April 26, 2012

REVISION OF SECTION 618

PRESTRESSED CONCRETE

**NOTICE**

This is a standard special provision that revises or modifies CDOT’s *Standard Specifications for Road and Bridge Construction* It has gone through a formal review and approval process and has been issued by CDOT’s Project Development Branch with formal instructions for its use on CDOT construction projects. It is to be used as written without change. Do not use modified versions of this special provision on CDOT construction projects, and do not use this special provision on CDOT projects in a manner other than that specified in the instructions unless such use is first approved by CDOT’s Standards and Specifications Unit. The instructions for use on CDOT construction projects appear below.

Other agencies which use the *Standard Specifications for Road and Bridge Construction* to administer construction projects may use this special provision as appropriate and at their own risk.

**Instructions for use on CDOT construction projects:**

Use on projects having prestressed concrete members.

Section 618 of the Standard Specifications is hereby deleted for this project and replaced with the following:

**DESCRIPTION**

**618.01** This work consists of fabricating, furnishing and installing prestressed concrete members in accordance with the requirements of the Contract.

This work includes the furnishing and installation of all appurtenant items necessary for the particular prestressing systems 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 herein shall be considered to mean the concrete which is to be prestressed.

The term "tendon" as referenced herein shall be considered to mean the prestressing steel within a duct.

Both temporary and permanent post-tensioning shall comply with the requirements of this Section.

The term temporary post-tensioning is referring to the post-tensioning required to control stresses during handling and erection of precast elements.

**MATERIALS**

**618.02** Materials shall conform to the following:

Anchorage devices shall meet the requirements of subsection 714.02. Prestressing steel shall meet the requirements of subsection 714.01.

Elastomeric bearing pads shall meet the requirements of subsection 512.

All reinforcing and embedment item supports, bolsters, chairs, and spacers shall be CDOT approved. These items shall be plastic, rubber, or epoxy coated at all areas that will contact external concrete surfaces, unless otherwise shown on the plans.

* 1. *Prepackaged Grout for Post-tensioned Ducts.*

Water. The water used in the grout shall conform to subsection 712.01.

Shall meet the requirements of subsection 618.09(b). Grout.

* 1. *Steel and Metal for Prestress Members.*  All steel and metal products incorporated into the work shall meet the requirements of Section 106. The Contractor shall keep Certified Mill Test Reports (CMTR's) on file for all steel and metal products used, and shall furnish copies of CMTR's when requested.

Galvanizing and metallizing of steel products shall be done in accordance with the product applicable ASTM method. The product shall be galvanized after welding and fabrication is complete. Minor repair of galvanizing shall be brush coated with an approved zinc-rich compound that is acceptable to the QA Representative.

Materials and fabrication procedures shall conform to ASTM or ANSI / AWS requirements. The materials and work shall conform to the following requirements and specifications, unless otherwise indicated in the Contract.

1. Reinforcing Bars. All reinforcing bar material shall be Grade 60 minimum and shall conform to ASTM A 615, or ASTM A 706; epoxy coated bars shall also meet ASTM D 3963. Reinforcing bars that require welding shall conform to ASTM A 706. Welding of A 706 bars shall be done in accordance with ANSI /AWS D.1.4.
2. Welded Wire Reinforcement. Steel welded wire reinforcement for concrete reinforcement shall conform to ASTM A497.
3. Plate Steel. All plate steel shall conform to ASTM A 709 Grade 36 specifications. Fabrication and welding of plate steel products shall be done according to ANSI / AWS D.1.1.
	* + 1. Steel and metal products shall be free of loose rust and foreign substances before incorporation into the cast product.

The presence of rust on strand shall not necessarily be cause for rejection. Light rust and rust that does not result in visible pitting of the prestressing steel with the unaided eye shall be acceptable. Prior to evaluation rust shall be removed from representative lengths of prestressing strand by heavy duty scouring pads or wire brush. After rust removal, visual comparisions shall be made to picture sets in the article “Evaluation of Degree of Rusting on Prestressed Concrete Strand” published in the 1992 May-June edition of the PCI Journal. Surface conditions comparable to picture sets 1 through 3 shall be acceptable, while conditions comparable to picture sets 4 and greater shall be cause for rejection of the prestressing strand.

* 1. *Concrete for Pretensioned and Combination Tensioned Products.*  Materials for Concrete class PS shall meet the requirements specified in the following subsections:

Hydraulic Cement 701.01

Fly Ash 701.02

Fine Aggregate 703.01

Coarse Aggregate 703.02

Curing Materials 711.01

Air Entraining Admixtures 711.02

Chemical Admixtures 711.03

Water 712.01

* 1. *Concrete and Steel for Other Members.* Concrete for other members shall conform to the requirements of Section 601 and the plans. Reinforcing steel for other members shall conform to the requirements of Section 602.

**CONSTRUCTION REQUIREMENTS**

**618.03 Prestressed Members.** Members may be pretensioned, post-tensioned, or a combination of pretensioned and post-tensioned. Members shall be fabricated and finished as shown in the Contract.

Minimum cover for prestressing steel shall be 1½ inches, unless otherwise shown in the Contract. Minimum clearance for reinforcing steel shall be 1 inch unless otherwise shown in the Contract.

If the plans show only pretensioning details, use of a post-tensioning system will be allowed only if complete details of all necessary modifications are approved by the Engineer of Record.

Cast-in-place members shall be post-tensioned unless otherwise shown on the plans. All falsework for cast-in-place members shall remain in place until all post-tensioning and grouting has been completed and accepted by the Engineer.

**618.04 Shop Drawings.**

1. *General.*  The Contractor shall furnish shop drawings in conformity with subsection 105.02 for all prestressed components. When the Contractor's Engineer completes or revises design details or engineering drawings, then those engineering drawings and details that are submitted to the Engineer shall contain the endorsement seal of a Professional Engineer registered in the State of Colorado. CDOT review of the shop drawings does not relieve the Contractor of the responsibility for the adequacy of the prestressed members. Minor changes to design details or engineering drawings that do not represent a significant change to the original design will not require a Professional Engineer seal. The Contractor shall submit supporting calculations for these changes along with the shop drawings
2. *Pretensioned Members.* The shop drawings shall include the following:
3. Superstructure Framing Plan.
4. All unit dimensions.
5. Location and arrangement of prestressing strands.
6. Initial and final jacking forces.
7. Location, description, and detail of structural reinforcing items, excluding minor items used for field erection.
8. Location of all hold-down devices.
9. Location and description of all plates.
10. Provisions for diaphragm connections.
11. Blockout and keyway dimensions, if any.
12. Location and detail of debonded strands.
13. Strand de-tensioning sequence.
14. *Post-tensioned Members.*  The shop drawings for post-tensioned members shall show the following:
15. Strand and bar properties, including material type, modulus of elasticity, ultimate strength, diameter, and cross-sectional area assumed in the design.
16. Duct properties, including material type, and minimum inside and maximum outside diameters, and friction coefficients of the duct-strand system if different from shown on the plans.
17. The position and profile of the ducts and tendons along the length of the member. Each duct position shall be defined at tenth points along the length of the member. The minimum clearance from the edge of concrete to the edge of a duct shall be shown.
18. Location of closure pours and associated duct splices and details of duct splice, including the details and specifications of the shrink sleeve material.
19. The maximum offset between the center of the duct and the center of force in the duct for each unique strand and bar and duct combination. The resultant force of all permanent tendons in the member shall match the profile indicated on the plans.
20. The initial and final force at each anchorage. The initial force is defined as the largest force at each anchorage before anchor set and after friction losses. The final force is defined as the residual force remaining after anchor set and long term losses.
21. Complete dimensions and properties necessary to fabricate and install each unique anchorage device, including the type of materials, yield strengths, distribution plates, wedges, trumpets, anchorage blocks, and other appurtenant items. Adjacent reinforcement shall be detailed showing how it will coordinate with the anchorage device and its reinforcement.
22. The dimensions and properties necessary to fabricate and install the bursting, splitting, and other reinforcement required by the prestressing system, as shown on the plans or as proposed by the Contractor. Included shall be cross-sectional areas, yield strength, the location of the reinforcement, and the diameter and pitch of the spirals. If no additional bursting steel is required, it shall be so stated on the shop drawings.
23. The minimum length of strand or bar projection at the live ends and accessible dead ends.
24. The preload force for each unique tendon. The preload force is defined as 20 percent of the jacking force.
25. The required total jacking force for each unique tendon.
26. The total final elongation, after dead and live end anchor sets, and the measurable elongation for each tendon. The measurable elongation is defined as the total elongation at the live end after preload while the stressing equipment is tensioning the tendon to the total jacking force. The tendon length used for calculations shall include the full length of strand that is being stressed.
27. The sequence of stressing, including temporary and permanent post-tensioning.
28. Blockout or buildout concrete dimensions and reinforcement details.
29. If the Contractor elects to submit an alternative system, as defined in subsection 618.07(c), the Contractor shall also provide the following, as appropriate.

