracks or splits (partial or full depth) across the section will be rejected.

Cut, bevel, drill, countersink and otherwise install products in accordance with the manufacturer's recommendations. Set all material accurately to required levels and lines, with members plumb and true and accurately cut and fitted. Securely attach all materials to substrate by anchoring and fastening as shown in the shop drawings. Perform all cutting and drilling in a manner that allows for the collection of all debris and dispose of properly.

Field installation of grout or concrete inside of hollow wales is not allowed.

Install piles in accordance with Section 455.

471-8 Method of Measurement.

The quantity for the entire fender system to be paid will be lump sum.

471-9 Basis of Payment.

471-9.1 Price and payment for fender system will be full compensation for the work specified in this Section including all labor, equipment and materials required to furnish and install the piles to the pile cut-off elevations shown in the Plans, and all wales, dimensional lumber, material, storage costs, disposal of unused material and waste, transportation costs, fasteners and other necessary items required for completing the work.

Payment will be made under:

Item No. 471- 3- Fender System Polymeric - lump sum.

SECTION 502
SHEAR CONNECTORS

502-1 Description.

Furnish and install welded shear connectors on steel beams and girders at locations shown in the Contract Documents. Field weld shear connectors located on the top flange only after the deck forms are in place. Installation of shear connectors in the fabrication plant is not permitted.

502-2 General Requirements.

502-2.1 Design: Provide shear connector studs of a design suitable for end-welding to steel beams and girders, with automatically timed stud welding equipment. Provide the type, size or diameter, and length of stud as specified by the Contract Documents, and as approved by the Engineer. Meet the allowable tolerances on dimensions as specified in 502-7.

502-2.2 Arc-Shield: Furnish an arc-shield (ferrule), of heat-resistant ceramic or other suitable material, with each stud. Use material that is not detrimental to the welds, does not cause excessive slag, and has sufficient strength not to crumble or break due to thermal or structure shock before the weld is completed.

502-2.3 Flux: Furnish flux for welding with each stud, either attached to the end of the stud or combined with the arc-shield for automatic application in the welding operation.

502-2.4 Coatings: Do not paint or galvanize studs.

502-2.5 Qualification: Use only qualified studs, passing the tests prescribed in 502-6. Use the same arc-shield in production as used in the qualification tests.

502-2.6 Data to be Submitted: Before placing orders for studs, submit to the Engineer for approval, the following information on the studs to be purchased:

1. The name of the manufacturer.
2. A detailed description of the stud and arc-shield to be furnished.
3. A certification from the manufacturer that the stud is qualified as specified in 502-2.5.
4. The qualification test report as certified by the testing laboratory.

502-2.7 Freedom from Defects: After welding, ensure that the studs are free from any defect or substance that would interfere with their function as shear connectors.

502-3 Materials.

502-3.1 Metal: For shear connector studs, meet the requirements of ASTM A108, cold-drawn bar, Grades 1015, 1017, or 1020, either semi-killed or fully-killed. If using flux-retaining caps, use caps of a low-carbon grade steel suitable for welding and meeting the requirements of ASTM A109.

502-3.2 Mechanical Properties: For tensile properties as determined by tests of bar stock after drawing, or of finished studs, meet the following requirements:

Tensile strength	60,000 psi (minimum)
Yield strength*	50,000 psi (minimum)
Elongation	20% in 2 inches (minimum)

Reduction of area ..... 50% (minimum)
*As determined by 0.2% offset method.

Determine tensile properties in accordance with ASTM A370. Perform tensile tests of finished studs on studs welded to test plates. If fracture occurs outside of the middle half of the gage length, repeat the test.

502-3.3 Quality and Finish: Provide finished studs of uniform quality and condition, free from injurious laps, fins, seams, cracks, twists, bends, and other injurious defects. Produce a finish by cold drawing, cold rolling, or machining.

502-3.4 Certification: Ensure that the manufacturer certifies that the studs, as delivered, are in accordance with the materials requirements of this Subarticle. Submit certified in-plant quality control test reports to the Engineer upon request.

502-4 Construction Requirements.

502-4.1 Equipment: End weld stud shear connectors to steel beams or girders with automatically timed stud welding equipment connected to a suitable power source.

502-4.2 Interlocking: If two or more stud welding guns are to be operated from the same power source, interlock them so that only one gun at a time can operate and the operating gun finishes each weld before starting another weld.

502-4.3 Condition of Studs: At the time of welding, ensure that the studs are free from rust, rust pits, scale, oil, and other deleterious matter which would adversely affect the welding operation.

502-4.4 Weather Limitations: Do not weld when the base metal temperature is below 0ºF, or when the surface is wet or exposed to rain or snow.

502-4.5 Position of Welding Gun: While operating, hold the welding gun in position without movement until the weld metal has solidified.

502-4.6 Preparation of Areas: Prepare the surface where studs are to be welded by wire-brushing, peening, prick-punching, grinding, or other approved methods to remove paint, scale, rust, oils, or other deleterious matter which would adversely affect the welding operation.

502-4.7 Spacing: Ensure that longitudinal and lateral spacing of studs with respect to each other and to edges of beam or girder flanges does not vary more than 1/2 inch from the dimensions shown in the Plans. However, the Engineer will allow a variation of 1 inch where required to avoid interference with other attachments on the beam or where welding a new stud to replace a defective stud. Provide a minimum distance of 1 inch from the edge of a stud to the edge of a beam, but where possible provide at least 1-1/2 inches.

502-4.8 Testing: After allowing them to cool, bend the first two studs welded on each beam or girder, 45 degrees by striking the stud with a hammer. If failure occurs in the weld of either stud, correct the procedure, and weld and test two successive studs successfully before welding any more studs to the beam or girder. Inform the Engineer of any changes in the welding procedure at any time during construction. When the temperature of the base metal is below 32ºF, bend one stud in each 100 studs welded 45 degrees in addition to the first two bent as specified above.

502-4.9 Repair of Welds: The Contractor may repair studs, on which a full 360 degrees weld is not obtained, in accordance with the procedures of ANSI/AASHTO/AWS D1.5, Bridge Welding Code.

502-4.10 Reduction in Height: If the reduction in the height of studs as they are welded becomes less than 1/16 inch, immediately stop welding and correct the cause. Do not resume welding until the cause has been corrected.

502-4.11 Replacing Studs: Before welding the replacement stud, remove the defective stud, grind the area smooth and flush or, in the case of a pullout of metal, fill the pocket with weld metal, using the shielded metal-arc process with low-hydrogen welding electrodes, and then grind flush. In compression areas of flanges, the Contractor may weld a new stud adjacent to the defective area in lieu of repair and replacement of the existing weld.

502-5 Inspection Requirements.

502-5.1 Bend Test: If visual inspection reveals any stud which does not show a full 360 degrees weld, any stud which has been repaired by welding, or any stud in which the reduction in height due to welding is less than normal, strike such stud with a hammer and bend 15 degrees off the vertical. For studs showing less than a 360 degrees weld, bend the stud in the direction opposite to the lack of weld. Replace studs that crack in either the weld or the shank. The Engineer may select additional studs to be subjected to the bend test specified above. The Contractor may leave the tested studs that show no sign of failure in the bent position.

502-5.2 Unsatisfactory Work: If, during the progress of the shear connectors work, inspection and testing indicate that the shear connectors being obtained are not satisfactory, make such changes in welding procedure, welding equipment, and type of shear connector as necessary to secure satisfactory results, at no expense to the Department.

502-5.3 Requalification: If the Engineer requests, require the manufacturer of the studs to submit sample studs for requalification in accordance with the procedures of 502-6, at no expense to the Department.

502-6 Qualification Procedure.

502-6.1 Purpose: The purpose of this procedure is to prescribe weldability tests which will qualify a shear connector stud for welding under shop or field conditions. The Contractor may have a university, independent laboratory, other testing authority, or agency perform the tests. Ensure that the agency performing the tests submits to the manufacturer of the stud a certified report giving procedures and results for all tests, including the information listed under 502-6.9.

502-6.2 Duration of Qualification: Once a type and size of stud with arc-shield has been qualified, the Engineer will consider the stud qualified until the manufacturer makes any change in the base of the stud, the flux, or the arc-shield, which affects the welding characteristics.

502-6.3 Preparation of Specimens: Prepare test specimens by welding representative studs to the center of square specimen plates, 1/2 to 3/4 inch thick, of structural steel, ASTM A36. The manufacturer may weld studs to a large plate and cut the specimen plates to a size suitable for test equipment used.

502-6.4 Welding Procedure: Weld studs with manufacturer recommended power source, welding gun, and control equipment. Measure welding voltage, current, and time by suitable instrumentation, and record these measurements for each specimen. Ensure that lift and plunge are at the manufacturer-recommended optimum setting.

