503 Prestressed Concrete Members

503.1 Description

(1) This section describes fabricating, furnishing, transporting, and erecting prestressed concrete girders, or other prestressed concrete members.

(2) These specifications provide for prestressing concrete members by the pretensioning method. In this method, stress the reinforcing tendons initially, then place and cure the concrete and release the stress from the anchorages to the concrete after developing specified concrete strength.

503.2 Materials

503.2.1 General

(1) Furnish materials conforming to the following:

Bar steel reinforcement.....505

(2) Use galvanized or epoxy-coated steel, stainless steel, or non-metallic materials for hardware incorporated into the finished structure.

503.2.2 Concrete

(1) Furnish concrete as specified in 501. If the design ultimate stress, f'_c, the plans show is 8000 psi or higher for a prestressed concrete I-type girder, extend 28-day strength requirements within 503 for that girder to 56 days.

(2) Ensure concrete attains a minimum 28-day compressive strength of 6000 psi for prestressed I-type girders. Base tests on 6-inch by 12-inch cylinders, or 4-inch by 8-inch cylinders, provided the engineer develops and approves a correlation factor. Mold concrete cylinders in steel or plastic molds. Cure concrete cylinders according to WTM R100, except cure the cylinders with the member until release strength is obtained, then cure the cylinders according to WTM R100. Maintain laboratory facilities and equipment according to AASHTO M201. Make 3 cylinders for each line of prestressed members poured and test each cylinder according to WTM T22. Calibrate cylinder-testing equipment at least annually according to AASHTO T67. Average the strengths of the 2 cylinders with the highest test results for each line and use the average to determine compliance with the 28-day strength requirement. Ensure that neither of the 2 cylinders with the highest test results has a strength less than 10 percent below the required strength.

(3) Instead of the above acceptance procedure, the engineer will allow early acceptance of the prestressed units, before the 28-day test, if 2 successive laboratory tests on standard test specimens, cured continuously with and in the same manner as the units, indicate compressive strength in excess of the required 28-day strength. Test the 28-day strength cylinders and record the results to maintain continuity of the contractor's quality control records.

(4) Have an HTCP-certified PCC Technician I sample concrete, perform fresh concrete testing, and fabricate and cure cylinders. Have an HTCP-certified Concrete Strength Tester, working in a department-qualified laboratory, perform cylinder and core compression tests. Determine the compressive strength in psi for each cylinder according to WTM T22. Test each cylinder to failure. Use a compression machine that automatically records the date, time, rate of loading on a load vs. time plot, and maximum load for each cylinder. Include a printout of this information with the strength documentation for each cylinder tested. Notify the engineer immediately if concrete cylinder compressive strengths are less than the required 28-day strength. Keep neatly documented records of cylinder testing on the day of the test and make them available to the engineer.

(5) Furnish prestressed concrete members cast from air-entrained concrete, except I-type girders may use non-air-entrained concrete. Use type I, IL, IS, IP, IT, II, or III cement. The contractor may replace up to 30 percent of type I, IL, II, or III cement with an equal weight of fly ash, slag, or a combination of fly ash and slag. Ensure that fly ash conforms to 501.2.4.2.2 and slag conforms to 501.2.4.2.3. Use only one source and replacement rate for work under a single bid item. Use a department-approved air-entraining admixture conforming to 501.2.5.2 for air-entrained concrete. Use only size No. 1 coarse aggregate conforming to 501.2.7.4.2.

(6) Determine proportions for the mix within the following limitations:

Water cementitious material ratio, w/cm.....0.45 or less[1]

Cementitious material content.....610-800 pounds per cubic yard

Air content:

Prestressed I-type girders..... 6.0 percent maximum

Other components.....4.5 - 7.5 percent

Slump..... 8 inches maximum[2]

[1] The water cementitious material ratio is the weight of the total added water plus the aggregate free water, divided by the combined weight of the cement, fly ash, and slag.

[2] Proportion the mix to provide a concrete of uniform quality and consistency with a slump no greater than necessary for proper placement and consolidation.