If the anchorage device will differ from what is shown on the plans, the Contractor shall submit calculations or manufacturer test certification consistent with the Contract. The calculations shall show the complete design of the anchorage device, including splitting steel, bursting reinforcement, the distribution plate, and the bearing stresses transmitted to the concrete by the anchorage device. The manufacturer's test certification shall certify the adequacy of the anchorage device. The shop drawings shall reflect the anchorage device design.

If the flare of the tendons is different from what is shown on the plans, the Contractor shall submit design and details of appropriate reinforcement and concrete dimensions to accommodate the flare.

Along with the shop drawing details, six copies of computations for friction losses, calculated measurable elongations, the maximum offset between the center of force and center of duct for each unique tendon, and the stressing sequence shall be submitted for review. The friction losses shall be determined in accordance with the plans and as provided for in the current"AASHTO LRFD Bridge Design Specifications."

(d.) For Combination Tensioned Members refer to 618.04 (b) and (c).

**618.05 Notification of Fabrication for Pretensioned and Combination Tensioned Members.**

* + 1. *Start of Work.* Prior to beginning the work, the Contractor shall provide notice to the Engineer and the Quality Assurance (QA) Representative, as defined in subsection 618.06(a), so that QA services may be provided. The notice shall be at least seven days before fabrication begins.

The anticipated production schedule, including the start of work, phase work and shipment dates shall be submitted in writing to the QA Representative before any work begins. Fabrication shall not be started until the shop drawings have been returned with the Engineer's review stamp, indicating Reviewed, no exception taken; or Reviewed, revise as noted; or Resubmit, revise as noted in accordance with subsection 105.02, and delivered to the Contractor's site of fabrication.

* + 1. *Production Schedule Changes.* Accelerated changes to the proposed production schedule, including start of work, phase work, and shipment dates, shall require advance written notification be provided to the Engineer and the QA Representative. The written notice of change shall be received at least 48 hours before fabrication begins, unless otherwise approved in writing by the Engineer or the QA Representative.
		2. *Notice of Shipment.* The QA Representative shall be notified in writing, at least 72 hours before shipment of prestressed members to the job site.
		3. *Notification.*  Failure to notify the Engineer or the designated QA Representative as described in this section may be cause for rejection.

**618.06 Inspection of Pretensioned, Post-tensioned and Combination Tensioned Members.**

1. *Quality Control and Quality Assurance*. Quality Control (QC) of prestressed concrete fabrication is the responsibility of the Contractor. The Contractor shall designate a QC Manager who shall be responsible for product quality requirements as defined in the specifications and the Contractor's approved QC plan (QCP). The QC Manager shall possess and maintain certification at Level II minimum, from the Prestressed Concrete Institute (PCI), or be a licensed Professional Engineer in the State of Colorado, and shall have one year minimum of construction related experience. The QC Manager shall not be supervised by the Contractor's production section. If grouting for post-tensioning ducts of combination tensioned members is done by the precast girder fabricator, the QC Manager shall possess and maintain an American Segmental Bridge Institute (ASBI) Certified Grouting Technician Certificate. If prestressing, duct and anchorage installation,inspection of duct and anchorage stressing of tendons, air testing of ducts, or grouting of ducts of multi-strand bonded tendons of the post-tensioning system for combination tensioned members is done by the precast girder fabricator the QC Manager shall possess a PTI Level I – Bonded Tendon Training Certificate.

Quality Assurance (QA) and product acceptance are the prerogatives of the Engineer. The QA Representative acts for and in behalf of the Engineer on all matters within the scope of the contract documents, as delegated by the Engineer. QA administration will be performed to the extent necessary to assure contract compliance. The QA Representative shall possess the American Segmental Bridge Institute Grouting Certification Training.

Repeated out of tolerance work, including dimensional non-conformance, shall be considered as recurring deficiencies. Recurring deficiencies shall be considered as evidence that required QC is not being provided. When the QA Representative determines that fabrication operations are producing recurring defects that do not conform to the Contract and the QCP requirements, the Contractor will be notified that the present work is unacceptable. Work shall not continue until the QC Manager has submitted a written proposal addressing corrective procedures that the Contractor will take to prevent recurrence of the non-conforming work. Fabrication shall not resume until the proposal has been reviewed and accepted in writing by the QA Representative.

1. *Quality Control Plan (QCP).* The Contractor shall submit a written QCP to the QA Representative prior to the beginning of fabrication. The QCP shall be reviewed and approved in writing by the Contractor's QC Manager. The QCP shall list all methods utilized by the Contractor to ensure that the work conforms to contract requirements. The QC section is responsible for establishing the QCP, as well as conformance to the QCP. Fabrication shall not begin until the QCP has been reviewed and accepted in writing by the QA Representative.

If work methods for a specific project or product are not listed in the original QCP, the Contractor shall submit written addenda addressing the proposed methods that are necessary to meet contract requirements. Fabrication shall not begin until the addenda have been reviewed and accepted in writing by the QA Representative.

The QCP shall address the following:

* + - 1. Names and qualifications of the QC Manager and personnel conducting inspection and testing. This list shall be updated when changes in personnel occur.
			2. List of material suppliers, post-tensioning system supplier, post-tensioning grout supplier and certified testing agencies used; the list shall be updated when vendors change.
			3. Materials sampling and testing schedule, showing testing methods and frequencies.
			4. QC inspection methods and procedures for all stages of fabrication operations.
			5. Methods for curing products and test specimens.
			6. Method and sequence for tensioning strands, including methods used for verifying equal distribution of jacking forces.
			7. Method and sequence of de-tensioning strands and procedure.
			8. Post-tensioning system. The responsible representative meeting the requirements of subsection 618.06(b)(8) shall possess an “American Segmental Bridge Institute (ASBI) Certified Grouting Technician” certificate and a PTI Level 1 – Bonded Tendon Training certificate. Duct and anchorage inspection schedule, duct splices at closure pour inspection schedule, and onsite duct air pressure testing schedule, including name(s) of the responsible representatives who will conduct inspections and testing.
			9. Written report format for materials sampling, testing, and inspection for all phases of the work.
			10. Copies of all concrete mix designs to be used, including mix design computations and test data.
			11. Provisions for fabrication operations during cold, windy, or hot weather conditions.
			12. Procedures for patching small production holes and holes left by strand hold-down devices.
			13. Procedures for identifying, evaluating and reporting defects, including dimensional non-conformance, discovered during QC/QA inspections and testing.
			14. Procedures for notifying the QA Representative of structural defects, and submittal of written proposal for repairs.
			15. Provisions for contingency operation when concrete delivery is interrupted due to malfunction of equipment during fabrication.
1. *Frequency.* QC inspection and testing at all intervals of duct and anchorage placement, duct splices at closure pours , onsite duct air pressure tests and forming, tensioning, steel and concrete placement, curing, and storage operations shall be performed in accordance with the accepted QCP. The QCP shall contain provisions for increased frequencies of inspection and testing when operations or products do not conform to the Contract.
2. *Written Records and Reports*. The QC Manager shall review and submit the following completed records and reports to the QA Representative before the product receives acceptance by the QC section:

Prestressing Steel - Tensioning reports for each setup, showing the jacking force calculations; initial and final jacking force used; calculated and final net measured elongation; applicable stressing corrections for seating, slippage, shortening, rotation movement, and temperature; Certified Mill Test Reports for prestressing steel used; jack identification number, date and time of stressing.

Concrete - A daily report of each mix design used, showing the fresh concrete slump, temperature, unit weight, and air content (if specified). The daily report shall also include the following data:

* 1. date and time of casting
	2. bed and setup location
	3. ambient conditions
	4. total cubic yards placed
	5. girder mark and unique sub-mark identifications
	6. actual product curing temperature charts or graphs
	7. actual curing enclosure humidity charts or graphs
	8. average release strength in psi
	9. date and time of release strength
	10. copies of individual batch tickets when requested by the QA Representative

Pre-pour Inspection Records shall include the items to be checked as listed in the QCP.

1. Post-pour Inspection Records shall include the items to be checked as listed in the QCP. These records shall include all discovered variances from product dimensional tolerances.
2. Report of minor repairs made to each individual product.
3. The following written records shall be submitted to the QA Representative before product shipment:
	1. Elastomeric Bearing Pads - Product manufacturer's certification and supplier's letter of compliance.
	2. Length measurement of beams within three days prior to shipping.
	3. Product camber measurement within seven days prior to shipping.
4. Steel and Metal. For reinforcing bars, welded wire reinforcement, plate steel, and miscellaneous steel and metal products incorporated into the work, QC Manager shall review and maintain all certified mill test reports (CMTRs). QC Manager shall certify in writing that all steel and metal products comply with the Contract. When requested, QC Manager shall furnish copies of CMTRs to the QA Representative.
5. Post-tensioning Ducts. The responsible representative meeting the requirements of subsection 618.06 (b)(8) shall submit to the QA Representative a letter certifying that the ducts, duct splices, and anchorages are installed according to the Contract and that they have been inspected by the responsible representative of the post-tensioning system supplier and adequately held an air pressure after stressing and before grouting.