502-6.5 Number of Test Specimens:

1. Weld 30 test specimens consecutively, with time held constant at optimum but with current 10% below optimum.

2. Weld 30 test specimens consecutively, with time held constant at optimum but with current 10% above optimum.

502-6.6 Qualification Tests:

502-6.6.1 Tensile Tests: Subject 10 of the specimens welded in accordance with 502-6.5(1), 10 in accordance with 502-6.5(2) to a tensile test. The Engineer will consider a stud qualified if all test specimens have a tensile strength above the minimum specified in 502-3.2.

502-6.6.2 Bend Tests: Place 20 of the specimens welded in accordance with 502-6.5(1), 20 in accordance with 502-6.5(2) in a bend testing device, and bend alternately 30 degrees in opposite directions until failure occurs. The Engineer will consider a stud qualified if, on all test specimens, fracture occurs in the shank of the stud and not in the weld.

502-6.7 Retest: If weld failure occurs in any of the tensile or bend test groups, the Contractor may retest that group. If weld failure repeats, consider the stud as having failed to qualify.

502-6.8 Qualification: For a manufacturer's studs and arc-shields to be qualified, ensure that each group of 30 studs, by test or retest, meets the requirements prescribed in 502-6.6.

502-6.9 Report of Tests: Include the following in the laboratory report:

1. Drawings which show shapes and dimensions with tolerances of studs, arc-shields, and flux.

2. A complete description of materials used in the studs and arc-shields, including the quantity and analysis of the flux.

3. A certification that the studs and arc-shields described in the report are qualified in accordance with 502-6.8.

502-7 Dimensions and Tolerances.

Meet the following dimensions and tolerances:

Table 502-1

C	L*	H	T
3/4 - 1/64 inch	4 +0.062 inches 4 -0.125 inches	1-1/4 ± 1/64 inch	3/8 inch minimum
7/8 - 1/64 inch	4 +0.062 inches 4 -0.125 inches	1-3/8 ± 1/64 inch	3/8 inch minimum

*4 inches length is standard.
The Contractor may obtain other lengths by special order.

Where:

C = Shaft diameter
L = Total stud length measured from top of head to base of shaft
H = Diameter of head
T = Thickness of head

502-8 Method of Measurement.

For the purpose of payment, shear connectors will be classified as Structural Steel. The quantity to be paid for will be determined in accordance with Section 460.

502-9 Basis of Payment.

Price and payment will be full compensation for all work specified in this Section, including furnishing and installing shear connectors.

Payment will be made in accordance with Section 460.

SECTION 504
STEEL GRID FLOORS

504-1 Description.

Furnish and erect open-type steel grid roadway and sidewalk floors, on the movable spans of bridges and at other locations shown in the Plans. Where specified in the Plans, completely fill the floor with concrete.

504-2 Materials and Construction Methods.

504-2.1 General: Meet the following requirements:

Portland Cement Concrete .....Section 346
Structural Steel and Miscellaneous Metals .....Section 460
Shop, Field, and Maintenance Painting of
Structural Steel.....Section 560

504-2.2 Roadway Floor: Construct the roadway floor as an open steel grid with rectangular openings. Place and weld the grid to the floor stringers as shown in the Plans. If the flooring requires secondary or supplemental stringers, the Department will consider these stringers and their fastenings a part of, and included in, the materials to be furnished and erected under this Section.

504-2.3 Sidewalk Floor: Erect sidewalk flooring consisting of a system of main bars and secondary bars, arranged in a system of rectangular, reticulum or U-shaped openings. Do not allow the clear distance in any opening to exceed 5/8 inch in one direction. Do not allow the longest dimension of any opening to exceed 3 inches. Place and weld the floor to the supporting members in accordance with the details shown in the Plans, or in accordance with the manufacturer's directions as approved by the Engineer.

504-2.4 Conformance with Manufacturer's Specifications: Meet the manufacturer's specifications for the material and construction methods, as approved by the Engineer, for any type of steel floor used.

504-2.5 Use of Trade Names: Where the Plans refer to the type of floor by manufacturer's designation or trade name, the Contractor may use a similar floor providing equivalent section modulus per unit width, and equivalent surface qualities, if approved by the Engineer.

504-3 Painting.

Apply to all exposed areas of steel grid floors the same number, type, and thicknesses of paint coatings as are specified for painting structural steel. Prepare the surface the same as required for painting structural steel. Although not required, the Contractor may apply paint on areas to be covered by concrete.

504-4 Method of Measurement.

The quantities to be paid for will be the plan quantity, in square feet, installed, complete and accepted. Proper deductions for open joints in the floor will be made in calculating plan quantity.

504-5 Basis of Payment.

Prices and payments will be full compensation for all work specified in this Section, including furnishing and installing the complete floor above the tops of the main floor members

shown in the Plans, furnishing and installing any secondary joists which are required in addition to the main floor members, filling any specified portion with concrete, furnishing paint materials, painting, and welding.

Payment will be made under:

Item No. 504-	1-	Steel Roadway Floor - per square foot.
Item No. 504-	2-	Sidewalk Floor Steel - Rehab - per square foot.

SECTION 506
BRIDGE DRAINAGE SYSTEM

506-1 Description.

Construct drainage facilities and accessories to collect and dispose of water from drains on the bridge structures, in accordance with the details shown in the Plans.

506-2 Materials.

Use materials as specified or required in the Plans. For aluminum materials, submit a certified mill analysis, along with a certificate from the producer stating that the materials used meet all requirements of these Specifications. Submit such reports to the Engineer.

506-3 Method of Measurement.

The quantity for bridge drainage system to be paid for will be at the Contract lump sum price.

If bridge drainage piping is included in the Contract, the quantity to be paid for will be at the length, in feet.

If bridge drains are included in the Contract, the quantity to be paid for will be at the Contract unit price for each.

506-4 Basis of Payment.

Prices and payments will be full compensation for all work, equipment, and materials specified in this Section or shown in the Plans, including the complete installation of the drainage system for the bridge structure.

Payment will be made under:

Item No. 506- 1-	Bridge Drainage System - lump sum.
Item No. 506- 2-	Bridge Drainage Piping - per foot.
Item No. 506- 3-	Bridge Drains - each.

SECTION 510
NAVIGATION LIGHTS FOR FIXED BRIDGES

510-1 Description.

Furnish and install navigation lighting systems, including all wiring, conduit, wiring devices, transformers, enclosures, grounding system, controls, protective devices, lights, etc., as shown in the Plans and in compliance with Code of Federal Regulations (CFR), Title 33, Part 118, which is further clarified in U.S. Coast Guard (USCG) Publication "A Guide to Bridge Lighting". Navigation lights must operate from sunset to sunrise and during periods of low visibility.

510-2 Coordination of Electrical Work.

Use experienced personnel in the type of work required by the Contract Documents to provide a complete and satisfactory fitting and fully operational installation. Perform all electrical work either by, or under the immediate supervision of an electrical journeyman.

Schedule and arrange electrical work in a neat, well-organized manner without interference with the work scheduling of other trades.

510-3 Materials and Equipment.

Meet the equipment and material requirements as shown in the Contract Documents.

Furnish and install only materials and equipment of new stock meeting ANSI, NEC, NEMA, and UL requirements, and approved by the Engineer, except where the Contract Documents allow or specify the use of other than new equipment.

Furnish and install marine type products manufactured of corrosion resistant materials.

Furnish and install only fasteners manufactured from ASTM 316 stainless steel with yield strength 35,000 psi or higher.

Furnish and install ASTM 300 series stainless steel conduit straps or hangers held at not less than two points.

Furnish and install framework for supporting boxes, switches, and other externally mounted electrical devices fabricated from ASTM A709 Grade 36 hot-dip galvanized structural steel.

510-4 Navigation Lights and Aids.

510-4.1 Navigation Lights: Equip all navigation lights with a LED array with a minimum of 50,000 hour life and bright enough to meet the visibility requirements of CFR Title 33, Part 118. Mount LED arrays on an internal shock and vibration isolator. Provide, in the circuit, a lightning surge suppressor capable of absorbing multiple strikes without replacement. Provide special power supply to provide current limited DC voltage to the LED array.

Furnish and install fixtures with unpainted housings of heavy duty cast aluminum or bronze construction with a 1-1/2 to 2 inch threaded conduit opening on the bottom. Use only marine type mounting boxes with minimum 3/4 inch conduit opening. Furnish and install fixtures with lenses that are standard marine molded, single-piece fresnel type, rigid, heat resistant glass or U.V. resistant polycarbonate and inside diameter of 7 to 8 inch. Furnish all stainless steel closure bolts, lens tie rods, and attachment hardware for a complete and accepted installation.

