Section 10
PRESTRESSING

10.1 GENERAL

10.1.1 Description

This work shall consist of prestressing precast or cast-in-place concrete by furnishing, placing, and tensioning of prestressing steel in accordance with details shown on the plans, and as specified in these specifications and the special provisions. It includes prestressing by either the pretensioning or post-tensioning methods or by a combination of these methods.

This work shall include the furnishing and installation of any appurtenant items necessary for the particular prestressing system to be used, including but not limited to ducts, anchorage assemblies and grout used for pressure grouting ducts.

For cast-in-place prestressed concrete, the term "member" as used in this section shall be considered to mean the concrete which is to be prestressed.

When members are to be constructed with part of the reinforcement pretensioned and part post-tensioned, the applicable requirement of this Specification shall apply to each method.

10.1.2 Details of Design

When the design for the prestressing work is not fully detailed on the plans, the Contractor shall determine the details or type of prestressing system for use and select materials and details conforming to these Specifications as needed to satisfy the prestressing requirements specified. The system selected shall provide the magnitude and distribution of prestressing force and ultimate strength required by the plans without exceeding allowable temporary stresses. Unless otherwise shown on the plans, all design procedures, coefficients and allowable stresses, friction and prestress losses as well as tendon spacing and clearances shall be in accordance with the Division I, Design, of the AASHTO *Standard Specifications for Highway Bridges.*

The prestressing may be performed by either pretensioning or post-tensioning methods unless the plans show only pretensioning details. If the plans show only pretensioning details, the use of a post-tensioning system will be allowed only if complete details of any necessary modifications are approved by the Engineer.

When the effective or working force or stress is shown on the plans, it shall be considered to be the force or stress remaining in the prestressing steel after all losses, including creep and shrinkage of concrete, elastic shortening of concrete, relaxation of steel, friction and take up or seating of anchorages, and all other losses peculiar to the method or system of prestressing have taken place or have been provided for. When the jacking force is shown on the plans, it shall be considered to be the force applied to the tendon prior to anchorage and the occurrence of any losses, including the anchor set loss.

10.2 SUPPLEMENTARY DRAWINGS

10.2.1 Working Drawings

Whenever the plans do not include complete details for a prestressing system and its method of installation, or when complete details are provided in the plans and the Contractor wishes to propose any change, the Contractor shall prepare and submit to the Engineer working drawings of the prestressing system proposed for use. Fabrication or installation of prestressing material shall not begin until the Engineer has approved the drawings.

The working drawings of the prestressing system shall show complete details and substantiating calculations of the method, materials and equipment the Contractor proposes to use in the prestressing operations, including any additions or rearrangement of reinforcing steel and any revision in concrete dimensions from that shown on the plans. Such details shall outline the method and sequence of stressing and shall include complete specifications and details of the prestressing steel and anchoring devices, working stresses, anchoring stresses, tendon elongations, type of ducts, and all other data pertaining to the prestressing operation, including the proposed arrangement of the prestressing steel in the members.

Working drawings shall be submitted sufficiently in advance of the start of the affected work to allow time for review by the Engineer and correction by the Contractor of the drawings without delaying the work.

10.2.2 Composite Placing Drawings

When required by the special provisions, in addition to all required working drawings, the Contractor shall prepare composite placing drawings to scale and in sufficient detail to show the relative positions of all items that are to be embedded in the concrete, and their embedment depth, for the portions of the structure that are to be prestressed. Such embedded items include the prestressing ducts, vents, anchorage reinforcement and hardware, reinforcing steel, anchor bolts, earthquake restrainers, deck joint seal assemblies, drainage systems, utility conduits and other such items. Such drawings shall be adequate to ensure that there will be no conflict between the planned positions of any embedded items and that concrete cover will be adequate. If during the preparation of such drawings conflicts are discovered, the Contractor shall revise his or her working drawing for one or more of the embedded items or propose changes in the dimensions of the work as necessary to eliminate the conflicts or provide proper cover. Any such revisions shall be approved by the Engineer before work on any affected item is started.

All costs involved with the preparation of such drawings and with making the necessary modifications to the work resulting therefrom shall be borne by the Contractor.

10.3 MATERIALS

10.3.1 Prestressing Steel and Anchorages

Prestressing reinforcement shall be high-strength seven-wire strand, high-strength steel wire, or high-strength alloy bars of the grade and type called for on the plans or in the special provisions and shall conform to the requirements of the following specifications.

10.3.1.1 Strand

Uncoated seven-wire strand shall conform to the requirements of AASHTO M 203 (ASTM A 416). Supplement S1 (Low-Relaxation) shall apply when specified.

10.3.1.2 Wire

Uncoated stress-relieved steel wire shall conform to the requirements of AASHTO M 204 (ASTM A 421).

10.3.1.3 Bars

Uncoated high-strength bars shall conform to the requirements of AASHTO M 275 (ASTM A 722). Bars with greater minimum ultimate strength, but otherwise produced and tested in accordance with AASHTO M 275 (ASTM A 722), may be used provided they have no properties that make them less satisfactory than the specified material.