After stressing and before grouting, install all grout caps, inlets and outlets and test the duct with compressed air to determine if duct connections require repair. In the presence of the Engineer, pressurize the duct to 30 psi and lock-off the outside air source. Record pressure loss for one minute. A pressure loss of 15 psi is acceptable for ducts having a length equal to or less than 150 feet and a pressure loss of 9 psi is acceptable for ducts longer than 150 feet. If the pressure loss exceeds the allowable, repair leaking locations using methods approved by the Engineer and retest.

**618.07 Fabrication.**

1. *Pretensioning - General.* Prestressing shall be done with calibrated jacking equipment that conforms to the requirements of subsection 618.10. Strands shall be tensioned in accordance with the approved sequence as indicated in the QCP. All indicating dials shall be at least 6 inches in diameter; calibrated digital display equipment is also acceptable.

The stressing sheet shall show the measurements, factors and computations for tension and elongation, including all stressing corrections; if these factors are not shown on the stressing sheet, they must be submitted with the shop drawing and calculation index. The applicable stressing corrections shall be applied at the time of final stressing. Before using any stressing correction for friction, the need for corrections shall be proven by load cell or dynamometer checks at both ends of the setup. Temporary overstressing shall not exceed 80 percent of the minimum ultimate tensile strength of the prestressing steel. Tensioned strands shall not be seated during temporary overstressing.

Tensioned strands shall maintain vertical and horizontal position, within allowable tolerances, as specified in subsection 618.14(b), throughout the entire length of the member; intermediate strand supports shall be used if the tolerances cannot be maintained. Tensioned strands shall not be entangled or intertwined with other strands, except for draped strands in the bundled area between hold down devices.

A QC employee shall witness and verify final tensioning operations and record the jacking forces and the net measured elongations. Jacking force shall be recorded to the nearest 100 pound increment used. Net elongation shall be measured to the nearest ⅛ inch. Tensioning operations shall also meet the following requirements:

* + - 1. Initial tensioning shall not exceed 20 percent of the jacking force.
			2. Tension load readings shall be taken from pressure gages, dynamometers or load cells. If pressure gages or dynamometers are used, the applied load shall register between 20 and 80 percent of the total reading capacity of the system. If load cells are used, the applied load shall register between 10 and 90 percent of the total load cell capacity. If a master gage system is used, a current certified calibrated graph or table correlating actual loads with the master gage readings, shall be given to the QA Representative.
			3. The jacking force applied shall be within plus or minus 5 percent of the design jacking force. The net measured elongation shall be within plus or minus 5 percent of the calculated elongation; if net measured elongation is not within tolerance, the strand shall be stressed from both ends. The algebraic comparison of the variation between the jacking force and the net measured elongation shall agree within plus or minus 7 percent. If these three tolerances are not achieved, tensioning operations shall cease; all stressing deficiencies shall be corrected before regular tensioning operations resume.
			4. If any wire or wires in a 7-wire strand breaks, whether or not that strand shall be removed and replaced shall be determined based on whether forces are within tolerances as specified in subsection 618.07(a)(3) and by referring to PCI MNL 116 5.2.6.
			5. Strand or spliced strand that exhibits unraveling after stressing, shall be removed and replaced with a sound strand. Strand splices shall not fall within the member to be cast.
			6. Strands that have received final tension shall be protected from temperature fluctuations greater than 40 °F until the time of concrete placement. The Contractor may apply stress corrections at the rate of 1 percent per 11 °F, for temperature variation between final tensioning and concrete placement. This requirement does not apply to self-stressing bed setups. The total stressing force applied shall not exceed 80 percent of the minimum ultimate tensile strength of the prestressing steel.
			7. Tensioned prestressing steel shall be free from dirt, mud, ice, snow build up, oil, grease, paint, loose rust, and all other bond inhibiting substances prior to concrete placement. Visibly pitted strand shall not be used.
			8. Draped Strand - Final stressing shall be accomplished by any of the methods described below:
		1. Jacking in Draped Position. Final stressing shall begin at one end of the bed. Strands that do not meet the tension vs. elongation tolerances shall be jacked from the other end so that all tolerances are achieved. If all draped strands conform to tolerances after jacking at one end, the jacking force shall be verified on at least two strands at the opposite end.
		2. Partial Stressing and Subsequent Strain. Initial and partial stress may be induced from either end of the bed. Final stress shall be attained by lifting or depressing the strands to the design location. Final stress and strain shall be applied in such a manner that uniform distribution of jacking force is attained throughout the bed setup and, all tension vs. elongation tolerances have been achieved. The distribution of force shall be verified on at least two strands at the opposite end.
		3. Stage Tensioning. Initial tensioning shall be done from one end. Partial tensioning may then be performed from either end. When final stressing is completed, the sum of the partial elongations shall be used to verify that all tension vs. elongation tolerances have been achieved. This method may also be used for tensioning of straight strands.
1. Hold-down devices shall be placed within a 20 inch horizontal tolerance from the locations shown on the contract drawings if placement is moved toward the center of girder and within a 40 inch horizontal tolerance from the locations shown on the contract drawings if placement is moved toward the girder ends; if minimum or maximum placement locations are shown on the contract drawings, the placement tolerances shall not encroach beyond those locations.

The hold-down device shall not encumber or displace adjacent straight strands out of tolerance; and shall not produce nicking of any drape or bundled strands. The device shall secure the draped or bundled stands in the positions shown on the shop drawings, within all tolerances required by subsection 618.14(b).

1. *Combination Tensioned Members*. Pretensioning of combination members shall be performed in accordance with subsection 618.07(a). All post-tensioning operations shall conform to subsection 618.07(c)
2. *Post-tensioning Method.*
3. Bonded Post-tensioning and Grouting Systems Review. Upon review of the shop drawings, the Engineer will schedule a meeting with the Contractor to review the post-tensioning and grouting procedures to be used on the project. The following individuals shall be in attendance at this meeting:
	1. The Engineer and QA Representative.
	2. The Contractor’s Superintendent.
	3. The post-tensioning system supplier. This individual shall have the following qualifications:
4. A Professional Engineer registered in the State of Colorado.
5. Knowledgeable in the analysis of post-tensioned structures, the design required for shop drawing development, field calculations for revising tendon elongations from the assumed parameters to the actual strand area and modulus used on the project as determined by tests conducted on the strand by CDOT, and stressing of tendons.
6. A holder of a current Certified Grout Technician Certificate from the American Segmental Bridge Institute (ASBI).
7. Able to be present during all tendon stressing and grouting to keep written records of these operations for submittal to the Engineer for review.
	1. A grout manufacturer’s field representative who is a full-time employee of the grout manufacturer, will provide technical product assistance to the grouting crew, and shall be present during start-up of grouting operations and shall be able to be present at the request of the Engineer should problems with the grout occur.
	2. The Contractor’s designee who will be in direct charge of the post-tensioning and grouting crews. This individual shall have the following qualifications:
8. Be skilled in the use of the post-tensioning and grouting equipment.
9. Have at least three years experience on previous projects supervising the post-tensioning and grouting of structures of similar type and magnitude.
10. Present on the project during the installation of the post-tensioning system, stressing operations, and grouting operations.
	1. Contractor’s QC Manager.
	2. Other individuals as deemed necessary by the Contractor or Engineer.

Ten days prior to the Post-Tensioning and Grouting System Review meeting, the Contractor shall submit a written plan for grouting the ducts. Grouting shall not begin until the Engineer has provided written approval of the grouting plan. The grouting plan shall provide at least the following information:

1. The name, training, and experience records of the person supervising the grouting operations.
2. Other individuals as deemed necessary by the Contractor or Engineer.
3. Name of the grout material and the required certifications and test results.
4. Manufacturer and type of grout mixer and pump to be used, including provisions for back-up equipment and spare parts.
5. Grouting procedure and the role of each person on the crew.
6. Theoretical grout volume calculations.
7. Method for closing all duct orifices as grouting progresses.
8. Air testing of ducts.
9. Grout mixing and pumping procedures.
10. Location of grout inlet and direction of pumping.
11. Procedures for handling blockages, procedures and equipment required for flushing ducts of grout if necessary, and how and when it will be decided whether or not to flush ducts.
12. Methods to inspect behind anchorages, grout inlets and outlets, and vents for voids.
13. List of production testing along with acceptable values according to Table 618-1.
14. Acceptable specific gravities for mud balance test provided by the grout manufacturer.
15. Procedures for post grouting repair of all grout voids detected.
16. Procedure for installing corrosion inhibitor inside tendons if necessary.
17. Alternative Post-tensioning Systems. The Contractor may choose to supply the design and details of the prestressing system shown on the plans or submit an alternative for approval. The following alternatives may be presented to the Engineer for his review and approval:
	1. Alternative anchorage systems. Alternative anchorage systems, including all associated anchor zone reinforcing steel associated with the alternative anchorage system, and all details of the alternative anchorage system shall be shown on approved shop drawings and stamped by a Professional Engineer registered in the State of Colorado and who is an employee of the post-tensioning system supplier or anchorage supplier.
	2. Alternative number or sizes of ducts. The duct pattern must conform to an acceptable pattern as indicated on the plans.
	3. Alternative jacking ends.
	4. Alternative number of strands, provided the minimum area of steel and the center of force matches that indicated on the plans.
	5. Alternative duct type, friction coefficients, or anchor set.