Furnish and install pier/fender lights, center channel lights and channel margin lights with cast aluminum or bronze swivel assembly and mounting bracket, complete with

stainless steel pivot, watertight “O” ring seal, bronze bearings, cable entrance fitting, and stainless steel service chain rated for a minimum 225 pounds load. Use a 1-1/2 or 2 inch galvanized pipe or stainless steel pipe as a hanger stem with automatic lock at service and operating positions. Furnish and install a 60% counterweight if stem exceeds 5 feet in length.

Ensure the pier/fender Light is equipped with a red 180 degree lens, the center channel light is equipped with a green 360 degree lens and the channel margin light is equipped with a red 180 degree lens.

510-4.2 Clearance Gauge Lights: Furnish and install one-piece die-cast aluminum fixture housing fitted with watertight gasket, stainless steel hinges and fasteners, and adjustable aiming capability, equipped with a 120 V_{AC} 50 watt, high-pressure sodium lamp. Use a heavy cast aluminum connection box body and cover with stainless steel swing bolts, watertight gasket and provisions for mounting to a platform with four stainless steel lag bolts or screws.

510-5 Disconnect Switches.

Furnish and install switches that are HP rated and meet Federal and NEMA Specifications with NEMA Type 4X (stainless steel) enclosures, and with metal factory nameplates that are front cover mounted and contain a permanent record of switch type, catalog number, and HP rating. Provide switch with visible blades, reinforced fuse clips, and non-teasible, positive, quick make-quick break mechanisms. Provide switch assembly plus operating handle as an integral part of the enclosure base.

Use switches with defeat able door interlocks that prevent the door from opening when the operating handle is in the ON position, and whose handle position is easily recognizable and is padlockable in the OFF position. Use heavy-duty switches with line terminal shields.

510-5.1 Fusible Switch Assemblies: Furnish and install NEMA KS 1 type; load interrupter enclosed knife switch. Provide fuse Clips that are designed to accommodate Class R fuses.

510-5.2 Non-fusible Switch Assemblies: Furnish and install NEMA KS 1; HD type, load interrupter enclosed knife switch.

510-5.3 Enclosures: Furnish and install NEMA KS 1 type enclosure as shown in the Contract Documents.

510-5.4 Installation: Install disconnect switches where indicated in the Contract Document or where required by the Engineer. Use separate conduits for line and load conductors. Install fuses in fusible disconnect switches.

510-6 Supporting and Mounting Devices.

Ensure the sizes, and types of anchors, fasteners and supports used are adequate to carry the load of the equipment and conduit, including the wire in the conduit.

Space conduit supports to avoid conflicts with reinforcing steel at 5 feet maximum. For concrete mounting, use anchor bolts and all matching parts and tools recommended by and provided by the same manufacturer, as well as suitable for dynamic loading caused by vibration due to traffic. To mount conduit supports and pull boxes, use 1/4 inch diameter anchor system. To mount channel lights use minimum 1/2 inch diameter anchor system with 3-1/2 inch embedment and 8 inch edge distance.

Use ASTM 300 series stainless steel conduit straps or hangers held at not less than two points.

Do not use powder-actuated anchors. Do not drill or weld structural steel members. Do not use bolts smaller than 1/4 inch in diameter except as may be necessary to fit the mounting holes in small and light devices. Install surface-mounted boxes with minimum of three anchors.

510-7 Conduit.

510-7.1 General: Furnish and install conduit in the quantities and sizes required to complete the work as shown in the Plans and as required by NEC. Use products listed and classified by UL as suitable for purpose specified and shown. Do not use non-metallic flexible conduit, aluminum, or electrical metallic tubing (EMT).

510-7.2 Liquid-Tight Flexible Metal Conduit: Furnish and install, liquid-tight flexible metal conduit of interlocked steel construction with PVC jacket, and fittings meeting the requirements of ANSI/NEMA FB 1.

510-7.3 PVC Conduit: Furnish and install, schedule 80 PVC 3/4 inch minimum diameter conduit meeting the requirements of ASTM D1785 and NEMA TC 2 and fittings and conduit bodies meeting the requirements of ASTM D2467 and NEMA TC 3.

510-7.4 Fiberglass Reinforced Epoxy Conduit: Furnish and install rigid non-metallic fiberglass reinforced epoxy conduit and fittings manufactured in accordance with the applicable standards of ANSI and NEMA TC-14B.

Ensure the conduit has a bell and spigot type coupling and the coupling seal is made rigid by using an adhesive that will provide a water and vapor tight joint with a tensile strength equal to that listed for the conduit. An alternative type assembly may be used by applying a triple seal ribbed gasket of water resistant rubber material. Ensure the gasket is held firmly in place with a compatible adhesive.

Ensure that all fittings, adapters, and bends are manufactured from the same materials as the conduit and conform to the dimensional requirements of NEMA TC-14.

Use only fiberglass reinforced epoxy conduit and fittings made by the same manufacturer to insure proper fit and assembly, listed on the UL approved list and labeled for Type I service sizes 2 to 6 inches.

Ensure that each piece of conduit and fitting is clearly marked with durable contrasting ink, stenciled with the following:

1. Nominal size,
2. Bends to show the degree and radius of curvature,
3. Type: SW or HW,
4. Manufacturers' name or trademark.

510-7.5 Installation: Install conduit in accordance with National Electrical Contractors Association (NECA) "Standard of Installation" and manufacturer's instructions.

Arrange supports to prevent misalignment during wiring installation. Support conduit using straps, lay-in adjustable hangers, clevis hangers, and split hangers. Do not support conduit with wire or perforated pipe straps, plastic straps, or plastic hangers. Ensure that all wire used for temporary supports is removed upon completion of installation.

Install an expansion fitting for specified PVC conduit at all structure expansion joints or where movement between adjacent sections of conduit is expected. Submit certification to the Engineer from the manufacture that the expansion fitting meets the following minimum requirements: compatibility with the connected conduits, water proof, UV protected, and allows longitudinal movement equal to that of the expansion joint or movement expected.

Route exposed conduit parallel and perpendicular to walls and concrete barriers or route conduit in traffic railings. Install conduits to be continuous and watertight between boxes

or equipment. Protect conduits at all times from the entrance of water and other foreign matter by being capped or well plugged overnight and when the work is temporarily suspended.

Cut conduit square using saw or pipe cutter; de-burr cut ends. Bring conduit to shoulder of fittings; fasten securely. Use conduit hubs to fasten conduit to metal boxes. Do not install more than the equivalent of three 90 degree bends (total 270 degrees) between boxes. Use conduit bodies to make sharp changes in direction such as around diaphragms.

Join PVC conduit using cement recommended by manufacturer. Wipe PVC conduit dry and clean before joining. Apply full even coat of cement to entire area inserted in fitting. Allow joint to cure for a minimum of 20 minutes before pulling conductors.

Do not use flexible conduit extensions greater than 24 inches in length. Ensure that all flexible conduit extensions are equipped with bonding jumpers.

Do not allow moisture traps; provide pull box with drain fitting at low points in exposed conduit system.

510-8 Wiring.

510-8.1 General: Do not use aluminum conductors. Use only SE or RHW on incoming service and use single conductor with XHHW insulation, unless otherwise noted in the Plans.

Do not use wire smaller than No. 12 AWG.

Furnish insulated conductors of seven or nineteen strand copper with a minimum 98% conductivity and connector accessories for copper in sufficient quantities for a complete installation.

510-8.2 Installation: Use pull boxes wherever necessary to facilitate the installation of the conductors. Do not use condulets for pulling more than ten conductors or for branching conductors.

Splice only in accessible boxes. Make lug connections with high pressure indent connector tools as recommended by the lug manufacturer. Make splices and taps to carry full ampacity of conductors without perceptible temperature rise. Tighten all connections to manufacturer's recommendations. Tape uninsulated conductors and connectors with electrical tape to 150% of the insulation value of conductor. Ensure all splices are waterproof.

Use solderless pressure connectors with insulating covers for No. 8 AWG and smaller wire splices and taps. Use split bolt connectors for No. 6 AWG and larger wire splices and taps.

Pull all conductors into a raceway at the same time. Use soap base wire pulling lubricant for pulling No. 4 AWG and larger wire.

510-8.3 Testing: Test each circuit for continuity and short-circuits for its complete length before being connected to its load.

Inspect wire and cable for physical damage and proper connection.

510-8 Method of Measurement.

The quantity to be paid for will be at the Contract lump sum price, completed and accepted.

510-9 Basis of Payment.

Price and payment will be full compensation for all work specified in this Section.