10.3.2 Post-Tensioning Anchorages and Couplers

All anchorages and couplers shall develop at least 95% of the actual ultimate strength of the prestressing steel, when tested in an unbonded state, without exceeding anticipated set. The coupling of tendons shall not reduce the elongation at rupture below the requirements of the tendon itself. Couplers and/or coupler components shall be enclosed in housings long enough to permit the necessary movements. Couplers for tendons shall be used only at locations specifically indicated and/or approved by the Engineer. Couplers shall not be used at points of sharp tendon curvature.

10.3.2.1 Bonded Systems

Bond transfer lengths between anchorages and the zone where full prestressing force is required under service and ultimate loads shall normally be sufficient to develop the minimum specified ultimate strength of the prestressing steel. When anchorages or couplers are located at critical sections under ultimate load, the ultimate strength required of the bonded tendons shall not exceed the ultimate capacity of the tendon assembly, including the anchorage or coupler, tested in an unbonded state.

Housings shall be designed so that complete grouting of all of the coupler components will be accomplished during grouting of tendons.

10.3.2.2 Unbonded Systems

For unbonded tendons, a dynamic test shall be performed on a representative anchorage and coupler specimen and the tendon shall withstand, without failure, 500,000 cycles from 60% to 66% of its minimum specified ultimate strength, and also 50 cycles from 40% to 80% of its minimum specified ultimate strength. The period of each cycle involves the change from the lower stress level to the upper stress level and back to the lower. The specimen used for the second dynamic test need not be the same used for the first dynamic test. Systems utilizing multiple strands, wires, or bars may be tested utilizing a test tendon of smaller capacity than the full-sized tendon. The test tendon shall duplicate the behavior of the full-sized tendon and generally shall not have less than 10% of the capacity of the full-sized tendon. Dynamic tests are not required on bonded tendons, unless the anchorage is located or used in such manner that repeated load applications can be expected on the anchorage.

Anchorages for unbonded tendons shall not cause a reduction in the total elongation under ultimate load of the tendon to less than 2% measured in a minimum gauge length of 10 feet.

All the coupling components shall be completely protected with a coating material prior to final encasement in concrete.

10.3.2.3 Special Anchorage Device Acceptance Test

10.3.2.3.1 The test block shall be a rectangular prism. It shall contain those anchorage components which will also be embedded in the structure's concrete. Their arrangement has to comply with the practical application and the suppliers specifications. The test block shall contain an empty duct of size appropriate for the maximum tendon size which can be accommodated by the anchorage device.

10.3.2.3.2 The dimensions of the test block perpendicular to the tendon in each direction shall be the smaller of the minimum edge distance or the minimum spacing specified by the anchorage device supplier, with the stipulation that the cover over any confining reinforcing steel or supplementary skin reinforcement be appropriate for the particular application and environment. The length of the block along the axis of the tendon shall be at least two times the larger of the cross-section dimensions.

10.3.2.3.3 The confining reinforcing steel in the local zone shall be the same as that specified by the anchorage device supplier for the particular system.

10.3.2.3.4 In addition to the anchorage device and its specified confining reinforcement steel, supplementary skin reinforcement may be provided throughout the specimen. This supplementary skin reinforcement shall be specified by the anchorage device supplier but shall not exceed a volumetric ratio of 0.01.

10.3.2.3.5 The concrete strength at the time of stressing shall be greater than the concrete strength of the test specimen at time of testing.

10.3.2.3.6 Either of three test procedures is acceptable: cyclic loading described in Article 10.3.2.3.7, sustained loading described in Article 10.3.2.3.8, or monotonic loading described in Article 10.3.2.3.9. The loads specified for the tests are given in fractions of the ultimate load F_{pu} of the largest tendon that the anchorage device is designed to accommodate. The specimen shall be loaded in accordance with normal usage of the device in post-tensioning applications except that load can be applied directly to the wedge plate or equivalent area.

10.3.2.3.7 Cyclic Loading Test

10.3.2.3.7.1 In a cyclic loading test, the load shall be increased to $0.8F_{pu}$. The load shall then be cycled between $0.1F_{pu}$ and $0.8F_{pu}$ until crack widths stabilize, but for not less than 10 cycles. Crack widths are considered stabilized if they do not change by more than 0.001 inch over the last three readings. Upon completion of the cyclic loading the specimen shall be preferably loaded to failure or, if limited by the capacity of the loading equipment, to at least $1.1F_{pu}$.

10.3.2.3.7.2 Crack widths and crack patterns shall be recorded at the initial load of $0.8F_{pu}$, at least at the last three consecutive peak loadings before termination of the cyclic loading, and at $0.9F_{pu}$. The maximum load shall also be reported.

10.3.2.3.8 Sustained Loading Test

10.3.2.3.8.1 In a sustained loading test, the load shall be increased to $0.8F_{pu}$ and held constant until crack widths stabilize but for not less than 48 hours. Crack widths are considered stabilized if they do not change by more than 0.001 inch over the last three readings. After sustained loading is completed, the specimen shall be preferably loaded to failure or, if limited by the capacity of the loading equipment, to at least $1.1F_{pu}$.