The stressing sequence, details, or procedures shall not differ from what is called for on the plans, such that it would cause a change in the jacking force times initial stress ratios at the critical points identified on the plans, beyond an acceptable tolerance of 0 to +5 percent.

If the Contractor elects to submit alternative details, the alternative details shall conform to the following:

* 1. The final center of force shall match that as indicated on the plans.
	2. If the plans call for a tendon to be composed of a certain number of strands, the Contractor's alternative shall have that same tendon composed of the same number of strands.
	3. If the plans call for a tendon to be composed of bars, the Contractor's alternative shall have that same tendon composed of bars.
	4. If the plans call for ducts and tendons internal to the member, the Contractor's alternative shall also have internal ducts. Similarly, if the plans call for ducts and tendons external to the member, then the Contractor's alternative shall also have external ducts.
	5. The alternative shall include details or calculations supporting the adequacy of the Contractor's alternative as specified in the shop drawing and calculation requirements of this specification.
	6. Bridge cross-sectional geometries, dimensions, and clearances shall match those indicated on the plans, with the exception of girder flares near anchorages.
1. Duct Fabrication and Placement. Duct enclosures for prestressing steel shall be either rigid corrugated plastic or galvanized, corrugated, rigid ferrous metal.

Metal ducts shall be fabricated with either welded or interlocked seams. Galvanizing of the welded seams for metal ducts will not be required.

The ducts shall be mortar tight and accurately placed within ½ inch of the positions shown on the approved shop drawings. Ducts shall be securely fastened to maintain their correct alignment during placing of concrete. Joints between sections of duct shall be positive rigid connections which do not result in angle changes at the joints. Waterproof tape shall be used at the connections. Ducts shall be bent without crimping or flattening. Transition couplings connecting ducts to anchoring devices need not be galvanized. Ducts shall be free of kinks. All changes of direction shall have a radius of 20 feet, unless otherwise shown on the plans. Shrink sleeves at duct splices at closure pours shall be used.

The duct area shall be at least twice the net area of the prestressing steel for tendons composed of multiple wires, bars, or strands.

The duct diameter shall be at least ¼ inch larger than the nominal diameter of the wire, bar, or strand for tendons made up of a single wire, bar, or strand.

All ducts shall have grout openings at each end. Grout vents shall be provided at all high points and low points of draped tendons. In addition, at draped tendon high points, secondary high point gout vents shall be located three feet beyond all high points in the direction that the grout will be pumped.

Grout openings and vents shall be securely fastened to the ducts and forms or reinforcing steel to prevent displacement while placing concrete. The vents shall be mortar tight, taped as necessary and shall provide means for injection of grout. Ends of grout vents shall be removed to 1 inch inside the face of concrete surface after the grouting has been completed and the holes filled with an approved epoxy or non-shrink grout and finished smooth.

Prior to installation of the prestressing steel, the Contractor shall show that the ducts are free from debris and water. For ducts which are internal to the member, the Contractor shall show that the ducts are free from any blockage or damage from the concrete placing operations. The Contractor shall do this immediately after the concrete encasing the duct has achieved initial set. The precast fabricator shall be responsible for the condition of the ducts during fabrication if the member is precast.

The precast fabricator shall demonstrate to the QA Representative that the ducts are free and clear of any obstructions or damage and are able to accept the intended post-tensioning tendons by passing a torpedo through the ducts. A torpedo of the same cross-sectional shape as the duct that is 1/8 inch smaller all around than the clear, nominal inside dimension of the duct. No deductions shall be made to the torpedo section dimensions allowed in the manufacture or fixing of the ducts. For curved ducts the length shall be determined so that when both ends of the torpedo touch the outermost wall of the duct, the torpedo is 1/8 inch clear of the innermost wall. Acceptance shall be based on the torpedo passing through the duct easily. Nonconformance is when the torpedo does not pass through the ducts easily and shall be addressed per 618.13.

Once installed, the ducts (including the ends of the ducts at the anchorages, grout ports, and duct vents) shall be sealed immediately to prevent the entry of water or other debris until the tendons are grouted.

The use of water soluble oil in the ducts and flushing the ducts with water will not be allowed.

1. Post-tensioning Equipment and Procedure.

Installing Tendons. Excess water in ducts shall be removed by blowing oil-free compressed air through the ducts.

Post-tensioning strands to make up tendon shall be pushed or pulled through the ducts using methods which will not snag on any lips or joints in the ducts.

The ends of strands which are pushed through the duct shall be rounded off or fitted with a smooth protective cap. Strand that is pushed shall not be intentionally rotated by any mechanical device during the installation of the post-tensioning into the duct.

The ends of strands which are pulled through the duct shall be assembled to form the tendon and pulled using a special steel wire sock (“Chinese finger”) or other device attached to the end. The ends of the strands may be electric arc welded together for this purpose as long as at least 1 foot to 5 ft of the strands from the welded end, depending on size of tendon, is removed after installation. The ends of strands of the pre-assembled tendon shall be rounded to facilitate smooth passage through the duct.

Cut strands using an abrasive saw or equal. Flame cutting or plasma cutting of strands is allowed only with permission from the Engineer.

The responsible representative shall be present at all times during stressing of bonded post-tensioned members.

Tensioning shall be done with approved jacking equipment. Hydraulic jacks shall be equipped with accurate pressure gauges at least 6 inches in diameter. The combination of jack and gauge shall have been calibrated within the last 12 months, in accordance with subsection 618.10(a). A certified calibration chart, graph, or table showing this calibration of the jack and gauge combination shall be furnished to the Engineer. The range of calibrations shall encompass the range of required forces indicated on the shop plans. The jacking equipment shall be capable of simultaneously stressing all wires, strands, or bars for each individual tendon.

Tendons shall be stressed in accordance with the sequence as indicated on the approved shop drawings. If the Contractor chooses to deviate from the sequence, the Contractor shall resubmit the shop drawings for approval. The sequence shall not cause stresses in excess of the maximum allowable stresses shown on the plans.

Tendons shall be preloaded to 20 percent of their total jacking force, before measuring elongations.

Measured elongations shall be within ± 7 percent of the calculated values, unless otherwise approved by the Engineer.

A broken or damaged strand is cause for rejection of the tendon. If a strand is rejected, the remaining strands in the tendon will be evaluated by the Engineer for reuse.

Where dead end anchorages and tendons are accessible, the anchorage system and length of projecting prestressing steel shall permit jacking with the same jacking equipment that was used on the live end.

Tendon projections at the live end and accessible dead ends shall not be cut off until all post-tensioning is completed and accepted.

The representative of the post-tensioning system supplier shall keep a record of the following items for each tendon installed and provide a copy to the Engineer the day stressing is completed:

1. Project name and number.
2. Contractor and subcontractor.
3. Tendon location, strand diameter, and number of strands.
4. Date strand was first installed in the ducts.
5. Heat number of the strands.
6. Assumed and actual strand cross-sectional area and modulus of elasticity.
7. Date stressed.
8. Date of calibration of the jack and pressure gauge combination with their identification numbers.
9. Required initial and final jacking force and the gauge pressure.
10. Anticipated and actual elongations and anchor set.
11. All deviations from the plans, specifications, and approved shop drawings shall be brought to the attention of the Engineer for immediate resolution.

**618.08 Post-Tensioning Anchorages and Distribution.** Prestressing steel shall be secured at the ends by means of approved permanent type anchoring devices.

Anchorages and couplers shall develop at least 95 percent of the minimum specified ultimate strength of the prestressing steel. The coupling of tendons shall not reduce the elongation at rupture below the requirements of the tendon itself. Couplers and coupler components shall be enclosed in housings long enough to permit necessary movements. Couplers for tendons shall be used only at locations specifically indicated or approved by the Engineer.

Couplers shall not be used at points of sharp tendon curvature.

Permanent anchorage grout caps are required and shall be installed before grouting begins.

Anchorage devices shall have a minimum clear concrete or grout coverage of 2 inches in every direction. Alternative corrosion protection methods for anchorages shall be shown on the shop drawings submitted by the Contractor.

The prestressing force shall be effectively distributed to the concrete by means of an approved anchoring device. Such devices shall conform to the following requirements:

* 1. The average concrete bearing stresses on the concrete-created anchorage distribution plates shall not exceed the values allowed by the following equations:

During jacking:



After jacking:



Where:

 *fcp* = permissible compressive concrete stress

 *f'ci* = compressive strength of concrete at time of jacking

 *f'c* = compressive strength of concrete

 *A'b* = maximum area of the portion of the concrete anchorage surface that is geometrically similar to and concentric with the area of the anchorage

 *Ab* = bearing of the anchorage

If bursting steel is not used, the peak bearing pressure on the concrete at the time of jacking from the distribution plate shall not exceed 0.90 f'ci. If the distribution plate or anchorage device is within 4 inches of any concrete edge or corner or another distribution plate or anchorage device, the pressure on the concrete shall not exceed 0.70 f'ci. Construction joints shall not pass under distribution plates or anchors.