Payment will be made under:

Item No. 510- 1- Navigation Lights - lump sum.

SECTION 514
GEOSYNTHETIC FOR DRAINAGE APPLICATIONS

514-1 Description.

This Section specifies the construction requirements for geosynthetics used in drainage, slope protection, and material separation applications.

514-2 Material.

Use geosynthetic materials meeting the requirements of Section 985 and listed on the Approved Product List (APL). Ensure the geosynthetic materials received at the job site are in unopened shipping packages and the packages are clearly labeled with the manufacturer's name, product name, style number, roll dimension and LOT number, otherwise, the Engineer will reject the material. Store geosynthetic materials in accordance with the manufacturer's instructions ensuring to protect the geosynthetic material from physical damage, debris, and temperatures greater than 140° F. Prevent mud, fluid concrete, asphalt, or other deleterious materials from coming in contact with the geosynthetic materials that could impact the performance of the geosynthetic material. Replace geosynthetic materials with defects, tears, punctures, flaws, deterioration, or other damage at no additional cost to the Department.

514-3 Construction Methods.

514-3.1 Geosynthetic Materials for Drainage Applications: Select a geosynthetic material meeting the appropriate application as specified in 985-3. Place and install the geosynthetic material at the proper elevation, location and orientation as shown in the Contract Documents and in accordance with the manufacturer's instructions. Place the geosynthetic material on areas with a uniform slope that are reasonably smooth, free from mounds, windrows, and any debris or projections which might damage the geosynthetic material. When overlapping is necessary, the Contractor may sew the seams to reduce overlaps as specified in 985-2.6.

After placement of the geosynthetic material, do not exceed the manufacturer's recommendations for exposure to ultraviolet light or five days, whichever is less. If the exposure time is exceeded, remove and replace the geosynthetic material.

514-3.2 Subsurface Drainage Applications: When indicated in the Plans, place the geosynthetic material with the long dimension parallel to the trench. Place and install the geosynthetic material to provide a minimum 12-inch overlap for each joint or in accordance with the manufacturer's recommendation, whichever is greater. Do not drop coarse aggregate materials from heights greater than 3 feet.

514-3.3 Revetment System Applications: Overlap adjacent strips of geosynthetic material at a minimum of 24 inches and in accordance with the manufacturer's recommendations, whichever is greater. Anchor the geosynthetic materials with securing pins inserted through both strips of geosynthetic material along a line through the midpoint of the overlap and to the extent necessary to prevent movement of the geosynthetic material.

Place the geosynthetic material so that the upstream (upper) strip of geosynthetic material overlaps the downstream (lower) strip. Stagger vertical laps a minimum of 5 feet. Use full rolls of geosynthetic material whenever possible to reduce the number of vertical laps. Do not drop bedding stone or riprap from heights greater than 3 feet onto the geosynthetic material.

514-3.4 Repairs: Replace geosynthetic material damaged during or after installation at no cost to the Department. Repair geosynthetics damaged during or after installation only after

the manufacturer establishes that the intended use and stability is not affected and after obtaining the Engineer's approval. Make such repairs as follows:

Remove materials placed within the damaged geosynthetic area plus an additional 4 feet in all directions beyond the limits of the damage. Place a patch consisting of the same material as the geosynthetic material over the damaged area in accordance with the manufacturer's recommendation. Overlap the undamaged geosynthetic material with the patch at a minimum of 3 feet in all directions. Place backfill material on the geosynthetic material in accordance with the Contract Documents after repairs have been completed.

For repairs of Geosynthetic material placed on slopes adjacent to water, place geosynthetic material so that the upstream (upper) strip of geosynthetic material overlaps the downstream (lower) strip.

514-4 Acceptance Criteria.

Submit to the Engineer the product label with the manufacturer's name, product name, style number, roll dimension and LOT number at least fourteen days prior to placement. In addition, provide two 8-inch by 10-inch samples of geosynthetic materials for product identification to the Engineer. The acceptance of the geosynthetic material is subject to the approval of the State Materials Office (SMO).

514-5 Basis of Payment.

No separate payment will be made for the work specified in this Section. The cost of furnishing, placing, and sewing or overlapping the fabric will be included in the Contract price for the items to which it is incidental.

SECTION 515
METAL PEDESTRIAN/BICYCLE RAILINGS, GUIDERAILS, AND HANDRAILS

515-1 Description.

Furnish and install metal pedestrian/bicycle railings, including bullet rails, guiderails and handrails in accordance with the Plans and Standard Plans.

515-2 Materials.

Meet the following requirements:

Concrete	Section 346
Anchor Bolts, Rods, Nuts and Washers*	Section 962
Adhesive Anchors**	Section 937
Aluminum**	Section 965
Bearing Pads**	932-2.5
Epoxy Mortar**	Section 926
Steel**	Section 962

*Do not use expansion anchors.

**Use products listed on the Department's Approved Product List (APL).

515-3 Construction Requirements.

515-3.1 General: Space posts to clear obstacles without exceeding maximum post spacing and maintain a uniform spacing with reasonable consistency. Place splices in approximately the same place within a railing section.

Railings must be free of burrs and sharp edges and all plug welds ground smooth.

515-3.2 Welds: An American Welding Society certified welding inspector must visually inspect all welds for final approval. Nondestructive testing of welds is not required, unless otherwise shown in the Plans. Prior to installation of the railings, a certifying statement from the welding inspector must be provided. The document must identify the project information, date of inspection, welding inspector name, and inspector certification number.

515-3.2.1 Aluminum Railing: Welds must be in accordance with Section 965. Filler material for seal welds, plug welds and bend splices may be ER4303.

515-3.2.2 Steel Railing: Meet the requirements of Section 962, except weld connections must be in accordance with AWS D1.1, Structural Welding Code, using E70XX weld material, unless otherwise shown in the Plans.

515-3.3 Coatings:

515-3.3.1 Aluminum Railing: Coating is not required, unless otherwise shown in the Plans. Finished product must have a smooth uniform appearance.

When a colored coating is required, use a fluoropolymer based powder coating system complying with American Architectural Manufacturers Association (AAMA) Specification No. 2605.

515-3.3.2 Steel Railing: Components must be hot-dip galvanized after fabrication in accordance with Section 962, unless otherwise shown in the Plans. When a colored coating is required, meet the requirements of 649-4.

515-4 Shop Drawings.

Submit shop drawings and obtain approval prior to fabrication in accordance with Section 5. Show project specific geometry (line and grade), post type and locations, expansion joint and splice locations.

Include other project specific details such as tapered end transitions, continuity or transition details post and panel infill type, and anchor bolt general details.

515-5 Installation.

515-5.1 General: Place a 1/8 inch thick bearing pad with dimensions matching the base plate between the base plate and concrete surface.

515-5.2 Bullet Railings: Install rail posts perpendicular to the profile grade longitudinally and plumb transversely.

515-5.3 Pedestrian /Bicycle Railings and Guiderails: For locations other than bridges, fabricate and install posts plumb. On bridges, fabricate and install posts perpendicular to the profile grade line longitudinally and plumb transversely. Use aluminum shim plates to make necessary adjustments. Bond stacked shim plates with adhesive bonding material and field trim shim plates to match the foundation contours. Beveled shim plates may be used in lieu of trimmed flat shim plates.

If shims greater than 1/2 inch total thickness are required, provide longer anchor bolts. Bolts must be long enough to secure washers and nuts and meet the minimum embedment length.

Post tolerance from plumb is plus or minus one inch, measured at 42 inches above the foundation. Rails must form a smooth continuous line without hills or dips greater than 1/2 inch between any three posts or side sway greater than 1/2 inch between post assemblies.

515-5.4 Anchoring:

515-5.4.1 General: Secure nuts to a snug tight condition. Tack weld nuts to stem or distort bolt threads to prevent nut loosening and removal. Coat damaged galvanizing on bolt stems, nuts, and tack welds in accordance with Section 562.

515-5.4.2 Adhesive Anchors: Install anchors in accordance with Section 416.

515-5.4.3 C-I-P and Thru-Bolt Anchors: Use galvanized hex head anchor bolts. When thru-bolting is used, coat cut reinforcing steel inside the drilled hole with a zinc galvanizing compound in accordance with Section 562 prior to installing bolts.

515-5.4.4 Embedded Guiderail Posts: Core holes into the foundation concrete, then clean holes, in accordance with the manufacturer's instructions. At a minimum, use oil free compressed air to remove loose particles, brush the inside surface to free loose particles, then use compressed air again to remove any remaining particles. Use a Type AB, or F epoxy compound to secure guiderail posts into the cored holes.

515-6 Method of Measurement.

The quantity of railing to be paid for will be the plan quantity, in linear feet, installed and accepted. The quantity will be measured along the centerline of the top rail.