10.3.2.3.8.2 Crack widths and crack patterns shall be recorded at the initial load of $0.8F_{pu}$, at least three times at intervals of not less than 4 hours during the last 12 hours before termination of the sustained loading, and during loading to failure at $0.9F_{pu}$. The maximum load shall also be reported.

10.3.2.3.9 Monotonic Loading Test

10.3.2.3.9.1 In a monotonic loading test, the load shall be increased to $0.9F_{pu}$ and held constant for 1 hour. The specimen shall then be preferably loaded to failure or, if limited by the capacity of the loading equipment, to at least $1.2F_{pu}$.

10.3.2.3.9.2 Crack widths and crack patterns shall be recorded at $0.9F_{pu}$ after the 1-hour period, and at $1.0F_{pu}$. The maximum load shall also be reported.

10.3.2.3.10 The strength of the anchorage zone must exceed:

Specimens tested under cyclic or sustained loading .... $1F_{pu}$

Specimens tested under monotonic loading ...... $1.2F_{pu}$

The maximum crack width criteria specified below must be met for moderately aggressive environments. For higher aggressivity environments the crack width criteria shall be reduced by at least 50%.

(1) No cracks greater than 0.010 inch at $0.8F_{pu}$ after completion of the cyclic or sustained loading, or at $0.9F_{pu}$ after the 1-hour period for monotonic loading.
(2) No cracks greater than 0.016 inch at $0.9F_{pu}$ for cyclic or sustained loading, or at $1.0F_{pu}$ for monotonic loading.

10.3.2.3.11 A test series shall consist of three test specimens. Each one of the tested specimens must meet the acceptance criteria. If one of the three specimens fails to pass the test, a supplementary test of three additional specimens is allowed. The three additional test specimen results must meet all acceptance criteria of Article 10.3.2.3.10.

For a series of similar special anchorage devices, tests are only required for representative samples unless tests for each capacity of the anchorages in the series are required by the engineer-of-record.

10.3.2.3.12 Records of the anchorage device acceptance test shall include:

(1) Dimensions of the test specimen.
(2) Drawings and dimensions of the anchorage device, including all confining reinforcing steel.
(3) Amount and arrangement of supplementary skin reinforcement.
(4) Type and yield strength of reinforcing steel.
(5) Type and compressive strength at time of testing of concrete.
(6) Type of testing procedure and all measurements required in Articles 10.3.2.3.7 through 10.3.2.3.10 for each specimen.

10.4 PLACEMENT OF DUCTS, STEEL, AND ANCHORAGE HARDWARE

10.4.1 Placement of Ducts

Ducts shall be rigidly supported at the proper locations in the forms by ties to reinforcing steel which are adequate to prevent displacement during concrete placement. Supplementary support bars shall be used where needed to maintain proper alignment of the duct. Hold-down ties to the forms shall be used when the buoyancy of the ducts in the fluid concrete would lift the reinforcing steel.

Joints between sections of duct shall be coupled with positive connections which do not result in angle changes at the joints and will prevent the intrusion of cement paste.

After placing of ducts, reinforcement and forming is complete, an inspection shall be made to locate possible duct damage.

All unintentional holes or openings in the duct must be repaired prior to concrete placing.

Grout openings and vents must be securely anchored to the duct and to either the forms or to reinforcing steel to prevent displacement during concrete placing operations.

After installation in the forms, the ends of ducts shall at all times be covered as necessary to prevent the entry of water or debris.

10.4.1.1 Vents and Drains

All ducts for continuous structures shall be vented at the high points of the duct profile, except where the curvature is small, as in continuous slabs, and at additional locations as shown on the plans. Where freezing conditions can be anticipated prior to grouting, drains shall be installed at low point in ducts where needed to prevent the accumulation of water. Low-point drains shall remain open until grouting is started.

The ends of vents and drains shall be removed 1 inch below the surface of the concrete after grouting has been completed, and the void filled with mortar.

10.4.2 Placement of Prestressing Steel

10.4.2.1 Placement for Pretensioning

Prestressing steel shall be accurately installed in the forms and held in place by the stressing jack or temporary anchors and, when tendons are to be draped, by hold-down devices. The hold-down devices used at all points of change in slope of tendon trajectory shall be of an approved low-friction type.

Prestressing steel shall not be removed from its protective packaging until immediately prior to installation in the forms and placement of concrete. Openings in the packaging shall be resealed as necessary to protect the unused steel. While exposed, the steel shall be protected as needed to prevent corrosion.

10.4.2.2 Placement for Post-Tensioning

All prestressing steel preassembled in ducts and installed prior to the placement of concrete shall be accurately placed and held in position during concrete placement.

When the prestressing steel is installed after the concrete has been placed, the Contractor shall demonstrate to the satisfaction of the Engineer that the ducts are free of water and debris immediately prior to installation of the steel. The total number of strands in an individual tendon may be pulled into the duct as a unit, or the individual strand may be pulled or pushed through the duct.

Anchorage devices or block-out templates for anchorages shall be set and held so that their axis coincides with the axis of the tendon and anchor plates are normal in all directions to the tendon.