* 1. Bending moments in the plates or assemblies induced by the pull of the prestressing steel shall not exceed the plastic strength of the material or cause visible distortion of the distribution plate when 100 percent of the ultimate prestress load is applied as determined by the Engineer.
	2. Distribution plates may be omitted if the anchorage device distributes the stresses in the concrete consistent with these specifications, and provided that this anchorage device is used in conjunction with embedded bursting and splitting reinforcement.
	3. **Bonding and Grouting.**
1. *General.* Post-tensioned prestressing steel shall be bonded by completely filling the void space within a duct with grout. Prestressing steel to be bonded shall be free of dirt, loose rust, or other deleterious substances. The ducts shall be kept free of water, dirt, or other deleterious foreign materials that will inhibit bond until the tendons are grouted. Time from installing the prestressing steel in the ducts in an unstressed condition to grouting after stressing shall not exceed thirty days. If a corrosion inhibitor, as specified below, is used on the strands in the ducts, the time limit shall not exceed sixty days. Grouting shall proceed as soon as possible after stressing of the prestressing steel in the ducts. If a corrosion inhibitor is used on the strands in the ducts, it shall be applied after post-tensioning is completed and accepted and grouting accessories are installed so that tendons are sealed. The post-tensioning system installer shall submit an installation log. A copy of the log that documents the day the strands were installed within the duct and the corrosion inhibitor applied to the strands in the duct, with the duct given an identification easily referenced to the plans, shall be provided to the Engineer. All pertinent product numbers, the brand and the corrosion inhibitor type shall be documented in the log. Verfication shall be made weekly that the tendons remain sealed and grout vents, drains and caps have not been damaged.
2. *Grout.*  Grout shall be prepackaged in bags.

The following information shall be printed on the grout bags: product name, name of the producer, date of packaging, lot number, and mixing instructions.

Grout shall not contain any lumps or other evidence of hydration.

The grout shall not contain aluminum powder or compounds, which will produce hydrogen gas, carbon dioxide, or oxygen. In addition, the grout shall not contain fluorides, sulphites, nitrates,, or acid-soluble chloride ions which exceed 0.08 percent by weight of the cementitious materials. The Contractor shall provide the Engineer with written certification from the grout manufacturer that the grout does not contain or produce these elements or compounds with the grouting plan.

The grout shall conform to the following Standard and Modified ASTM Tests in Table 618-1 when mixed in accordance with the manufacturer's instructions:

**Table 618-1**

|  |  |  |
| --- | --- | --- |
| **Property** | **Test Value** | **Test Method** |
| Total Chloride Ions | Max. 0.08% by weight ofCementitious material | ASTM C 1152 |
| Fine Aggregate (If utilized) | Max. Size: 300 µm (No. 50 Sieve) | ASTM C 33 |
| Volume Change at 24 hours and 28 days | 0.0% to + 0.3% | ASTM C 1090 1 |
| Expansion | 0.0%(minimum)2%(maximum) for up to 3 hours | ASTM C 940 |
| Compressive Strength at 28 days (Average of 3 cubes) | 7,000 psi minimum | ASTM C 942 |
| Initial set of the grout | 3 hours minimum12 hours maximum | ASTM C 953 |
| Bleeding at 3 hours | Maximum 0.0 % | ASTM C 940 4 |
| Permeability at 28 days | Maximum 2500 coulombsAt 30 Volts for 6 hours | ASTM C 1202 |
| **FLUIDITY TEST 2** |
|  | **Efflux Time from****Flow Cone** | **ASTM Method** |
| (a) Immediately after mixing | 11 Seconds Minimum30 Seconds Maximum | ASTM C 939 |
| OR5 Seconds Minimum30 Seconds Maximum | ASTM C 939 3 |
| (b) 30 minutes after mixing with remixing for 30 seconds | 30 Seconds Maximum | ASTM C939 |
| OR30 Seconds Maximum | ASTM C 939 3 |
| **Table 618-1 and footnotes continued on next page.** |

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| --- |
| **Footnotes for Table 618-1**1 ASTM C 1090 shall be modified to include verification at both 24 hours and 28 days.2 Adjustments to flow rates shall be achieved by strict compliance with the manufacturer’s recommendations.3 Grout fluidity shall meet either the Standard ASTM C 939 flow cone test or the Modified Test described herein. Modify the ASTM C 939 Test by filling the cone to the top instead of to the standard level. The efflux time is the time to fill a one liter container placed directly under the flow cone.4 ASTM C 940 shall be modified to conform with the wick induced bleed test as follows:1. Use a wick made of a 20 inch length of ASTM A 416 seven wire 0.5 inch diameter strand. Wrap the strand with two inch wide duct or electrical tape at each end prior to cutting to avoid splaying to the wires when it is cut. Degrease (with acetone or hexane solvent) and wire brush to remove any surface rust on the strand before temperature conditioning.
2. Condition the dry ingredients, mixing water, prestressing strand and test apparatus overnight to 65 to 75 °F.
3. Mix the conditioned dry ingredients with the conditioned mixing water and place 800 ml of the resulting grout into the 1,000 ml cylinder. Measure and record the level of the top of the grout.
4. Completely insert the strand into the graduated cylinder. Center and fasten the strand so it remains essentially parallel to the vertical axis of the cylinder. Measure and record the level of the top of the grout.
5. Store the mixed grout at the temperature range listed in (ii).
6. Measure the level of the bleed water every 15 minutes for the first hour and hourly for two successive readings thereafter.
7. Calculate the bleed water, if any, at the end of the three hour test period and the resulting expansion In accordance with the procedures outlined in ASTM C 940, with the quantity of bleed water expressed as a percent of the initial grout volume. Note if the bleed water remains above or below the top of the original grout height. Note if any bleed water is absorbed into the specimen during the test.
 |

Grout used on the project shall have been sampled and tested within the last twelve months in accordance with the above referenced test procedures. The Contractor shall provide certified test reports for the grout used on the project from an independent AASHTO Accredited Laboratory and a sample of the grout for evaluation by the Department with the plan for grouting the ducts. The grout sample submitted to the Project shall be at least 2,000 grams in a sealed container. Grout which does not meet the above requirements shall not be used.

1. *Mixing of Grout.* All grout shall be mixed with a high speed shear (colloidal) mixer.
2. *Grouting.* All grouting operations shall be performed under the immediate control of the Contractor’s designee. An individual of the post-tensioning system supplier, who possesses an ASBI Certified Grouting Technician Certificate and the grout supplier’s field representative shall be available to provide technical expertise to the Contractor’s designee as required during grouting.

The Contractor shall either perform or contract a commercial testing entity experienced with the following tests, in the presence of the Inspector/Engineer and report the results to the Engineer:

1. One pressure bleed test per day in accordance with the “Schupack Pressure Bleed Test” using a Gelman Filter in accordance with the requirements in Appendix C of the “Specification for Grouting of Post-Tensioned Structures” by the Post-Tensioning Institute. The Gelman filtration funnel shall be secured vertically plumb in a stand. The maximum percent bleed shall be zero when the funnel is pressurized to 50 psi for evaluating installed ducts having a vertical rise greater than 6 feet; the maximum percent bleed shall be 2percent when the funnel is pressurized to 30 psi for evaluating installed ducts having a vertical rise greater than 2 feet but less than 6 feet; and the maximum percent bleed shall be 4 percent when the funnel is pressurized to 20 psi for evaluating installed ducts having a vertical rise that is less than 2 feet.
2. Two mud balance tests, one at grout mixer and one at duct outlet, per day or when there is a visual or apparent change in the characteristics of the grout in accordance with the API Recommended Practice 13B-1 “Standard Procedure for Field Testing Water-Based Drilling Fluids”. Acceptable specific gravity values for the grout shall be provided by the grout manufacturer and included with the grouting plan.
3. Minimum of one strength test per day in accordance with ASTM C942 and the minimum 28 day compressive strength shall be 7000 psi.
4. Minimum of two fluidity tests (flow cone) – one at the mixer and one at the duct outlet in accordance with ASTM C939, “Standard Tests Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)”. The efflux time shall be as shown in Table 618-1.

Grout shall be injected from the lowest end of a tendon to the highest end in an uphill direction. A continuous, one-way flow of grout shall be maintained for each duct.

All grout vent openings shall be open when grouting starts. Grout shall be allowed to flow to the first vent from the inlet pipe until residual slugs of water or entrapped air have been eliminated and the grout has the same consistency as that of the grout being injected. The vent shall then be capped or otherwise closed. Remaining vents shall be capped or closed in sequence in the same manner except that at draped tendon high points, the secondary vents placed a short distance downstream from the high point vent shall be closed before the highpoint vent.

The Contractor shall inspect the interiors of box girders during grouting operations for grout leakage. Leaks shall be sealed before grouting is continued.

Grout shall be pumped through the duct and continuously wasted at the outlet pipe until all visible slugs of water or air are ejected. To insure that the tendon remains filled with grout, the outlet shall be closed and the pumping pressure allowed to build to a minimum of 75 psi and held for one minute before the inlet vent is closed.