515-7 Basis of Payment.

Price and payment will be full compensation for all work specified in this Section, including all materials, hardware, labor, and incidentals required to complete the installation.

For relocation of existing railing, price and payment will be full compensation for the

removal and reinstallation, including all materials, hardware, labor, and incidentals required to complete the installation.

Payment will be made under the following:

Item No. 515- 1- Pipe Handrail-Guiderail - per linear foot.
Item No. 515- 2- Pedestrian/Bicycle Railing - per linear foot.
Item No. 515- 3- Handrail - Retrofit to Existing Railing - per linear foot.
Item No. 515- 4- Aluminum Bullet Railings - per linear foot.

SECTION 520
CONCRETE GUTTER, CURB ELEMENTS, AND TRAFFIC SEPARATOR

520-1 Description.

Construct portland cement concrete curb. Curb will include concrete curb and gutter, concrete traffic separator, valley gutter, special concrete gutter, curb for sidewalk curb ramps and driveways, and any other types of concrete curb not specified in other Sections.

520-2 Materials.

520-2.1 Concrete: Use concrete meeting the requirements of Section 347.

520-2.2 Reinforcement: For all steel reinforcement required by the Plans, meet the requirements of Section 415.

520-2.3 Joint Materials: Meet the requirements of Section 932.

520-2.4 Toll Header Curb Concrete: Use concrete meeting the requirements of Section 346, Class II.

520-3 Forms.

520-3.1 Form Materials: Construct forms for this work of either wood or metal. Provide forms that are straight, free from warp or bends, and of sufficient strength, when staked, to resist the pressure of the concrete without deviation from line and grade. For all items constructed on a radius, use flexible forms.

520-3.2 Depth of Forms: Ensure that forms have a depth equal to the plan dimensions for the depth of concrete being deposited against them.

520-3.3 Machine Placement: The Contractor may place these items by machine methods with the approval of the Engineer provided that the Contractor consistently produces an acceptable finished product, true to line, grade, and cross section.

520-4 Excavation.

Excavate to the required depth, and compact the foundation material upon which these items are to be placed as specified in 120-9.

520-5 Placing Concrete.

Place the concrete in the forms, and tamp and spade it to prevent honeycombing, and until the top of the structure can be floated smooth and the edges rounded to the radius shown in the Plans.

520-6 Joints.

520-6.1 Contraction Joints: Except for machine placed items, the Contractor may form joints by using dummy joints (either formed or sawed) or by using sheet metal templates. If using sheet metal templates, ensure that they are of the dimensions, and are set to the lines, shown in the Plans. Hold templates firmly while placing the concrete. Leave templates in place until the concrete has set sufficiently to hold its shape, but remove them while the forms are still in place.

Saw contraction joints, for machine placed items, unless the Engineer approves an alternate method. Saw the joints as soon as the concrete has hardened to the degree that excessive raveling will not occur and before uncontrolled shrinkage cracking begins.

Space contraction joints at intervals of 10 feet except where closure requires a lesser interval, but do not allow any section to be less than 4 feet in length.

520-6.2 Expansion Joints: Construct expansion joints at all inlets, at all radius points, and at other locations indicated in the Plans. Locate them at intervals of 500 feet between other expansion joints or ends of a run. Ensure that the joint is 1/2 inch in width.

520-7 Finishing.

520-7.1 Repair of Minor Defects: Remove the forms within 24 hours after placing the concrete, and then fill minor defects with mortar composed of one part portland cement and two parts fine aggregate. The Engineer will not allow plastering on the face of the curb. Remove and replace any rejected curb, curb and gutter, or valley gutter without additional compensation.

520-7.2 Final Finish: Finish all exposed surfaces while the concrete is still green. In general, the Engineer will only require a brush finish. For any surface areas, however, which are too rough or where other surface defects make additional finishing necessary, the Engineer may require the Contractor to rub the curb to a smooth surface with a soft brick or wood block, using water liberally. Also, if necessary to provide a suitable surface, the Engineer may require the Contractor to rub further, using thin grout or mortar.

520-7.3 Imprinted Concrete: Install imprinted concrete as shown in the Plans.

520-8 Curing.

520-8.1 General: Continuously cure the concrete for a period of at least 72 hours. Commence curing after completely finishing and as soon as the concrete has hardened sufficiently to permit application of the curing material without marring the surface. Immediately replace any curing material removed or damaged during the 72 hour period.

After removing the forms, cure the surfaces exposed by placing a berm of moist earth against them or by any of the methods described below, for the remainder of the 72 hour curing period.

520-8.2 Wet Burlap Method: Place burlap, as specified in 925-1, over the entire exposed surface of the concrete, with sufficient extension beyond each side to ensure complete coverage. Overlap adjacent strips a minimum of 6 inches. Hold the burlap securely in place such that it will be in continuous contact with the concrete at all times, and do not allow any earth between the burlap surfaces at laps or between the burlap and the concrete. Saturate the burlap with water before placing it, and keep it thoroughly wet throughout the curing period.

520-8.3 Membrane Curing Compound Method: Apply clear membrane curing compound or white pigmented curing compound, as specified in 925-2, by a hand sprayer meeting the requirements of 350-3.10, in a single coat continuous film at a uniform coverage of at least one gallon per 200 square feet. Immediately recoat any cracks, checks, or other defects appearing in the coating. Thoroughly agitate the curing compound in the drum prior to application, and during application as necessary to prevent settlement of the pigment.

520-8.4 Polyethylene Sheeting Method: Place polyethylene sheeting, as specified in 925-3, over the entire exposed surface of the concrete, with sufficient extension beyond each side to ensure complete coverage. Overlap adjacent strips a minimum of 6 inches. Hold the sheeting securely in place and in continuous contact with the concrete at all times.

520-9 Backfilling and Compaction.

After the concrete has set sufficiently, but not later than three days after pouring, refill the spaces in front and back of the curb to the required elevation with suitable material. Place and thoroughly compact the material in layers not thicker than 6 inches.

520-10 Surface Requirements.

520-10.1 Straightedge: Test the gutter section of curb and gutter with a 10 foot straightedge laid parallel to the centerline of the roadway and while the concrete is still plastic. Perform straightedging along the edge of the gutter adjacent to the pavement or along other lines on the gutter cross-section, as directed by the Engineer. Immediately correct irregularities in excess of 1/4 inch.

520-10.2 Elevation and Cross Slope: Place curb and gutter so the calculated actual roadway or shoulder cross slope to be placed within the curb and gutter is within +/- 0.2% of the calculated design cross slope for that location. Once per 500 feet, check the elevation of lip of curb and gutter and calculate actual cross slope between curb and gutter on each side of a lane or set of adjacent lanes. Perform these checks prior to placement of the curb and gutter and adjust to ensure cross slope tolerance is met. After placement and curing of curb and gutter, perform the above checks again. Correct any curb and gutter found to be outside the cross slope tolerance described above.

520-11 Method of Measurement.

For curb or curb and gutter, the quantity to be paid will be the plan quantity, in feet, measured along the face of the completed and accepted curb or curb and gutter. Curb for sidewalk curb ramps or driveways will be paid at the Contract unit price for the adjacent curb type.

For valley gutter or shoulder gutter, the quantity to be paid will be the plan quantity, in feet, measured along the gutter line of the completed and accepted valley gutter or shoulder gutter.

For concrete traffic separator of constant width, meeting the requirements of Standard Plans, Index 520-020, the quantity to be paid will be the plan quantity, in feet, measured along the center of its width, completed and accepted, including the length of the nose.

For concrete traffic separator of nonstandard or varying width, the quantity to be paid will be the plan quantity, in square yards, completed and accepted.

For curb of any type next to concrete pavement, the curb-pavement joint quantity to be paid will be the plan quantity, in feet, measured along the face of the completed and accepted curb.

520-12 Basis of Payment.

520-12.1 Concrete Gutter, Curb Elements, and Traffic Separator: Price and payment will be full compensation for all work specified in this Section, including reinforcement steel, dowels, asphalt pavement and base under traffic separator, joint materials and asphalt curb pad.

520-12.2 Excavation: Excavation for new installations will be paid for as roadway excavation in accordance with 120-13.2.

520-12.3 Payment Items: Payment will be made under:

Item No. 520-	1-	Concrete Curb and Gutter - per foot.
Item No. 520-	2-	Concrete Curb - per foot.
Item No. 520-	3-	Concrete Valley Gutter - per foot.

Item No. 520- 4-	Curb-Concrete Pavement Joint - per foot.
Item No. 520- 5-	Concrete Traffic Separator - per foot.
Item No. 520- 6-	Concrete Shoulder Gutter - per foot.
Item No. 520- 70-	Concrete Traffic Separator - per square yard.