The prestressing steel shall be distributed so that the force in each girder stem is equal or as required by the plans, except as provided herein. For box girders with more than two girder stems, at the Contractor's option, the prestressing force may vary up to 5% from the theoretical required force per girder stem provided the required total force in the superstructure is obtained and the force is distributed symmetrically about the center line of the typical section.

10.4.2.2.1 Protection of Steel After Installation

Prestressing steel installed in members prior to placing and curing of the concrete, or installed in the duct but not grouted within the time limit specified below, shall be continuously protected against rust or other corrosion by means of a corrosion inhibitor placed in the ducts or directly applied to the steel. The prestressing steel shall be so protected until grouted or encased in concrete. Prestressing steel installed and tensioned in members after placing and curing of the concrete and grouted within the time limit specified below will not require the use of a corrosion inhibitor described herein and rust which may form during the interval between tendon installation and grouting will not be cause for rejection of the steel.

The permissible interval between tendon installation and grouting without use of a corrosion inhibitor for various exposure conditions shall be as follows:

Very Damp Atmosphere or over Saltwater (Humidity > 70%)	7 days
Moderate Atmosphere (Humidity from 40% to 70%)	15 days
Very Dry Atmosphere (Humidity < 40%)	20 days

After tendons are placed in ducts, the openings at the ends of the ducts shall be sealed to prevent entry of moisture.

When steam curing is used, steel for post-tensioning shall not be installed until the steam curing is completed.

Whenever electric welding is performed on or near members containing prestressing steel, the welding ground shall be attached directly to the steel being welded. All prestressing steel and hardware shall be protected from weld spatter or other damage.

10.4.3 Placement of Anchorage Hardware

The constructor is responsible for the proper placement of all materials according to the design documents of the engineer of record and the requirements stipulated by the anchorage device supplier. The Contractor shall exercise all due care and attention in the placement of anchorage hardware, reinforcement, concrete, and consolidation of concrete in anchorage zones. Modifications to the local zone details verified under provisions of Article 9.21.7.3. in Division I and Article 10.3.2.3 in Division II shall be approved by both the engineer of record and the anchorage device supplier.

10.5 IDENTIFICATION AND TESTING

All wire, strand, or bars to be shipped to the site shall be assigned a lot number and tagged for identification purposes. Anchorage assemblies to be shipped shall be likewise identified.

Each lot of wire or bars and each reel of strand reinforcement shall be accompanied by a manufacturer's certificate of compliance, a mill certificate, and a test report. The mill certificate and test report shall include the chemical composition (not required for strand), cross-sectional area, yield and ultimate strengths, elongation at rupture, modulus of elasticity, and the stress strain curve for the actual prestressing steel intended for use. All values certified shall be based on test values and nominal sectional areas of the material being certified.

The Contractor shall furnish to the Engineer for verification testing the samples described in the following subarticles selected from each lot. If ordered by the Engineer, the selection of samples shall be made at the manufacturer's plant by the Inspector.

All samples submitted shall be representative of the lot to be furnished and, in the case of wire or strand, shall be taken from the same master roll.

The actual strength of the prestressing steel shall not be less than specified by the applicable ASTM Standard, and shall be determined by tests of representative samples of the tendon material in conformance with ASTM Standards.

All of the materials specified for testing shall be furnished free of cost and shall be delivered in time for tests to be made well in advance of anticipated time of use.

10.5.1 Pretensioning Method Tendons

For pretensioned strands, one sample at least 7 feet long shall be furnished in accordance with the requirements of paragraph 9.1 of AASHTO M 203.

10.5.2 Post-Tensioning Method Tendons

The following lengths shall be furnished for each 20 ton, or portion thereof, lot of material used in the work.

(a) For wires requiring heading—5 feet.
(b) For wires not requiring heading—sufficient length to make up one parallel-lay cable 5 feet long consisting of the same number of wires as the cable to be furnished.
(c) For strand to be furnished with fittings—5 feet between near ends of fittings.
(d) For bars to be furnished with threaded ends and nuts—5 feet between threads at ends.

10.5.3 Anchorage Assemblies and Couplers

The Contractor shall furnish for testing, one specimen of each size of prestressing tendon, including couplings, of the selected type, with end fittings and anchorage assembly attached, for strength tests only. These specimens shall be 5 feet in clear length, measured between ends of fittings. If the results of the test indicate the necessity of check tests, additional specimens shall be furnished without cost.

When dynamic testing is required, the Contractor shall perform the testing and shall furnish certified copies of test results which indicate conformance with the specified requirements prior to installation of anchorages or couplers.

For prestressing systems previously tested and approved on projects having the same tendon configuration, the Engineer may not require complete tendon samples provided there is no change in the material, design, or details previously approved. Shop drawings or prestressing details shall identify the project on which approval was obtained, otherwise testing shall be conducted.

10.6 PROTECTION OF PRESTRESSING STEEL

All prestressing steel shall be protected against physical damage and rust or other results of corrosion at all times from manufacture to grouting. Prestressing steel shall also be free of deleterious material such as grease, oil, wax, or paint. Prestressing steel that has sustained physical damage at any time shall be rejected. The development of pitting or other results of corrosion, other than rust stain, shall be cause for rejection.