(7) Incorporate a department-approved high range water-reducing admixture conforming to ASTM C494, type G. Instead of a type G admixture, the contractor may use type F and type D admixtures in combination to achieve equivalent results.

(8) Use a department-approved set retarding admixture as specified in 501.2.5.3 at the recommended rate if the ambient air temperature is 70 F or higher. The contractor may use it if the ambient air temperature is less than 70 F.

(9) Do not add more admixtures or water after mixing is complete.

(10) Use admixtures that do not have significant chlorides or chlorides added during manufacture.

(11) Use admixtures compatible with other ingredients of the concrete mixture.

503.2.3 Pretensioning Reinforcement

(1) Use high tensile strength, 7-wire strands of the nominal diameter the plans show and conforming to ASTM A416, grade 270.

503.2.4 Plant Certification

(1) Obtain prestressed concrete members from fabrication plants that comply with the department's plant certification program for fabrication of prestressed concrete members, unless the engineer agrees to accept these items according to the alternate procedures set forth in the department's plant certification program.

503.3 Construction

503.3.1 General

(1) Submit shop drawings to the engineer conforming to 105.2 with electronic submittal to the fabrication library under 105.2.2. Certify that shop drawings conform to quality control standards by submitting department form DT2328 with each set of shop drawings. Department review does not relieve the contractor from responsibility for errors or omissions on shop drawings.

(2) Ensure that the fabricator submits a fabrication progress report on department form DT2336 electronically to the department’s fabrication library. Update this form weekly for each structure in fabrication.

503.3.2 Stressing Procedure

503.3.2 Add pretensioned grider strand initial load values for 0.5-inch and 0.6-inch diamter strands.

(1) Ensure the strands of a pretensioned girder are free from kinks or twists before starting tensioning operations. Ensure no strand unwinds more than one turn after starting tensioning operations. Tension strands 1500 pounds each before starting elongation readings, or as the contractor determines; however, do not use an initial load greater than 4000 pounds for 0.5-inch diameter strands or 5000 pounds for 0.6-inch diamter strands. This initial tension in any strand must not vary by more than 5 percent. Use equipment to produce the initial tensioning load that provides a way of accurately measuring the force. If applying the initial tensioning load by pressure jacks, equip them with a proper gaging system for the initial force.

(2) If tensioning draped pretensioned strands in a horizontal position, tension them to a less than required the design stress so that the increased strain from jacking the drape in the strands results in a stress equal to the required design stress.

(3) If tensioning the draped strands in their draped position, support them by rollers at points of change in direction. Ensure the hold-up rollers between girders and at the ends of the end girders have either bronze bushings or roller bearings, and are well lubricated. Use free running rollers at the hold-down points that produce minimal friction. If stressing from one end results in a difference of more than 5 percent between the load calculated from elongation and the gauge load then tension draped strands from both ends. The sum of elongation at both ends must agree within 5 percent of that indicated by the jack gauges.

(4) Provide to the contractor's project file details showing number, spacing, and method of draping pretensioned strands.

(5) The department will allow one splice per pretensioning strand provided the splices are positioned so only one splice occurs within a member. Ensure that spliced strands have the same twist or lay. Make allowance for splice slippage in computing strand elongation.

(6) The engineer may accept failure of one wire in a 7-wire pretensioning strand if it attains 85 percent of the required tension load before failure, and the failed wire constitutes not more than 2 percent of the total area of strands in an individual beam or girder.

(7) If using a jacking system equipped with an automatic release valve that closes if the required prestressing force is reached, there is no requirement to measure strand elongation for all horizontal strands; however, this measurement is required for the first and last strand tensioned and for at least 10 percent of the remaining strands. If performing elongation computations, take into account strand anchorage slippage, horizontal movement of abutments, and any change in temperature of the prestressing steel between tensioning and when concrete takes its initial set, if this change is expected to exceed 30 F.