SECTION 521
CONCRETE BARRIERS, TRAFFIC RAILINGS, AND PARAPETS

521-1 Description.

Construct precast or cast in place concrete barriers, traffic railings, opaque visual barriers, and parapets, herein referred to as rigid barrier, in accordance with the Standard Plans and the details shown in the Plans. Use stationary removable forms or sliding forms to construct the rigid barrier. Do not use permanent precast concrete rigid barrier on bridge or box culvert structures.

Submit written certification from the manufacturer of the precast rigid barrier that the barrier meets the requirements of this Section. Rigid barrier is produced using certification acceptance; therefore, assume responsibility for performance of quality control testing and inspections required by Sections 346 and 400. Perform all Quality Control Testing and inspections using CTQP qualified testing personnel. Perform compressive strength testing in a laboratory inspected by CCRL or CMEC.

Ensure that each shipment of products to the job site includes a list of products shipped and the required written certification statement for each product. Submit this list and certifications to the Engineer.

521-2 Materials.

Meet the following requirements:

Flowable Fill	Section 121
Concrete	Sections 346 and 347
Reinforcing Steel	Section 415
Joint Materials	932-1.1
Joint Materials*	932-1.2 and 932-1.3
Barrier Delineators *	Sections 705

*Use products listed on the Department's Approved Product List (APL).

521-3 Requirements.

521-3.1 Precast Temporary Concrete Barrier: Meet the requirements of 102-9.5.

521-3.2 Precast Noise Wall Barrier Requirements: Obtain precast concrete components from a plant that is currently on the Department's Production Facility Listing. Producers seeking inclusion on the list must meet the requirements of Section 105.

Do not accept products that are not permanently and clearly stamped on the tongue and groove portion of the panel and posted with the type, date cast, project number, and the manufacturer's name or symbol by the Producer.

521-3.2.1 Casting Tolerances: Maintain the following casting tolerances:

1. Overall Height and Width: +/- 1/4"
2. Thickness: +/- 1/4"
3. Out of Square: 1/8" per 6 ft., but not more than 3/8" total along any side
4. Warping: 1/16" per foot distance to nearest corner
5. Bowing: 1/240 segment dimension
6. Surface Smoothness: +/- 1/16"
7. Tongue and groove joint dimensions: +/- 1/4"

521-3.2.2 Shop Drawing Submittal: Submit shop drawings for precast elements, when required, in accordance with Section 5, showing a plan and elevation with the following project specific information:

1. Begin and end wall stations with offsets
2. Horizontal and vertical alignments of the wall
3. Segment locations and lengths
4. Segment locations for:
    a. Graphic details for architectural inlays as required
    b. Special detailing for drainage requirements
5. Elevations of top of segments
6. Existing ground and finished grade elevations
7. Top panel to precast base grouted and dowelled joint dowel and sleeve locations
8. Non-standard precast component details
9. Lifting devices

521-4 Construction.

521-4.1 General: The Contractor may use stationary removable forms or slip form construction methods provided a completed rigid barrier with acceptable alignment and finish is obtained. Do not use forms which are damaged or are not in alignment. At no expense to the Department, remove and replace sections of rigid barrier having unconsolidated concrete, surface blemishes, deviations in alignment or profile which exceed tolerances, or other defects which cannot be repaired to the satisfaction of the Engineer.

521-4.2 Stationary Form Construction: Provide precast or cast in place concrete rigid barrier constructed using stationary forms in accordance with Section 400 and provide a general surface finish. Align and erect the stationary form so that all plane surfaces of the finished barrier will have no deviation greater than 3/8 inch measured as an ordinate between the concrete and a 10 foot straightedge. Correct all alignment deviations greater than 3/8 inch. Straightedge by half lapping the straightedge for the full length of all plane surfaces.

521-4.3 Slip Form Construction: When electing to use the slip form method in lieu of the stationary forming method, place the concrete with a slip form machine approved by the Engineer. The concrete cover tolerance is plus or minus 3/4 inches from the plan dimensions, except the minimum concrete cover, as constructed, must not be less than 1-3/4 inches.

Provide a finished texture to the slip formed rigid barrier by hand troweling, brushing, or both to eliminate pockmarks, blemishes and any other discontinuities in surface texture. Ensure that the final finish has a fine texture and is free of pinholes, pockmarks, and blemishes.

Remove and recast or repair sections of slip formed rigid barrier having areas of unconsolidated concrete, having surface blemishes, and/or having pockmarks greater than 1/2 inch in diameter after hand troweling and brushing. Repair areas of unsatisfactory surface finish by hand methods using mortar screened from the concrete used to construct the rigid barrier. Use the mortar screened from the rigid barrier concrete only to fill holes and surface blemishes below the slip formed surface of the concrete. Do not use mortar as a surface overlay coating on the rigid barrier concrete.

During the finishing operation, while the concrete remains plastic, straightedge all plane surfaces of the slip formed rigid barrier with a 10 foot straightedge. Straightedge by half lapping the straightedge for the full length of the plane surfaces. Correct any deviation found

during straightedging, greater than 3/8 inch, measured as an ordinate between the concrete surface and the straightedge, in an approved manner at no expense to the Department. Do not use surface overlay coatings of mortar screened from the concrete, or surface overlay coatings of concrete to correct alignment deviations.

521-5 Curing.

Meet the requirements of Section 400.

521-6 Joints.

521-6.1 General: Place expansion and contraction joints in concrete rigid barrier either mounted on or adjoining rigid structures in a manner similar to the type and method of jointing used in the supporting or adjoining structure or as shown in the Contract Documents. Place expansion and contraction joints in concrete rigid barrier supported by soil or flexible foundation materials in the manner detailed in the Plans.

521-6.2 Contraction Joints in Rigid Barrier Supported by or Adjoining Rigid Structures: The Contractor may form or saw contraction joints. When sawing contraction joints, saw them as soon as the concrete has hardened sufficiently to permit sawing without raveling and before uncontrolled cracking occurs, but in no case later than 12 hours after casting. Match contraction joints to adjacent contraction joints in the structure. Space contraction joints at 15 to 30 foot intervals. For rigid barrier on bridge structures or approach slabs, space contraction joints as shown in the Contract Documents.

521-6.3 Expansion Joints in Rigid Barrier Supported by or Adjoining Rigid Structures: Construct expansion joints at right angles to the face, and extend them through the entire cross-section of the rigid barrier. Construct expansion joints at the same location and width as the expansion joints in the structure on which the rigid barrier rests and at other locations shown in the Contract Documents. Form expansion joints with an expansion filler material or removable forming materials and secure to the forms as required to provide proper position.

521-7 Repairs and Rejection.

For permanent precast concrete rigid barrier that has not been installed, evaluate cracks, spalls and other deficiencies in accordance with 450-12. Repair deficiencies in accordance with 450-13 or the plant's approved repair methods that are included as part of the Quality Control (QC) Plan. Ensure that the original performance and durability of the repaired rigid barrier is maintained. Use materials for concrete repair that will meet or exceed the strength requirement for the class of concrete used. Materials meeting the requirements of Section 930 may be substituted for non-shrink grout when required by 450-13. Concrete rigid barrier is subject to rejection if it fails to conform to any of the Specification requirements after repair. The disposition of concrete cracks in rigid barrier after installation shall be in accordance with 400-21.

521-8 Method of Measurement.

The quantity to be paid for under this Section will be the plan quantity, in feet, completed and accepted. The quantity will be measured along the centerline of the rigid barrier from begin to end station, including transitional and end sections, with no deduction for expansion joints, open joints, or leave-outs.

521-9 Basis of Payment.

Price and payment will be full compensation for all work specified in this Section, including all reinforcing, concrete, flowable fill, soil stabilization, miscellaneous materials, and incidentals necessary to complete the work.

Payment will be made under:

Item No. 521- 1-	Median Concrete Barrier - per foot.
Item No. 521- 5-	Concrete Traffic Railing - Bridge - per foot.
Item No. 521- 6-	Concrete Parapet - per foot.
Item No. 521- 8-	Concrete Barrier - with Junction Slab - per foot.
Item No. 521- 9-	Opaque Visual Barrier - per foot.
Item No. 521- 72-	Shoulder Concrete Barrier - per foot.

SECTION 522
CONCRETE SIDEWALKS AND DRIVEWAYS

522-1 Description.

Construct concrete sidewalks and driveways in accordance with the Plans and the Standard Plans. Sidewalk will include curb ramps, landings, transition slopes, sidewalk curb, and edge beams.

522-2 Materials.

Meet the requirements specified in 520-2 and the embankment utilization requirements of Standard Plans Index 120-001.