Prestressing steel shall be packaged in containers or shipping forms for the protection of the strand against physical damage and corrosion during shipping and storage. A corrosion inhibitor which prevents rust or other results of corrosion shall be placed in the package or form, or shall be incorporated in a corrosion inhibitor carrier type packaging material, or when permitted by the Engineer, may be applied directly to the steel. The corrosion inhibitor shall have no deleterious effect on the steel or concrete or bond strength of steel to concrete or grout. Packaging or forms damaged from any cause shall be immediately replaced or restored to original condition.

The shipping package or form shall be clearly marked with a statement that the package contains high-strength prestressing steel, and the type of corrosion inhibitor used, including the date packaged.

All anchorages, end fittings, couplers, and exposed tendons, which will not be encased in concrete or grout in the completed work, shall be permanently protected against corrosion.

10.7 CORROSION INHIBITOR

Corrosion inhibitor shall consist of a vapor phase inhibitor (VPI) powder conforming to the provisions of Federal Specification MIL-P-3420 or as otherwise approved by the Engineer. When approved, water soluble oil may be used on tendons as a corrosion inhibitor.

10.8 DUCTS

Ducts used to provide holes or voids in the concrete for the placement of post-tensioned bonded tendons may be either formed with removable cores or may consist of rigid or semi-rigid ducts which are cast into the concrete.

Ducts formed with removable cores shall be formed with no constrictions which would tend to block the passage of grout. All coring materials shall be removed.

Ducts formed by sheath left in place shall be a type that will not permit the intrusion of cement paste. They shall transfer bond stresses as required and shall retain shape under the weight of the concrete and shall have sufficient strength to maintain their correct alignment without visible wobble during placement of concrete.

10.8.1 Metal Ducts

Sheathing for ducts shall be metal, except as provided herein. Such ducts shall be galvanized ferrous metal and shall be fabricated with either welded or interlocked seams. Galvanizing of welded seams will not be required. Rigid ducts shall have smooth inner walls and shall be capable of being curved to the proper configuration without crimping or flattening. Semi-rigid ducts shall be corrugated and when tendons are to be inserted after the concrete has been placed their minimum wall thickness shall be as follows: 26 gauge for ducts less than or equal to 2⅝-inch diameter, 24 gauge for ducts greater than 2⅝-inch diameter. When bar tendons are preassembled with such ducts, the duct thickness shall not be less than 31 gauge.

10.8.2 Polyethylene Duct

As an alternative to metal ducts, ducts for transverse tendons in deck slabs and at other locations where shown or approved may be of high density polyethylene, conforming to the material requirements of ASTM D 3350.

Polyethylene duct shall not be used when the radius of curvature of the tendon is less than 30 feet.

Semi-rigid polyethylene ducts for use where completely embedded in concrete shall be corrugated with minimum material thickness of 0.050 ± 0.010 inch. Such ducts shall have a white coating on the outside, or shall be of white material with ultraviolet stabilizers added.

Rigid polyethylene ducts for use where the tendon is not embedded in concrete shall be rigid pipe manufactured in accordance with ASTM D 2447, Grades P33 or P34; F714 or D3350 with a cell classification of PE345433C. For external applications, such duct shall have an external diameter to wall thickness ratio of 21 or less.

For applications where polyethylene duct is exposed to sunlight or ultraviolet light, carbon black shall be incorporated into the polyethylene pipe resin in such amount to provide resistance to ultraviolet degradation in accordance with ASTM D 1248.

10.8.3 Duct Area

The inside diameter of ducts shall be at least ¼ inch larger than the nominal diameter of single wire, bar, or strand tendons, or in the case of multiple wire, bar or strand tendons, the inside cross-sectional area of the sheathing shall be at least two times the net area of the prestressing steel. When tendons are to be placed by the pull through method, the duct area shall be at least 2½ times the net area of the prestressing steel.

10.8.4 Duct Fittings

Coupling and transition fittings for ducts formed by sheathing shall be of either ferrous metal or polyethylene, and shall be cement paste intrusion proof and of sufficient strength to prevent distortion or displacement of the ducts during concrete placement.

All ducts or anchorage assemblies shall be provided with pipes or other suitable connections at each end of the duct for the injection of grout after prestressing. As specified in Article 10.4.1.1, ducts shall also be provided with ports for venting or grouting at high points and for draining at intermediate low points.

Vent and drain pipes shall be ½-inch minimum diameter standard pipe or suitable plastic pipe. Connection to ducts shall be made with metallic or plastic structural fasteners. The vents and drains shall be mortar tight, taped as necessary, and shall provide means for injection of grout through the vents and for sealing to prevent leakage of grout.

10.9 GROUT

Materials for use in making grout which is to be placed in the ducts after tendons are post-tensioned shall conform to the following.

10.9.1 Portland Cement

Portland cement shall conform to one of the following: Specifications for Portland Cement—AASHTO M 85 (ASTM C 150), Types I, II, or III. Cement used for grouting shall be fresh and shall not contain any lumps or other indication of hydration or "pack set."

10.9.2 Water

The water used in the grout shall be potable, clean, and free of injurious quantities of substances known to be harmful to Portland cement or prestressing steel.