For all vertical tendons that are 20 feet and taller, a standpipe shall be provided at the upper end of the tendon to collect bleed water and allow it to be removed from the grout. This device shall be designed with commercial steel plumbing fittings so that the grout level will not drop below the elevation at the highest point in the upper anchorage device due to bleeding. If the level of the grout drops below the highest point in the upper anchorage device, additional grout shall immediately be added to the standpipe. After the grout has hardened, the standpipe shall be removed.

For vertical internal tendons, if the grouting pressure exceeds the maximum recommended pumping pressure, the grout shall be injected at increasingly higher outlets (which become inlets) that have been or are ready to be closed as long as one-way flow of grout is maintained. Grout shall be allowed to flow from each outlet until all slugs of air and water have been purged prior to using that outlet for injection.

Plugs, caps, and valves thus required shall not be removed or opened until the grout has set.

The Contractor shall monitor all anchorages, grout ports and vents periodically until the grout sets. The Engineer shall be notified if bleed water is dripping from these locations. Bleed water may be an indication of voids and will require investigation by the Contractor after the grout sets.

After the grout has set, the grout port and vent plugs shall be removed. The Contractor shall inspect the tendon anchorages, grout ports and vents for voids or other evidence of incomplete grouting. If evidence is found of voids in these areas, the Contractor shall submit a plan for regrouting the voids to the Engineer for approval. All costs for remedial grouting will not be measured andpaid for separately but shall be included in the work.

1. *Temperature Considerations.*

The temperature of the concrete adjacent to the ducts shall be 40 °F or higher from the time of grouting until site cured 2-inch grout cubes, tested in accordance with AASHTO T 106, reach a minimum compressive strength of 800 psi.

Grout shall be between 40 and 90 °F during mixing and pumping. If necessary, the mixing water shall be heated or cooled.

**618.10 Equipment.** Equipment used for fabrication of pretensioned and combination tensioned members shall conform to the following requirements:

1. *Jacking Equipment and Load Cells.*  All equipment shall be calibrated as a system that represents actual use. Jacks, gage and pump systems, and load cells shall be calibrated at intervals not longer than 12 months, or whenever the tensioning system yields erratic results. Master gage systems shall be calibrated at intervals not longer than six months, or whenever the tensioning system yields erratic results. If load, sensor or indicator components are replaced or repaired, the system shall be recalibrated before resuming jacking operations. System error shall not exceed plus or minus 1 percent of the applied loads.

Calibration shall be performed by an agency or service that uses equipment certified by the National Institute for Standards and Technology (NIST). Accuracy of the calibration equipment shall be traceable to the NIST records. The calibration procedures used shall conform to ASTM Standard Practices E 4 and E 74. Each time that calibration verification is performed, a copy of the certified test report shall be furnished to the QA representative or the Engineer.

1. *Concrete Batching Equipment.*  The weighing system shall be calibrated at intervals no longer than 12 months. If disassembly, replacement, damage or repair of scales or balance indicators should occur, the weighing system shall be recalibrated before resumption of mix operations. Scale calibrations shall be performed in conformance with the State of Colorado - Department of Agriculture requirements. Current calibration labels shall be visibly displayed on the equipment.

The batching system shall record the weights of all concrete mix ingredients for each batch. Ingredient weights shall meet the requirements of ASTM C 94, Section 8, Measuring Materials.

The batching system shall be equipped with a flow meter which measures the weight or volume of the added mixing water within plus or minus 1 percent of the total water added to each batch.

1. *Concrete Load Testing Machine.* The test machine shall meet the requirements of ASTM C 39.
2. *Concrete Cylinder Molds.* Shall meet the requirements of ASTM C470.
3. *Forms.* Forms shall be sufficiently mortar tight to minimize fresh mortar paste leakage, and sufficiently rigid to prevent product distortion due to concrete pressure or consolidation operations. Form joints shall be kept clean, smooth and adjusted to minimize form finish irregularities.

Forms shall be constructed and erected to produce units that conform to the product dimensional tolerances required by subsection 618.14(b); the forms shall also meet smoothness tolerances required by this subsection.

Forms shall be treated with a form release agent that does not adhere to or significantly discolor the final concrete product.

Forms that have known deviations from the typical sections shown on the plans shall be approved by the Engineer before use. The deviations shall be submitted on working or shop drawings.

1. *Miscellaneous Test Equipment*. All miscellaneous test equipment used during fabrication shall be kept in a condition such that accurate test results are obtained. Proper equipment maintenance and calibration shall be the responsibility of the Contractor's QC section.

**618.11 Concrete for Pretensioned and Combination Tensioned Products.** The Contractor shall furnish and place concrete according to this subsection.

1. *Classification.* Concrete shall be designated as class PS. The Contractor shall be responsible for the actual mix proportions and adjustments necessary to produce the specified strength. The specified strengths and air content shall be as stated on the plans. Fly ash may be substituted for hydraulic cement up to a maximum of 25 percent by weight. If fly ash is used in the mix, the weight of the total cementitious material content shall be the sum of the weights of the hydraulic cement and fly ash.

When voluntary use of fly ash by the Contractor results in delays, changes in mix quantities or materials sources, or unsatisfactory work, the costs of such delays, changes or corrective actions shall be borne by the Contractor.

1. *Concrete Mix Components.* Materials sources shall be listed in the Contractor's QCP. The QC Manager must notify the QA representative in writing before changing the sources as listed in the QCP. For new sources, the Contractor must submit certified data for review and acceptance by the Engineer, at least 30 days before the sources can be used for production. Materials shall conform to the requirements of subsection 618.02(c).
2. *Proportioning.* The minimum total cementitious material content shall be 610 pounds per cubic yard of concrete. Fine aggregates shall not exceed 55 percent of the total aggregate volume. Aggregates from different sources and of different gradings shall not be stockpiled together.
3. *Batching and Mixing.* Concrete shall be batched and mixed according to ASTM C 94.
4. *Placing Concrete.* Forms shall be free of dirt, mortar, debris, and foreign substances before depositing the fresh concrete. Rust areas shall be cleaned to prevent rust staining of the finished products.

The concrete shall be consolidated with suitable mechanical vibrating equipment. Vibration time shall be of sufficient duration to accomplish adequate consolidation throughout the entire product, but shall not be prolonged to the point that segregation of the fresh concrete occurs.

The Contractor shall use the procedures listed in the QCP, to protect the freshly deposited concrete from rapid drying and surface moisture loss due to extreme ambient or climatic conditions.

Temperature limitations are as follows:

* + - 1. The temperature of the plastic concrete during placement operations shall not be lower than 50 °F.
			2. Mixed concrete that has a temperature in excess of 90 °F shall not be placed.
			3. Unless a suitable retarder is used the concrete shall be deposited in place within 90 minutes after batching; any load or portion of a load shall not be placed after the 90 minute limit.
			4. Inner form temperature shall be within 40 °F of the fresh concrete temperature at time of concrete placement.
			5. Minimum inner form temperature shall be 40 °F at the time of concrete placement.
			6. Maximum inner form temperature shall be 130 °F at the time of concrete placement.
1. *Finishing Fresh Concrete*. Open surfaces of fresh concrete shall be worked as little as possible to obtain the finish shown on the plans. Water shall not be added to the surfaces to ease finishing. Excessive water or laitance brought to the surface through vibration shall be removed before the surface is final finished. All hand finishing, required for precast members that have surfaces that become part of the final bridge deck surface, shall be performed in conformance with subsection 601.12(a).

Monomolecular film coatings or fogging systems, as approved by the QA Representative, may be used to retard evaporation during extreme ambient conditions. Application methods shall deposit a fine mist spray over the concrete surface. Streaming, puddling, or droplet application of coatings shall not be permitted. The concrete surfaces shall not be reworked after application of mist.

1. *Concrete Testing*. The Contractor's QC section shall make representative cylinder test specimens for QC/QA testing. The Contractor shall forward test cylinders to the QA representative, for 28-day strength tests, and for shipping strength tests as required by subsection 618.15. Concrete tests shall be performed in accordance with the following requirements:

Test cylinder specimens shall be made in accordance with ASTM C 31. Vibration consolidation shall not be allowed unless the slump is less than 1 inch. Specimens shall be cured as listed in the accepted QCP.

Cylinders shall be tested in accordance with ASTM C 39. The average strength of at least two test cylinders shall be greater than the minimum required strength. No individual strength test shall be more than 7 percent below the minimum required strength.

Cylinder test specimens shall be made to verify stress transfer strength and to verify 28-day design strength. If the products will be shipped prior to 28-day testing, additional test specimens shall be available to verify product strength prior to shipment.

Representative cylinders shall be molded for each 50 cubic yards or portion thereof, for each different concrete mix design used per day per product line.

Air Content, when specified, shall be determined in accordance with either ASTM C 173 or ASTM C 231. Air entrained mixes shall be tested a minimum of once per day to assure specified air entrainment.