522-3 Forms.

Provide forms as specified in 520-3.

522-4 Foundation.

Shape and compact the foundation materials with suitable equipment to a firm, uniform, smooth, even surface, true to grade and cross-slope that is free of debris and irregularities.

For the following conditions proof roll the graded areas with a vibratory roller or mini plate compactor in such manner that a firm and unyielding foundation is established within 1 foot beyond each side of the sidewalk or driveway, when right-of-way conditions allow:

1. For all fill areas not exceeding 6 inches.
2. All cut areas.
3. Existing sidewalk and driveways to be replaced in the same location, horizontal alignment, profile grade, and cross slope.

For fill areas 6 inches or greater, compact the foundation below the bottom of the concrete and 1 foot beyond each side of the sidewalk or driveway when right-of-way conditions allow, to a density not less than 95% of the maximum density as determined by FM 1-T099 for the following conditions:

1. For fill areas not exceeding 2 feet, take densities for the entire fill height.
2. For fill areas 2 feet or greater, take densities on the last (upper) 2 feet of fill height.

Meet the testing frequency and maximum lift thickness requirements of Section 120. Record density test results in the Earthwork Records System (ERS) section of the Department's database. Compact the material in the remaining fill areas to match the adjacent area density.

522-5 Joints.

Install expansion and contraction joints in accordance with the Plans and the Standard Plans.

522-6 Placing Concrete.

Place the concrete as specified in 520-5.

522-7 Finishing.

522-7.1 Screeding: Strike-off the concrete by means of a wood or metal screed, used perpendicular to the forms, to obtain the required grade and remove surplus water and laitance.

522-7.2 Surface Requirements: Imprint concrete as detailed in the Plans, otherwise provide a broom finish. Ensure that the surface variations are not more than 1/4 inch under a

10-foot straightedge or more than 1/8 inch on a 5-foot transverse section. Finish the outer edges of the concrete with an edging tool having a radius of 1/2 inch.

522-7.3 Sidewalk Cross Slope Requirements: Construct sidewalk with cross slope as shown in the Plans and Standard Plans. Sidewalks must have some cross slope, but no more than 2.0%, in either the positive or negative direction after construction.

522-8 Curing.

Cure the concrete as specified in 520-8.

522-9 Opening Sidewalk to Pedestrian Traffic.

Install detectable warnings, when shown in the Plans, in accordance with Section 527 on completed sections of sidewalk before opening to pedestrian traffic.

522-10 Method of Measurement.

The quantity to be paid will be plan quantity, in square yards, completed and accepted.

522-11 Basis of Payment.

Price and payment will be full compensation for all work specified in this Section. Excavation for new installations will be paid for under the items for the grading work on the project.

Payment will be made under:

Item No. 522-	Concrete Sidewalks and Driveways - per square yard.

SECTION 523
PATTERNED PAVEMENT

523-1 Description.

Patterned pavement is defined as a post applied surface marking material to either the pavement surface or to an imprinted pavement surface.

523-2 Materials.

Use patterned pavement products listed on the Department's Approved Product List (APL) meeting the requirements of Section 974.

Prior to installation, submit pattern and color samples to the Engineer for confirmation that the product meets the pattern and color specified in the Plans. Do not begin installation until acceptance by the Engineer.

The Engineer will take random samples of all material in accordance with the Department's Sampling, Testing and Reporting Guide schedule.

523-3 Construction Requirements.

Install patterned pavement on asphalt or concrete locations with the color and pattern as specified in the Plans. Prepare the surface and install patterned pavement in accordance with the manufacturer's installation instructions, using materials and equipment recommended and approved by the manufacturer.

Install overlay products to a thickness not exceeding 180 mils.

Patterns and variations within the installation shall comply with ADA requirements.

Complete all utility, traffic loop detector, and other items requiring a cut and installation under the finished surface, prior to product installation.

Protect treated surfaces from traffic and environmental effects until the product is completely installed, including drying and curing according to the manufacturer's instructions.

For installation on new asphalt roadways, apply patterned pavement a minimum of 14 days after placement of the adjacent pavement.

Patterned pavements shall be weather resistant, friction resistant, and through normal wear, shall show no signs of failure due to tearing, stretching, rollback, blistering, excessive cracking, chipping, discoloration, poor adhesion to the pavement, pavement damage, or vehicular damage.

Upon completion of the installation, the Engineer will check the area at random locations for geometric accuracy. If any of the chosen areas are found to be deficient, correct the entire patterned area at no additional cost to the Department.

Submit certification to the engineer, including the APL number and that the patterned pavement was installed in accordance with the manufacturer's installation instructions and this Section.

523-4 Method of Measurement.

The quantity to be paid will be the plan quantity in square yards of patterned pavement, completed and accepted. No deduction will be made for areas occupied by landscaping, manholes, inlets, drainage structures, or by any public utility appurtenances within the area.

523-5 Basis of Payment.

Price and payment will be full compensation for all work specified in this Section.

Payment will be made under:

Item No. 523- 3- Patterned Pavement - per square yard.

SECTION 524
CONCRETE DITCH AND SLOPE PAVEMENT

524-1 Description.

Construct concrete pavement in the flow channel of drainage ditches and on slopes as shown on the Plans and in accordance with the Standard Plans.

524-2 Materials.

Concrete .....Section 347
Preformed Expansion Joint Material and Hot Poured Sealer .....
.....Section 932
Filter Fabric*.....Section 985
Reinforcing Steel .....Section 415
*Use products listed on the Department's Approved Product List (APL).

524-3 Forms.

Provide forms as specified in 520-3.

524-4 Foundation.

Shape and compact the foundation materials, upon which the pavement is to be constructed, to a firm, even surface, true to grade and cross slope.

Dispose of surplus material.

524-5 Joints and Weep Holes.

524-5.1 Joints:

524-5.1.1 Joints in Ditch Pavement: Construct formed (construction joint) or tooled contraction joints, spaced at 25 feet maximum intervals. Open joints are prohibited. Construct expansion joints with 1/2-inch preformed joint filler at all inlets, endwalls, and at intervals of not more than 200 feet.

524-5.1.2 Joints in Slope Pavement: Form open or tooled (dummy) type joints as shown in the Plans. Form open joints by staking a metal bulkhead in place and placing the concrete on both sides of it. When the concrete has set sufficiently to preserve the width and shape of the joints, remove the bulkhead. Upon finishing the pavement over the joint, open and edge the slot with a tool having a 1/4-inch radius.

524-5.2 Method of Placing Slope Pavement: Place slope pavement in vertical strips, 4 feet, plus or minus 1 inch, wide, except taper radii strips from the 4-foot width at the bottom to a minimum width of 1 foot at the top. Score the strips horizontally at intervals of 2 feet, plus or minus 1 inch, with a tool having a double 1/4-inch radius. Edge construction joints between strips with a tool having a 1/4-inch radius. The Engineer will allow construction joints at horizontal scorings.

524-5.3 Weep Holes: Locate and construct weep holes as shown in the Plans. Construct weep holes at the toe of slope for all slope pavements.

524-5.4 Filter Fabric: Place filter fabric directly beneath all concrete ditch pavement for the entire length and width of the pavement, regardless of the pavement thickness. Place filter fabric below weep hole aggregate to form a mat continuous with the pavement filter fabric or underlapping the pavement filter fabric, if present.

524-6 Placing Concrete.

Place the concrete in the forms, tamp and spade it to prevent honeycombing, and until the top of the structure can be floated smooth and the edges rounded.

524-7 Finishing.

Roughen the surface of ditch pavement after screeding concrete, unless otherwise specified, to the approximate shape and grade by a rake or other suitable tool drawn perpendicular to the direction of flow. Ensure that the furrows are at least 1/4 inch deep.

Strike off slope pavement or smooth surfaced ditch pavement, when specified, true to line and cross slope and remove all surplus water and laitance from the surface. Lightly broom the finish.

524-8 Curing.

Cure the concrete as specified in 520-8.

524-9 Method of Measurement.

524-9.1 Concrete Ditch and Slope Pavement: The quantities to be paid for Concrete Ditch Pavement and Concrete Slope Pavement will be the plan quantity, in square yards, completed and accepted. Where the Plans show headers or cut-off walls at the end or edge of the pavement, the volume of the additional thickness of pavement that constitutes the headers, calculated in accordance with plan dimensions, will be converted into equivalent square yards of standard thickness pavement and included in the quantity to be paid for.

No deduction will be made for any areas occupied by manholes, inlets, or other drainage structures or by public utility appurtenances within the pavement area. The square yard quantity includes any ditch blocks with ditch or slope pavement on top. When steel reinforcement is called for in the Plans, payment will be included in the square yard item.