10.9.3 Admixtures

Admixtures, if used, shall impart the properties of low-water content, good flowability, minimum bleed, and expansion if desired. They shall contain no chemicals in quantities that may have harmful effect on the prestressing steel or cement. Admixtures which, at the dosage used, contain chlorides in excess of 0.005% of the weight of the cement used or contain any fluorides, sulphites, and nitrates shall not be used.

When a grout expanding admixture is required, or is used at the Contractor's option, it shall be well dispersed through the other admixtures and shall produce a 2% to 6% unrestrained expansion of the grout.

Amount of admixture to obtain a desired amount of expansion shall be determined by tests. If the source of manufacture or brand of either admixture or cement changes after testing, new tests shall be conducted to determine proper proportions.

All admixtures shall be used in accordance with the instructions of the manufacturer.

10.10 TENSIONING

10.10.1 General Tensioning Requirements

Prestressing steel shall be tensioned by hydraulic jacks so as to produce the forces shown on the plans or on the approved working drawing with appropriate allowances for all losses. Losses to be provided for shall be as specified in Division I, Article 9.16. For post-tensioned work the losses shall also include the anchor set loss appropriate for the anchorage system employed.

For pretensioned members, the strand stress prior to seating (jacking stress) shall not exceed 80% of the minimum ultimate tensile strength of the prestressing steel ($0.80\,f_s'$). This allowable stress, which slightly exceeds the values allowed in Division I, Article 9.15.1, may be permitted to offset seating losses and to accommodate compensation for temperature differences specified in Article 10.5.2.

For post-tensioned members, the strand stress prior to seating (jacking stress) and the stress in the steel immediately after seating shall not exceed the values allowed in Division I, Article 9.15.1.

The method of tensioning employed shall be one of the following as specified or approved:

(1) Pretensioning; in which the prestressing strand or tendons are stressed prior to being embedded in the concrete placed for the member. After the concrete has attained the required strength, the prestressing force is released from the external anchorages and transferred, by bond, into the concrete.
(2) Post-tensioning; in which the reinforcing tendons are installed in voids or ducts within the concrete and are stressed and anchored against the concrete after the development of the required concrete strength. As a final operation under this method, the voids or ducts are pressure-grouted.
(3) Combined Method; in which part of the reinforcement is pretensioned and part post-tensioned. Under this method all applicable requirements for pretensioning and for post-tensioning shall apply to the respective reinforcing elements using these methods.

During stressing of strand, individual wire failures may be accepted by the Engineer, provided not more than one wire in any strand is broken and the area of broken wires does not exceed 2% of the total area of the prestressing steel in the member.

10.10.1.1 Concrete Strength

Prestressing forces shall not be applied or transferred to the concrete until the concrete has attained the strength specified for initial stressing. In addition, cast-in-place concrete for other than segmentally constructed bridges shall not be post-tensioned until at least 10 days after the last concrete has been placed in the member to be post-tensioned.

10.10.1.2 Prestressing Equipment

Hydraulic jacks used to stress tendons shall be capable of providing and sustaining the necessary forces and shall be equipped with either a pressure gauge or a load cell for determining the jacking stress. The jacking system shall provide an independent means by which the tendon elongation can be measured. The pressure gauge shall have an accurately reading dial at least 6 inches in diameter or a digital display, and each jack and its gauge shall be calibrated as a unit with the cylinder extension in the approximate position that it will be at final jacking force, and shall be accompanied by a certified calibration chart or curve. The load cell shall be calibrated and shall be provided with an indicator by means of which the prestressing force in the tendon may be determined. The range of the load cell shall be such that the lower 10% of the manufacturer's rated capacity will not be used in determining the jacking stress. When approved by the Engineer, calibrated proving rings may be used in lieu of load cells.

Recalibration of gauges shall be repeated at least annually and whenever gauge pressures and elongations indicate materially different stresses.

Only oxygen flame or mechanical cutting devices shall be used to cut strand after installation in the member or after stressing. Electric arc welders shall not be used.

10.10.1.3 Sequence of Stressing

When the sequence of stressing individual tendons is not otherwise specified, the stressing of post-tensioning tendons and the release of pretensioned tendons shall be done in a sequence that produces a minimum of eccentric force in the member.

10.10.1.4 Measurement of Stress

A record of gauge pressures and tendon elongations for each tendon shall be provided by the Contractor for review and approval by the Engineer. Elongations shall be measured to an accuracy of $+1/16$ inch. Stressing tails of post-tensioned tendons shall not be cut off until the stressing records have been approved.

The stress in tendons during tensioning shall be determined by the gauge or load cell readings and shall be verified with the measured elongations. Calculations of anticipated elongations shall utilize the modulus of elasticity, based on nominal area, as furnished by the manufacturer for the lot of steel being tensioned, or as determined by a bench test of strands used in the work.

All tendons shall be tensioned to a preliminary force as necessary to eliminate any take-up in the tensioning system before elongation readings are started. This preliminary force shall be between 5% and 25% of the final jacking force. The initial force shall be measured by a dynamometer or by other approved method, so that its amount can be used as a check against elongation as computed and as measured. Each strand shall be marked prior to final stressing to permit measurement of elongation and to insure that all anchor wedges set properly.