* + - 1. Slump of fresh concrete shall be determined in accordance with ASTM C 143. The slump shall be tested whenever test cylinder sets are made.
			2. Unit Weight of fresh concrete shall be determined in accordance with ASTM C 138. Unit weight shall be tested a minimum of once per day for each different concrete mix design used.
			3. Temperature of fresh concrete shall be taken as needed, to assure compliance with the temperature requirements.

**618.12 Curing.**

1. *Pretensioned and Combination Tensioned Members.*  Members shall be uniformly cured from the time of concrete placement until at least two representative product test specimens achieve an average strength that meets or exceeds 0.7 f 'c, or the specified release strength, f 'ci, whichever is higher.

Where:

f 'c = 28 Day Compressive Strength of Concrete

f 'c i = Required Concrete Strength at Release of Prestress Force

Additional curing requirements shall be maintained until the above strength requirements are achieved, and are as follows:

Exposed concrete surfaces shall be kept moist from the time of concrete placement until the freshly finished concrete is covered with an enclosure that retains heat and moisture. After enclosure, moist curing shall be maintained at a minimum 70 percent relative humidity.

The Contractor shall monitor the temperature and humidity conditions from the initial curing period through the end of the accelerated curing stage.

Temperature of the concrete shall be maintained above 50 °F.

The internal and surface temperature of the concrete shall not exceed 160 °F.

Concrete shall attain initial set prior to application of the accelerated curing cycle. If initial set was not determined in accordance with ASTM C 403, accelerated curing shall not be induced for 4 hours, or 6 hours if retarding admixtures are used.

While waiting for the initial set period, low cycle heat may be applied to maintain the curing chamber temperature; however, the temperature rise shall not exceed 10 °F per hour during the waiting period.

The rise in temperature in the curing chamber during accelerated curing cycle shall not exceed 40 °F per hour.

1. *Cast-in-Place Members.*  The curing of cast-in-place members shall conform to the requirements of subsection 601.13. The concrete shall not be exposed to temperatures below freezing for six days after casting, or until it has reached the strength required for applying the prestressing force. The minimum strength of the concrete shall be at least, 3500 psi for post-tensioned members, or as given on the plans whichever is greater, before prestressing.
2. *Other Precast Members.* Precast members that do not contain pretensioned steel shall meet curing requirements as follows:

Exposed surfaces of freshly finished concrete shall be covered with moisture retaining material, or shall be treated with a concrete curing compound approved by the QA representative.

Temperature of the concrete shall be maintained above 50 ° F from the time of concrete placement until the curing is complete.

Uniform curing shall continue until at least two representative product test specimens achieve an average strength that meets or exceeds 0.7 f 'c or the specified release strength f 'c i, whichever is higher.

The internal and surface temperature of the concrete shall not exceed 150 ° F.

**618.13 Repairs of Pretensioned and Combination Tensioned Members.**Repairable product defects discovered during QC or QA inspection, shall be corrected at the Contractor's expense prior to shipping. Damage incurred during handling, storage, shipment and erection shall be repaired or replaced at the Contractor's expense.

Defects shall be categorized as minor, structural, or rejectable. The QC section shall examine and record all defects. The QC section shall submit a written proposal for minor repairs to the QA Representative for review and acceptance prior to correcting the minor defects. The proposal shall also address the measures the Contractor will take to prevent recurring defects in future members. The QA Representative will approve, or reject, the finished repair work in writing.

Small production holes that are less than ½ inch in depth and less than 1 square inch in surface area, shall not be considered defects. Larger production holes shall be repaired according to the procedures listed in the QCP.

Structural and rejectable defects shall be examined by the Contractor's Engineer. A written proposal for repair of structural or rejectable defects shall be submitted to the QA Representative for review and acceptance prior to correcting any defects. The proposal shall include a detailed description and sketch of the defects, detailed repair procedures, description of repair materials, and the methods the Contractor will use to evaluate the finished repair work. The proposal shall also include the measures the Contractor will take to prevent recurring defects in future members.

Completed repairs shall be cured as needed to ensure soundness of the reworked area.

The defect categories and repair requirements are defined as follows:

1. *Minor Defects*. Minor defects are those which do not affect the ability of the product to withstand service or construction loads. Minor defects include superficial discontinuities such as cracks; small spalls, voids and honeycombed areas; and defects that do not extend beyond the centerline of any reinforcing steel or into any elements of the tensioning system. Minor defects of other types may also be designated by the QA Representative.

Repair methods shall not affect the structural integrity of the product. The finished repair work shall meet the approval of the QA Representative and the Engineer.

1. *Structural Defects*. Structural defects, as determined by the QA Representative or the Engineer, include defects which may impair the ability of the product to adequately withstand construction or service loads. Defects that extend beyond the centerline of any reinforcing steel or into any element of the tensioning system are classified as structural defects. Such defects also include cracks, spalls, honeycombed areas, voided areas, significant concrete breakage areas, cold joints, and segregated concrete areas. Structural defects of other types may also be designated by the QA Representative or the Engineer.

Repair methods shall adequately restore structural integrity of the product. When repairs have been completed, the Contractor's Engineer shall examine and analyze the product for construction and service load ability, and certify in writing that the repair work is structurally adequate. Evaluation and test data shall be submitted along with the written certification. The finished repair work, including aesthetic acceptability, shall meet the approval of the Engineer.

1. *Rejectable Defects*. Rejectable defects or damages, as determined by the QA Representative or the Engineer, are those which impair the ability of the product to adequately withstand construction or service loads, and which cannot be successfully repaired to structural and architectural acceptability. Structurally defective or rejected products shall not be incorporated into the work but shall be replaced with acceptable products supplied at the Contractor's expense.

Damaged and defective products will also be rejected by the QA Representative for the following reasons:

1. Failure by the Contractor's Engineer to approve and submit proposed repair procedures in writing before repair work begins.
2. Failure by the Contractor to execute the repair work according to QA approved procedures.
3. Failure by the Contractor to provide written certification of acceptable structural repair, along with submittal of evaluation and test data, if applicable.
4. Failure by the Contractor to correct recurring defects.
5. Determination by the QA Representative that the work, or materials used in the work, does not meet all contract requirements.

**618.14 Other Fabrication Requirements for Pretensioned and Combination Tensioned Members.**

* 1. *Finishing Hardened Concrete Products.* Finished and repaired areas shall reasonably match the coloration and profile characteristics of the adjacent concrete. Loose concretious laitance shall be removed from the product before storage.

Each finished product shall clearly display legible identification markings that show the cast date, piece mark and unique sub-mark. The marking shall also identify the setup location where the product was cast.

Finishing operations shall also conform to the following requirements:

Excessive laitance and unsound rubble shall be removed from surfaces to be bonded.

Fins and irregular projections shall be removed from the formed surfaces.

Bulges or offsets on the formed surfaces greater than ¼ inch shall be smoothed by stoning, sawing, or grinding.

Dented and inset surfaces greater than 4 square inches in area and deeper than ½ inch shall require a written repair proposal before repair or finish work begins.

Patches in areas of exposed steel or prestressing strand shall be bonded with an approved bonding agent and patched with an approved non-shrink grout.

If liquid membrane curing compounds are used on the concrete surfaces which are to be bonded, they shall be removed by sandblasting, prior to shipping the product.

* 1. *Product Dimensional Tolerances*. Tolerances for prestressed concrete products shall meet the unit tabulations listed in the PCI Manual MNL-116, unless otherwise stated in the Contract. The PCI tolerance figures and tabulations shall be specification requirements. Out-of-dimensional-tolerance variations shall be considered defects and shall be examined and evaluated by the Contractor's Engineer. The evaluation shall be submitted to the QA Representative in writing and shall contain written opinion of structural adequacy as determined by the Contractor's Engineer. The submittal shall meet the approval of the Engineer. Failure to submit the written evaluation and opinion will be cause for rejection.

The following work or products shall meet the specific PCI tolerance requirements described as follows, unless otherwise specified in the plans:

* + 1. Bulb-Tee Sections shall conform to Division VI, I-Beams.
		2. G-Series Sections shall conform to Division VI, I-Beams.
		3. Box Girders and U-Girders shall conform to Division VI, Box Beams.
		4. Deck Panels shall conform to the dimensional tolerances as listed in the PCI Special Report JR-343-88, Chapter 4, or the updated published edition thereof.
	1. *Handling, Storage, Shipment and Erection*. The Contractor shall handle the product in such a manner as to prevent cracking or damage. Cracked or damaged products shall be inspected by the QC section and repaired in accordance with subsection 618.13, or replaced at the Contractor's expense.

Braces, trusses, chains, cables, or other metal devices used for handling, storing, shipping, or erecting shall be adequately padded at points in contact with the concrete, to prevent chipping of the finished product.

Beam sections shall be handled, stored, shipped and erected with supports and devices that maintain the product in an upright position. Deck panels shall be lifted as directed in the Contract unless alternative lifting methods are allowed by the Engineer. Lifting of more than one panel at a time shall not cause panel cracking. Methods for multiple lifting of panels shall be shown on the working or shop drawings. Panel products shall be stacked in such a manner that damage does not occur.