(8) Equip prestressing systems with accurately calibrated gauges for measuring the loads produced. Ensure gauges are accurate to within 2 percent and are equipped with a gauge dial read to the nearest 250 pounds of prestressing force. Use a department-approved testing laboratory to calibrate the gauge, and furnish a certified calibration curve for each gauge. If gauges do not read loads directly in pounds, provide a chart tabulated in increments of at least 250 pounds for converting the readings to pounds. Calibrate the gauges with the gauges in place on the jacking system, completely assembled in the manner used in the prestressing operation.

(9) For gaging, use loads between 1/4 and 3/4 of the total graduated capacity of the gauge, unless calibration data clearly establish consistent accuracy over a wider range.

(10) Re-calibrate gaging devices at least once a year; however, if the gaging system gives erratic results, or if the gauge and elongation measurements indicate significantly different stresses, then re-calibrate the jack and the gauges.

(11) Measure the stress induced in the prestressing element by both jacking gauge pressure and by elongation of the prestressing steel. If these measurements differ, use the gauge pressure to indicate the true stress in the prestressing steel. There is an allowable master tolerance of +/- 5 percent between the actual gauge pressure and elongation and the calculated value of each. Additionally, there is a more restrictive 5 percent tolerance for algebraic comparison of the variation of gauge pressures to the variation of elongations. If the difference between gauge pressure and elongation exceeds 5 percent, carefully check the entire operation, determine, and correct the source of error before proceeding further.

(12) Mark each anchor (dead, live, and splice) and visually check for slippage in excess of that assumed in the calculations. Perform random measured checks.

(13) During prestressing operations, provide the safety measures and means necessary to prevent accidents in the event the prestressing steel, hold down devices, abutments, and beds break, or the grips slip.

(14) Tension the prestressing elements to provide the required prestress the plans show.

(15) Perform transfer of prestress to concrete after the concrete develops the minimum required strength for transfer determined by the test cylinders.

(16) Use the minimum required concrete strength at transfer of prestress that the plans show.

503.3.2.1 Placing and Fastening Steel

(1) Place steel units in the position the plans show and hold firmly during concrete placing and setting as specified in 505.3.

(2) Maintain distances from the forms by using stays, ties, hangers, or other engineer-approved supports. Separate layers of units by suitable devices. Do not leave wood blocks in the concrete.

(3) Position wires, wire groups, parallel-lay cables, and any other prestressing elements, correctly in the enclosures. Provide suitable horizontal and vertical spacers, if required, to hold the wires in true position in the enclosures.

(4) Ensure that prestressing steel is free of dirt, grease, wax, scale, rust, oil, or other foreign material that may prevent bonding between the steel and the concrete.

503.3.3 Concrete Operations

503.3.3.1 Placing Concrete

503.3.3.1.1 General

(1) Handle and place the concrete as specified in 502, except as specified otherwise below.

(2) Place and consolidate concrete in lifts in a way that prevents segregation, provides uniform consolidation throughout the member, and minimizes visible lift lines and dried concrete deposits along formed surfaces. Ensure not more than one-hour elapses between placing successive lifts.

(3) Consolidate the concrete in girders by internal, external, or both internal and external vibration. Avoid displacing reinforcing, conduits, or wires. Ensure that concrete is free from honeycombing throughout the member, free from voids around reinforcement and inserts, and free from excessive bug holing along formed surfaces.

503.3.3.1.2 Tolerances

(1) Cast prestressed concrete members to plan dimensions within the following applicable tolerances:

PRESTRESSED CONCRETE I-TYPE GIRDERS

Depth of the flange, web, and fillets	+/- 1/4"
Depth overall	+1/2" to -1/4"
Width of flanges and fillets	+3/8" to -1/4"
Width of web	+3/8" to -1/4"
Length of beam	+/- 1/8" per 10', up to a max of +/- 1 1/2"
Deviation from square of exposed beam ends	
Horizontally	+/- 1/4"
Vertically	+/- 1/8" per foot of beam depth
Side inserts, spacing between centers and from centers to beam ends	+/- 1/4"
Bearing plates, spacing between centers	the greater of +/- 1/8" per 10', or +/- 1/2"
Bearing plates, spacing from centers to beam ends	+/- 1/4"
Bearing plate or bearing area, deviation from plane	+/- 1/16"
Stirrup bars, projection above top of beam	+1/4" to -3/4"
Stirrup bars, longitudinal spacing	+/- 1"
End of stirrup bars from end of beam	2" or less
Horizontal alignment, deviation from a straight line, "sweep"	1/8" per 10' of member length
Camber, differential between adjacent beams	1/8" per 10' of span up to a max of 1"
Center of gravity of draped strand group	+/- 1/4"
Center of gravity of draped strand group at end of beam	+/- 1/2"
Position of hold-down points for draped strands	+/- 6"
Position of handling devices	+/- 6"

503.3.3.2 Curing

503.3.3.2.1 General

(1) Steam cure concrete members or cure by other methods identified by the contractor's fabrication quality control plan. Protect the surfaces of members exposed during curing from moisture loss until release strength is obtained. Do not use curing compound for this purpose.

503.3.3.2.2 Steam Curing

(1) If steam curing, enclose the concrete member in a chamber or enclosure, with at least 12 inches between the member and the enclosure. If using tarpaulins for enclosures, use at least 2 layers and arrange them to form a tight enclosure that leaks as little steam as possible. Use low-pressure steam and do not allow steam jets to spray directly on the concrete or on the forms. Maintain the relative humidity at approximately 100 percent within the enclosure.

(2) Maintain the concrete temperature at or near the pouring temperature until the initial set, according to AASHTO T197, before allowing the temperature to rise. The rate of temperature rise of the concrete must not exceed 40 F per hour.

(3) During curing maintain the internal concrete temperature between 50 F and 160 F. Ensure that the temperature of the concrete in different locations within the housing does not vary more than 20 F at any time.

(4) Place a minimum of 3 engineer-approved continuous recording thermometers in each line. Provide the engineer with complete temperature record charts for the curing period, including the heat-up and cool-down times. If the temperature records indicate that steam control produces rates or temperatures that do not conform to those specified, modify procedures to obtain specified results.

(5) Continue steam curing until the concrete develops the required strength for transfer of prestress. The contractor may then discontinue steaming and uncover the beam. Cure the test specimens used to determine the above strength as specified in 503.3.3.3.

(6) If steam-curing girders, release the prestressing strands immediately after steam curing. Cut or release strands in a sequence that minimizes eccentricity of prestress force in the beam.

(7) If the contractor wants to remove the forms before completing the steaming, the contractor may uncover the beam one side at a time and for as much length as required to remove the form sections. Immediately replace the covering after removing each form section. Do not expose the forms and beam surface for more than 30 minutes during this operation.

503.3.3.3 Test Cylinders for Release of Pretensioned Steel

(1) Make test cylinders for determining the time for releasing the pretensioned steel. Make 6-inch by 12-inch test cylinders and mold them in suitable steel or plastic molds. Cure the test cylinders with the represented concrete member until removal for capping and testing. Ensure that at least 2 cylinders have strengths above the minimum specified required strength, or average above the specified minimum with the lower not more than 5 percent below this strength, before releasing the tension. Make these test cylinders in addition to the cylinders designated in 503.2.2 for determining the 28-day strength.

503.3.3.4 Surface Finish

(1) The manufacturer of prestress concrete girders or other members shall notify the engineer of the following:

- Honeycomb deep enough to expose the prestressing steel.
- Defects that may affect bond length or transfer length.
- Any area that the manufacturer believes to be detrimental.

(2) The engineer responsible for inspection at the prestress concrete manufacturing plant will consult with the manufacturer to determine the corrective action required to repair the member. The prestress manufacturing plant is responsible for rejecting prestress members that cannot be effectively repaired. The engineer is responsible for acceptance.

(3) Provide a sack rubbed surface finish on the exposed surfaces of prestressed concrete girders as specified in 502.3.7.5 before shipping from the plant. Provide a wire brush or stiff broom finish on surfaces to be bonded. Provide a smooth trowelled finish on the top surface of the top flanges of bulb tee girders, except for the bonding region centered over the web.