It is anticipated that there may be discrepancy in indicated stress between jack gauge pressure and elongation. In such event, the load used as indicated by the gauge pressure, shall produce a slight over-stress rather than under-stress. When a discrepancy between gauge pressure and elongation of more than 5% in tendons over 50 feet long or 7% in tendons of 50 feet or less in length occurs, the entire operation shall be carefully checked and the source of error determined and corrected before proceeding further. When provisional ducts are provided for addition of prestressing force in event of an apparent force deficiency in tendons over 50 feet long, the discrepancy between the force indicated by gauge pressure and elongation may be increased to 7% before investigation into the source of the error.

10.10.2 Pretensioning Method Requirements

Stressing shall be accomplished by either single strand stressing or multiple strand stressing. The amount of stress to be given each strand shall be as shown in the plans or the approved working drawings.

All strand to be stressed in a group (multiple strand stressing) shall be brought to a uniform initial tension prior to being given their full pretensioning. The amount of the initial tensioning force shall be within the range specified in Article 10.5.1 and shall be the minimum required to eliminate all slack and to equalize the stresses in the tendons as determined by the Engineer. The amount of this force will be influenced by the length of the casting bed and the size and number of tendons in the group to be tensioned.

Draped pretensioned tendons shall either be tensioned partially by jacking at the end of the bed and partially by uplifting or depressing tendons, or they shall be tensioned entirely by jacking, with the tendons being held in their draped positions by means of rollers, pins, or other approved methods during the jacking operation.

Approved low-friction devices shall be used at all points of change in slope of tendon trajectory when tensioning draped pretensioned strands, regardless of the tensioning method used.

If the load for a draped strand, as determined by elongation measurements, is more than 5% less than that indicated by the jack gauges, the strand shall be tensioned from both ends of the bed and the load as computed from the sum of elongation at both ends shall agree within 5% of that indicated by the jack gauges.

When ordered by the Engineer, prestressing steel strands in pretensioned members, if tensioned individually, shall be checked by the Contractor for loss of prestress not more than 3 hours prior to placing concrete for the members. The method and equipment for checking the loss of prestress shall be subject to approval by the Engineer. All strands that show a loss of prestress in excess of 3% shall be retensioned to the original computed jacking stress.

Stress on all strands shall be maintained between anchorages until the concrete has reached the compressive strength required at time of transfer of stress to concrete.

When prestressing steel in pretensioned members is tensioned at a temperature more than 25°F lower than the estimated temperature of the concrete and the prestressing steel at the time of initial set of the concrete, the calculated elongation of the prestressing steel shall be increased to compensate for the loss in stress, due to the change in temperature, but in no case shall the jacking stress exceed 80% of the specified minimum ultimate tensile strength of the prestressing steel.

Strand splicing methods and devices shall be approved by the Engineer. When single strand jacking is used, only one splice per strand will be permitted. When multi-strand jacking is used, either all strands shall be spliced or no more than 10% of the strands shall be spliced. Spliced strands shall be similar in physical properties, from the same source, and shall have the same "twist" or "lay." All splices shall be located outside of the prestressed units.

Side and flange forms that restrain deflection shall be removed before release of pretensioning reinforcement.

Except when otherwise shown on the plans, all pretensioned-prestressing strands shall be cut off flush with the end of the member and the exposed ends of the strand and a 1-inch strip of adjoining concrete shall be cleaned and painted. Cleaning shall be by wire brushing or abrasive blast cleaning to remove all dirt and residue that is not firmly bonded to the metal or concrete surfaces. The surfaces shall be coated with one thick coat of zinc-rich paint conforming to the requirements of Federal Specification TT-P-641. The paint shall be thoroughly mixed at the time of application, and shall be worked into any voids in the strands.

10.10.3 Post-Tensioning Method Requirements

Prior to post-tensioning any member, the Contractor shall demonstrate to the satisfaction of the Engineer that the prestressing steel is free and unbonded in the duct.

All strands in each tendon, except for those in flat ducts with not more than four strands, shall be stressed simultaneously with a multi-strand jack.

Tensioning shall be accomplished so as to provide the forces and elongations specified in Article 10.5.1.

Except as provided herein or when shown on the plans or on the approved working drawings, tendons in continuous post-tensioned members shall be tensioned by jacking at each end of the tendon. For straight tendons and when one end stressing is shown on the plans, tensioning may be performed by jacking from one end or both ends of the tendon at the option of the Contractor.

10.11 GROUTING

10.11.1 General

When the post-tensioning method is used, the prestressing steel shall be provided with permanent protection and shall be bonded to the concrete by completely filling the void space between the duct and the tendon with grout.

10.11.2 Preparation of Ducts

All ducts shall be clean and free of deleterious materials that would impair bonding or interfere with grouting procedures.

Ducts with concrete walls (cored ducts) shall be flushed to ensure that the concrete is thoroughly wetted. Metal ducts shall be flushed if necessary to remove deleterious material.

Water used for flushing ducts may contain slack lime (calcium hydroxide) or quicklime (calcium oxide) in the amount of 0.1 lb per gallon.