Sod will be measured and paid in accordance with Section 570.

524-9.2 Concrete Core Ditch Blocks: The quantity to be paid for Concrete Core Ditch Blocks will be the plan quantity of concrete, in cubic yards, completed and accepted. When steel reinforcement is called for in the Plans, payment will be included in the cubic yard pay item. The cubic yard pay item includes any ditch block within a grass or earth ditch, without other pavement on top.

524-10 Basis of Payment.

Prices and payments will be full compensation for all work specified in this Section, including all earthwork, skimmers, and incidental materials necessary to complete the work.

Payment will be made under:

Item No. 524-	1-	Concrete Ditch Pavement - per square yard.
Item No. 524-	2-	Concrete Slope Pavement - per square yard.
Item No. 524-	3-	Concrete Core Ditch Block - per cubic yard.

SECTION 525
ASPHALT CONCRETE CURB

525-1 Description.

Construct an asphalt concrete curb on a previously laid pavement at the locations shown in the Plans.

525-2 Materials.

Meet the following requirements:

Superpave Type SP-12.5 (Traffic Level B or C) .....Section 334

525-3 Construction Methods.

Use a Type SP-12.5 (Traffic Level B or C) asphalt concrete mixture.

Sufficiently roughen the surface of the roadway pavement at the locations where the curb will be constructed to provide suitable bonding of the pavement and the curb.

Lay the curb by a machine or by other methods to provide the required cross-section. The Engineer may allow variation in the Plan cross-section for using the particular machine, provided the Contractor obtains the equivalent cross-sectional area and the specified height of curb. Provide appropriate compaction as directed by the Engineer.

525-4 Method of Measurement.

The quantity to be paid for will be the length plan quantity, in feet, completed and accepted. Any additions or deletions thereto as authorized by the Engineer will be determined by plan dimensions, station-to-station dimensions, final measurement, or any combination thereof, as measured along the face of the completed and accepted curb.

525-5 Basis of Payment.

Price and payment will be full compensation for all work specified in this Section, including all materials and incidentals necessary to complete the work.

Payment will be made under:

Item No. 525- 1- Asphaltic Concrete Curb - per foot.

SECTION 526
ARCHITECTURAL PAVERS

526-1 Description.

Furnish and install architectural pavers in accordance with this Section.

526-2 Materials.

526-2.1 General: Architectural pavers shall meet the following requirements:

Table 526-1
Architectural Paver Requirements

Proposed Use	ASTM C902 (Brick Paver)	ASTM C1272 (Brick Paver)	ASTM C936 (Concrete Paver)
Local Side Streets (≤ 35 mph Design Speed)	Do Not Use	X	X
Commercial Driveways	Do Not Use	X	X
Sidewalks and Medians	X	Do Not Use	X
Residential Driveways	X	Do Not Use	X

Ensure that the pavers are consistent in color, size, and appearance. Architectural paver type, pattern, shape and/or color will be in accordance with plan details, when specified.

526-2.2 Architectural Pavers - Roadway: For installations on roadways and commercial driveways, provide architectural pavers having a minimum thickness of 3-1/8 inch.

526-2.3 Architectural Pavers - Sidewalk: For installations on sidewalks, medians and residential driveways, provide architectural pavers having a minimum thickness of 2-3/8 inch.

526-2.4 Bedding and Joint Sands: Provide clean, non-plastic bedding and joint sand, free from deleterious or foreign matter, natural or manufactured from crushed rock.

Ensure the bedding sand meets the grading requirements of ASTM C33 Standard Specification for Concrete Aggregate.

Ensure the joint sand meets the grading requirements of ASTM C144 Standard Specification for Aggregate for Masonry Mortar.

Bedding sand may be used for joint sand. Do not use joint sand for bedding sand.

526-2.5 Bedding and Joint Grouts: A suitable grout, in thickness specified by the manufacturer and approved for use by the architectural paver manufacturer, may be substituted for either bedding sand, joint sand or both when specified in the Plans and approved by the Engineer.

526-3 Construction Methods.

526-3.1 General:

526-3.1.1 Submittals: For Architectural Pavers – Roadway, furnish full size samples to the Engineer for approval prior to beginning placement. For Architectural Pavers - Sidewalk, submit to the Engineer a certification that the architectural pavers meet the requirements of this Section. In addition, for all architectural pavers, submit a certified sieve analysis for gradation comparing results of the bedding sand and joint sand with the requirements of ASTM C33 or ASTM C144 as applicable.

526-3.1.2 Mock-ups: Prior to beginning placement, install a 6 foot by 6 foot paver area following these specifications. This area will be used to determine surcharge of the bedding material layer, joint sizes, lines, laying patterns and colors of the job. This area will be adjacent to an edge treatment, incorporated into the work, and will be the standard from which the work will be judged.

526-3.1.3 Environmental Conditions: Cover stockpiled materials with waterproof covering to prevent exposure to rainfall. Do not install bedding materials or architectural pavers during heavy rains or over wet substrata.

526-3.2 Installation: Install the architectural pavers in the following manner:

1. Spread the bedding material evenly over the base course and screed to plan thickness, not to exceed a thickness of 1-1/2 inch. Do not disturb the screeded bedding material. Ensure placement of sufficient bedding material to stay ahead of the laid architectural pavers. Do not use the bedding material to fill depressions in the base course.

2. Lay architectural pavers in the pattern(s) shown in the Plans and maintain straight pattern lines.

3. Joints between the architectural pavers, on average, will be between 1/16 to 3/16 inch wide.

4. Fill gaps at the edges of the paved area with cut or edge architectural pavers.

5. When utilizing bedding and joint sand:

   a. Use a low amplitude vibrator capable of 5,000 foot-pounds with 7-100 Hz frequencies to vibrate and compact architectural pavers into bedding sand.

   b. Vibrate the architectural pavers, sweeping dry joint sand into the joints and vibrating, until the joints are full. Do not vibrate within 3 feet of the unrestrained edges of the architectural pavers.

   c. At the end of each day, all work within 3 feet of laying face must be left fully compacted, with sand-filled joints.

   d. Sweep off the excess sand.

6. Leave a final surface elevation of architectural pavers of 1/8 to 1/4 inch above adjacent drainage inlets, concrete collars or channels.

7. Do not permit the final surface elevations of the pavers to deviate more than 3/8 inch under a 10 foot long straightedge, or more than 1/8 inch between adjacent pavers.

526-4 Method of Measurement.

The quantity to be paid for will be the plan quantity, in square yards, for architectural pavers completed and accepted. No deduction will be made for the areas occupied by ornamental trees left within and any other areas occupied by manholes, inlets, drainage structures or by public utility appurtenances within the normal areas of the architectural pavers.

526-5 Basis of Payment.

Price and payment will be full compensation for all work, including all materials, equipment, labor, and incidentals necessary to complete the work.

Payment shall be made under:

Item No. 526- 1- - Pavers, Architectural - per square yard.

SECTION 527
DETECTABLE WARNINGS

527-1 Description.

Detectable warnings are products used for the visually impaired and installed on newly constructed and/or existing concrete or asphalt walking surfaces (sidewalk curb ramps, sidewalks, shared use paths, etc.).

527-2 Materials.

Use detectable warnings as approved for use on uncured concrete, existing concrete, and asphalt surfaces. Use only products and materials appropriate for the surface on which they will be applied.

Use safety yellow, brick red, or black colored detectable warnings on concrete walking surfaces. Use safety yellow colored detectable warnings on asphalt walking surfaces.

Use detectable warnings listed on the Department's Approved Product List (APL) meeting the requirements of Section 974. Methods used to form detectable warnings in wet concrete will not be permitted.

527-3 Construction Requirements.

Prepare the surface and install detectable warnings in accordance with the manufacturer's installation instructions, using materials and equipment recommended and approved by the manufacturer. Construct in accordance with Standard Plans, Index 522-002.

Open the walking surface to pedestrian traffic within 72 hours for uncured concrete surfaces. Immediately open the walking surface to pedestrian traffic for asphalt and existing concrete surfaces.

Surface color and texture shall be complete and uniform. Detectable warnings will be securely installed as recommended by the manufacturer and free from lifting, cracking, missing or partial domes, and with no significant defects. Surfaces shall not deviate more than 0.10 inch from a true plane.

527-4 Method of Measurement.

Detectable warnings will be paid by plan quantity, per square foot, furnished, installed and accepted.

527-5 Basis of Payment.

Price and payment will be full compensation for all work specified in this Section, including all labor, surface preparation, removal of existing removable or surface applied detectable warnings, materials, equipment, and incidentals necessary to complete the work.

Payment will be made under:

Item No. 527- 2- Detectable Warnings - per square foot.