(4) After the sack rubbed finish adequately cures, apply engineer-approved gray-pigmented concrete sealer for non-trafficked surfaces uniformly to sack rubbed and smooth trowelled surfaces using the manufacturer’s recommended rate and procedures. Apply sealer and allow adequate time for sealer to dry before shipping prestressed concrete members from the plant.

(5) Fill exposed voids created for transport, erection, or deck forming. For voids with a surface opening greater than 2 inches in diameter, dry and uniformly coat void surfaces with an epoxy bonding agent conforming to ASTM C881 type II and following the bonding agent manufacturer's recommendations. Epoxy bonding agent is not required for voids with a surface opening of 2 or less inches in diameter. Fill with an engineer-approved non-shrink grout immediately after applying the bonding agent, unless the grout manufacturer recommends otherwise.

503.3.4 Transportation, Storage, and Erection

(1) Transport, handle and store the prestressed girders in an upright position, and ensure that points of support, and direction of the reactions with respect to the girder are approximately the same during transportation, storage, and erection as when the girder is in its final position. The maximum overhang from the point of support to the end of girder during storage, handling, and transporting must not exceed the depth of the girder unless the engineer allows a larger overhang.

(2) Handle, store and erect prestressed units in a way that prevents cracking or other damage to the unit. Discard and replace units damaged by improper handling or storing.

(3) Do not transport or erect prestressed girders before they attain a minimum 28-day compressive strength, determined from test cylinders made, cured, and tested as specified in 503.2.2. The engineer may allow delivery and erection of girders before their acceptance, pending strength tests, if the contractor provides in writing that it accepts responsibility for their removal and replacement in the event of rejection due to deficient strength.

(4) Do not place floors on girders until the specified tests made on representative test cylinders indicate they achieved their minimum 28-day strength.

(5) If, during the prestressed girders erection, the contractor elects to use a crane on the girders before placing and curing the concrete slab for the span, then the contractor shall submit details of the proposed temporary flooring, the strutting between the girders, and information about the crane used to the engineer for prior approval.

(6) Clean the exposed surface of stainless steel bearing plates on girders before setting the girder on the opposing bearing surface. Ensure that bearing surfaces are clean and free of materials that could adversely affect the function of the sliding bearing.

503.4 Measurement

(1) The department will measure the Prestressed Girder bid items by the linear foot acceptably completed.

503.5 Payment

(1) The department will pay for measured quantities at the contract unit price under the following bid items:

ITEM NUMBER	DESCRIPTION	UNIT
503.0100 - 0199	Prestressed Girder (type) (inch)	LF

(2) Payment for the Prestressed Girder bid items is full compensation for providing girders, including concrete, grout, mortar, reinforcement steel, tie bars, anchor plates, and other embedded metal; for casting and curing concrete; for jacking and prestressing; for handling, hauling and erecting; and for discarding and replacing units damaged by improper handling or storage.

(3) The department will accept prestressed concrete members with 28-day concrete cylinder strengths below the required 28-day compressive strength, as specified in 503.2.2, based on a pay reduction, if the 28-day concrete cylinder strength provided is greater than the engineer-determined design strength of the individual member. The department will reduce payment for an accepted member with 28-day concrete cylinder strength less than the required 28-day compressive strength by the greater of $500, or 20 percent of the contract unit price applied to the measured length of the member.

(4) If the 28-day concrete cylinder strength for the prestressed concrete member falls below the engineer-determined design strength of the individual member, obtain cores from each member according to WTM T24, test according to WTM T22, and evaluate for strength comparison. Obtain the engineer's approval for the core sample locations. If the average of 3 core strengths per member satisfies the design strength, and if none of the core strengths are less than 10 percent below the design strength, the engineer will accept the member based on the pay reduction defined above for deficient 28-day concrete cylinder strengths. The contractor may perform coring and testing, or an independent testing agency that the engineer approves may perform coring and testing. The engineer will observe coring and testing done by the contractor. Costs associated with taking, analyzing, and testing cores are the contractor’s responsibility.