After flushing, all water shall be blown out of the duct with oil-free compressed air.

10.11.3 Equipment

The grouting equipment shall include a mixer capable of continuous mechanical mixing which will produce a grout free of lumps and undispersed cement, a grout pump and standby flushing equipment with water supply. The equipment shall be able to pump the mixed grout in a manner which will comply with all requirements.

Accessory equipment which will provide for accurate solid and liquid measures shall be provided to batch all materials.

The pump shall be a positive displacement type and be able to produce an outlet pressure of at least 150 psi. The pump should have seals adequate to prevent introduction of oil, air, or other foreign substance into the grout, and to prevent loss of grout or water.

A pressure gauge having a full-scale reading of no greater than 300 psi shall be placed at some point in the grout line between the pump outlet and the duct inlet.

The grouting equipment shall contain a screen having clear openings of 0.125-inch maximum size to screen the grout prior to its introduction into the grout pump. If a grout with a thixotropic additive is used, a screen opening of 3⁄16 inch is satisfactory. This screen shall be easily accessible for inspection and cleaning.

The grouting equipment shall utilize gravity feed to the pump inlet from a hopper attached to and directly over it. The hopper must be kept at least partially full of grout at all times during the pumping operation to prevent air from being drawn into the post-tensioning duct.

Under normal conditions, the grouting equipment shall be capable of continuously grouting the largest tendon on the project in no more than 20 minutes.

10.11.4 Mixing of Grout

Water shall be added to the mixer first, followed by Portland cement and admixture, or as required by the admixture manufacturer.

Mixing shall be of such duration as to obtain a uniform, thoroughly blended grout, without excessive temperature increase or loss of expansive properties of the admixture. The grout shall be continuously agitated until it is pumped.

Water shall not be added to increase grout flowability which has been decreased by delayed use of the grout.

Proportions of materials shall be based on tests made on the grout before grouting is begun, or may be selected based on prior documented experience with similar materials and equipment and under comparable field conditions (weather, temperature, etc.). The water content shall be the minimum necessary for proper placement, and when Type I or II cement is used shall not exceed a water-cement ratio of 0.45 or approximately 5 gallons of water per sack (94 lb) of cement.

The water content required for Type III cement shall be established for a particular brand based on tests.

The pumpability of the grout may be determined by the Engineer in accordance with the U.S. Corps of Engineers Method CRD-C79. When this method is used, the efflux time of the grout sample immediately after mixing shall not be less than 11 seconds. The flow cone test does not apply to grout which incorporates a thixotropic additive.

10.11.5 Injection of Grout

All grout and high-point vent openings shall be open when grouting starts. Grout shall be allowed to flow from the first vent after the inlet pipe until any residual flushing water or entrapped air has been removed, at which time the vent should be capped or otherwise closed. Remaining vents shall be closed in sequence in the same manner.

The pumping pressure at the tendon inlet shall not exceed 250 psi.

If the actual grouting pressure exceeds the maximum recommended pumping pressure, grout may be injected at any vent which has been, or is ready to be capped as long as a one-way flow of grout is maintained. If this procedure is used, the vent which is to be used for injection shall be fitted with a positive shutoff.

When one-way flow of grout cannot be maintained, the grout shall be immediately flushed out of the duct with water.

Grout shall be pumped through the duct and continuously wasted at the outlet pipe until no visible slugs of water or air are ejected and the efflux time of the ejected grout, as measured by a flow cone test, if used, is not less than that of the injected grout. To ensure that the tendon remains filled with grout, the outlet shall then be closed and the pumping pressure allowed to build to a minimum of 75 psi before the inlet vent is closed. Plugs, caps, or valves thus required shall not be removed or opened until the grout has set.

10.11.6 Temperature Considerations

When temperatures are below 32°F, ducts shall be kept free of water to avoid damage due to freezing.

The temperature of the concrete shall be 35°F or higher from the time of grouting until job cured 2-inch cubes of grout reach a minimum compressive strength of 800 psi.

Grout shall not be above 90°F during mixing or pumping. If necessary, the mixing water shall be cooled.

10.12 MEASUREMENT AND PAYMENT

10.12.1 Measurement

The prestressing of cast-in-place concrete will be measured by the lump sum for each item or location listed in the schedule of bid items.

10.12.2 Payment

No separate payment will be made for prestressing precast concrete members. Payment for prestressing precast concrete members shall be considered as included in the contract price paid for the precast members as provided for in Section 8, "Concrete Structures."

The contract lump sum price paid for prestressing cast-in-place concrete shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals, and for doing all work involved in furnishing, placing, and tensioning the prestressing steel in cast-in-place concrete structures, complete in place, as shown on the plans, as specified in these Specifications and the special provisions, and as directed by the Engineer.

Full compensation for furnishing and placing additional concrete and deformed bar reinforcing steel required by the particular system used, ducts, anchoring devices, distribution plates or assemblies and incidental parts, for furnishing samples for testing, working drawings, and for pressure grouting ducts shall be considered as included in the contract lump sum price paid for prestressing cast-in-place concrete or in the contract price for furnishing precast members, and no additional compensation will be allowed therefore.