Pre-cast concrete members shall be erected to prevent damage to all elements of the structure and in a safe manner. Pre-cast concrete members to which the erection specification applies are those members that bear on the substructure of a bridge. The primary members such as beams and girders shall be temporarily anchored and braced as they are erected to preclude detrimental movement in any direction, and to prevent overturning and buckling. Struts, bracing, tie cables, and other devices used for temporary restraint shall be considered falsework and shall be designed to resist all loads imposed during each stage of construction until the deck concrete has attained the Field Compressive Strength shown in Table 601-1.

At least one week prior to the Pre-Erection Conference, the Contractor shall approve, sign and submit an Erection Plan to the Engineer for record purposes only. The Erection Plan shall be stamped “Approved for Construction” and signed by the Contractor. The Erection Plan will not be approved by the Engineer. If falsework is required, falsework drawings shall conform to and be submitted in accordance with subsection 601.11.

The Erection Plan and procedure shall provide complete details of the erection process with dimension tolerances including:

1. Falsework, struts, bracing, tie cables and other devices, material properties and specifications for temporary works, bolt torque requirements prior to releasing girders from the cranes (if required), connection details and attachments to other structure components or objects;
2. Procedure and sequence of operations, including a detailed schedule with completion times for work items that complies with the working hour limitations;
3. Minimum load chart lift capacity, outrigger size and reactions for each crane;
4. Assumed loads and girder weights, lift points, lifting devices, spreaders, and angle of lifting cables.
5. Girder stresses at critical points along the girder length during progressive stages of erection shall be investigated to assure that the structural integrity and stability of the girders is maintained. Stresses at lift points induced as a result of lifting shall be investigated and adequate bracing provided as indicated by the analysis.
6. Locations of cranes, trucks delivering girders, and the location of cranes and outriggers relative to other structures, including retaining walls, wingwalls and utilities.
7. Drawings, notes, catalog data showing the manufacturer’s recommendations or performance tests, and calculations clearly showing the above listed details, assumptions, and dimensions.
8. Contingency plans detailing what measures the Contractor will take in case of inclement weather (forecast or actual), equipment failure, delivery interruption, and slower than planned production.

A Pre-Erection Conference will be held at least one week prior to the beginning of erection. The Engineer, Contractor, erection subcontractor, and the Contractor’s Engineer shall attend the meeting. The erection subcontractor shall demonstrate his knowledge and familiarity of where the piece marks are located on the components to be erected, their orientation in the erected structure, and the shop drawing piece mark convention used by the girder fabricator at the Pre-Erection Conference. The girder fabricator shall either attend the meeting or participate in the conference, by way of speaker telephone. Participation is required during that portion in which the piece marks are discussed. The girder fabricator shall state whether the erection subcontractor has demonstrated a correct understanding of the piece marks, and if not, correct any misunderstanding.

Additional Pre-Erection conferences may be required for subsequent phases of construction, or for phases that differ from the original construction plan, as directed by the Engineer. Additional conferences may also be requested by the Contractor, and approved by the Engineer.

The Contractor shall submit a final Erection Plan to the Engineer prior to girder erection for record purposes only. The Contractor’s Engineer shall sign and seal (1), (5), and (7) listed above in the final Erection Plan. The final Erection Plan shall be stamped “Approved for Construction” and signed by the Contractor. The final Erection Plan will not be approved by the Engineer.

When a bridge spans traffic of any kind, except for construction traffic and the Contractor’s employees, the Contractor’s Engineer shall inspect and provide written approval of the erected girders prior to opening the area beneath the girders to traffic. For this specification, traffic is defined as the vehicles, railroad, pedestrians and watercraft moving along a route. The Contractor shall perform daily inspections of the erected girders and other permanent and temporary bridge elements until the deck concrete has attained the Field Compressive Strength. The Contractor’s Engineer shall provide an inspection form to the Engineer and the Contractor that lists the items the Contractor will document during the daily inspection of the erected girders. The inspection form shall include inspection items specific to each bridge being constructed. The Contractor shall provide the Engineer and the Contractor’s Engineer with written documentation of these inspections within 24 hours of each inspection.

All temporary struts, bracing, tie cables, other devices and extra material required shall be removed upon completion of the structure.

Falsework shall conform to subsection 601.11.

**618.15 Product Shipping Strength for Pretensioned and Combination Tensioned Members.** Products shall not be shipped before concrete strength meets or exceeds 0.95 f 'c , unless otherwise indicated on the plans. The average of at least two representative test specimens shall meet or exceed 0.95 f 'c. No individual specimen strength shall be more than 7 percent below 0.95 f 'c. The shipping strength test specimens shall be cured in the same environment as the actual product until the time of testing. The QC section shall test the specimens for actual shipping strength. The QA Representative may independently verify any shipping strength tests.

The Contractor may elect to take concrete cores from the actual product in lieu of curing cylinder test specimens with the product. If the Contractor chooses this test option, the QC Manager shall submit written request to the QA Representative. Core extraction shall not begin until the request has been accepted in writing by the QA Representative. The written request shall include the proposed location and time schedule for core extraction and testing.

The cores shall be delivered in a wrapped and moist condition to the certified test laboratory as listed in the QCP. The QA Representative may witness any or all stages of the core testing operations. The test laboratory shall provide a copy of the formal test report to the QA Representative.

The Contractor shall bear all expenses associated with the optional core testing requirements. Sampling and testing of the concrete core specimens shall conform to ASTM C 42 with the following addenda:

* 1. Samples may be removed at any age at the Contractor's sole risk of damage.
	2. Test cores shall not contain embedded reinforcement.
	3. A minimum of three core samples shall be taken from the product casting in question. Three specimens shall be tested for compressive strength. The average compressive strength of the three tests shall meet or exceed product f(c). If the compressive test result of any specimen differs from the average strength by more than 15 percent, those results shall be disregarded, and the compressive strength shall be determined from at least two remaining valid test results.
	4. If end capping of test specimens is necessary, the capping shall be done with sulfur mortar in accordance with ASTM C 617. Specimens shall be kept moist until end capping preparation begins.

Ends shall be trimmed or prepped as required, wiped with absorbent cloth and air-dried or fan-dried to prepare for end capping. The drying period shall not exceed 20 minutes before capping is completed.

Specimens shall be air-dried for 10 to 20 minutes after capping, then wrapped with a double layer of wet, thick cloth or burlap. Compressive testing shall not be started for at least one hour after wet-wrapping. The wrapped specimens shall be kept moist until compressive testing begins.

The Contractor shall submit a written repair proposal to the QA Representative for patching the core holes. Repair work shall not begin until the proposal is accepted in writing by the Engineer.

**METHOD OF MEASUREMENT**

**618.16** Prestressed units will be measured by one of the following methods as indicated in the Contract.

1. Prestressed girders will be measured by the linear foot from end to end or by the square foot, based on the plan length multiplied by the plan width, whichever is specified on the plans.
2. Prestressed concrete box girders and prestressed concrete slabs will be measured by the square foot based on the plan length multiplied by the plan width.
3. When measured by component materials, concrete and reinforcing steel will be measured and paid for in accordance with Sections 601 and 602 respectively.

The quantities of prestressing steel will not be measured but shall be the quantities shown on the plans, completed and accepted. MKFT equals the jacking force, in thousands of KIPS, times the length in feet.

Precast panel deck forms that are required by the plans will be measured by the square foot. The quantity will not be remeasured, but will be the quantity shown on the plans, except when a plan change is ordered or when it is determined that there are discrepancies in an amount of plus or minus two percent of the plan quantity.

**BASIS OF PAYMENT**

**618.17** The accepted quantities of prestressed units and prestressing steel will be paid for at the contract unit price per unit of measurement for each of the pay items listed below that is included in the bid schedule. Precast panel deck forms required by the plans will be paid for at the contract unit price for the area shown on the plans.

Payment will be made under:

**Pay Item Pay Unit**

Prestressing Steel Bar Pound or MKFT

Prestressing SteelStrand Pound or MKFT

Prestressed Concrete \_\_\_ (\_\_\_) Linear Foot or Square Foot

Prestressed Concrete Box (\_\_\_) Square Foot

Prestressed Concrete Slab (Depth \_\_\_\_\_\_\_) Square Foot

Payment will be full compensation for all work necessary to complete the designated pay item.

Prestressing steel bar and prestressing steelstrand shall include but not be limited to all anchorage devices, prestressing steel, ducts, grout, and miscellaneous hardware. Elastomeric leveling pads, and galvanized steel diaphragms and connectors will not be paid for separately, but shall be included in the work. Concrete and reinforcing steel not shown on the plans but required by the Contractor's alternative will not be paid for separately but shall be included in the work. All required testing will not be paid separately but shall be included in the work.

Concrete quantities will not be reduced for the volume occupied by the ducts, prestressing steel, anchorages, blockouts for tensioning, etc., and will not include web flares, projections, warts, etc., required to accommodate the prestressing system used.

All costs associated with the preparation and implementation of the Erection Plan will not be paid for separately, but shall be included in the work.

Concrete, reinforcing steel, and prestressing steel for permanent steel bridge deck forms will not be measured and paid for separately, but shall be included in the work.