POST-TENSIONING

**From Jamaica ER BRF 013-1(16)

XX. DESCRIPTION. This work shall consist of furnishing, installing, stressing, and grouting prestressing steel for precast and cast-in-place concrete elements. It shall also include the furnishing and installing of any appurtenant items necessary for the particular prestressing system used, including but not limited to anchorage assemblies, additional reinforcing bars required to resist stresses caused by anchorage assemblies, ducts, vents, inlets, outlets, and grout used for pressure grouting ducts.

XX. GENERAL REQUIREMENTS. Use of a post-tensioning system is subject to approval by the Agency. Only post-tensioning systems of the proper type and size for the tendons shown on the Plans shall be used. Substitution of components from different post-tensioning systems shall not be allowed. Post-tensioning systems shall utilize tendons fully encapsulated in anchorages and ducts. Systems that transfer prestress force by bonding the prestress steel directly to concrete shall not be used. Tendon couplers are not permitted, except as noted on the Plans. All post-tensioning material shall be stored in a weatherproof building, shed, or container until the time of use.

The supplier is the firm or organization responsible for supplying the proprietary post-tensioning hardware and equipment for incorporation in the structure. All components of a post-tensioning system, including steel pipes, shall come from a single supplier. Prestressing steel can be obtained from any supplier.

XX. POST-TENSIONING SYSTEMS DEFINITIONS.

ACTUAL ULTIMATE TENSILE STRENGTH (AUTS) - The actual breaking strength obtained in tests of a single representative strand or bar, breaking outside the anchorage. For multi-strand or bar tendons, AUTS equals the AUTS of a single tendon element (strand, bar) times the number of such elements in the tendon. Representative samples must be from the same coil of strands or the same bar from which strands or bars are cut and used in connection efficiency tests. (Reference PTI "Acceptance Standards for Post-Tensioning Systems". See also "GUTS" and "MUTS".)

ANCHOR NUT - The threaded device that screws onto a threaded bar and transfers the force in the bar to the bearing plate.

ANCHOR PLATE - That part of the anchorage hardware that bears directly on the concrete and by which the tendon force is transmitted to the structure.

ANCHORAGE ASSEMBLY - An assembly of various hardware components that secure a tendon at its ends after it has been stressed and imparts the tendon force into the concrete.

ANCHORAGE ZONE - The general expression for combined general and local zones; see "GENERAL ZONE", "LOCAL ZONE".

ANTICIPATED SET - The wedge set assumed to occur in the design calculation of the post-tensioning forces at the time of load transfer;

see "SET".

BAR - High strength steel bars, normally available from 5/8 to 1-3/4 inch diameter and usually threaded with a very coarse thread.

BASIC BEARING PLATE - Flat plate bearing directly against concrete meeting the analytical design requirements. Covered by this definition are square, rectangular, or round plates, sheared or torch cut from readily available steel plate, normally ASTM A 36.

BEARING PLATE - Any steel hardware that transfers the tendon force into a structure.

CONFINEMENT REINFORCEMENT - Non-prestressed reinforcement in the local zone. Confinement reinforcement in the concrete ahead of tendon anchorages is limited to the local zone. Confinement reinforcement consists of spirals, orthogonal reinforcing bars, or a combination of both. For basic bearing plates, confinement reinforcement is required in that volume of concrete in which compressive stresses exceed acceptable limits for unreinforced concrete as determined by rational analysis. For special bearing plates, confinement reinforcement is system dependent as determined by tests on individual anchorages. Test block reinforcement, in the portion surrounding the special bearing plate and immediately ahead of it, must represent the confinement reinforcement required in the local zone for that particular system.

COUPLER - A device used to transfer the prestressing force from one partial-length prestressing tendon to another. (Strand couplers are not permitted.)

DUCT - Material forming a conduit to accommodate post-tensioned tendon installation and provide an annular space for the grout which protects the prestressing steel.

FAMILY OF SYSTEMS - Group of post-tensioning tendon assemblies of various sizes which use common anchorage devices and design. All components within the family of systems are furnished by a single supplier and have a common design with varying sizes.

GENERAL ZONE - The region in which the concentrated prestressing force spreads out to a more linear stress distribution over the cross-section of the structural member (Saint Venant Region). It includes the local zone. The general zone extends from the anchorage along the axis of the member for a distance equal to the overall depth of the member. The height of the general zone is equal to the overall depth of the member.

GUARANTEED ULTIMATE TENSILE STRENGTH (GUTS) - The tensile strength of the material that can be assured by the Manufacturer. GUTS should not be confused with "f_{PU}" the specified ultimate tensile strength (AASHTO LRFD). (The term "GUTS" has been replaced by two definitions, "MUTS" and "AUTS" by the Post-Tensioning Institute.)

LOCAL ZONE - The local anchorage zone is the volume of concrete surrounding and immediately ahead of the anchorage device where concrete compressive stresses exceed acceptable values for unconfined

concrete (concrete without confinement reinforcement). The local zone is defined as a rectangular prism of concrete surrounding the bearing plate and any integral confinement reinforcement. The transverse dimensions of the prism are equal to those of the bearing plate, including any integral confinement reinforcement, plus the supplier's specified minimum edge covers. The length of the local zone extends over the confinement reinforcement. For anchorage devices with multiple bearing surfaces, the local zone extends over the distance from the loaded concrete surface to the bottom of each bearing surface of the anchorage device plus the maximum dimension of that bearing surface.

MINIMUM ULTIMATE TENSILE STRENGTH (MUTS) - When measured as a force, for a single strand or bar breaking outside of the anchorage or the multiple of those single strand or bar forces for multi-strand or bar tendons; MUTS is the force equal to the nominal cross-sectional area of strand, or bar, times their nominal ultimate tensile stress. (Reference PTI "Acceptance Standards for Post-Tensioning Systems". See also "AUTS" and "GUTS".)

POST-TENSIONING - A method of prestressing where tensioning of the tendons occurs after the concrete has reached a specified strength.

POST-TENSIONING SCHEME OR LAYOUT - The pattern, size, and locations of post-tensioning tendons shown by the Engineer of Record on the Design Plans.

POST-TENSIONING SYSTEM - An assembly of specific models of hardware, including but not limited to anchorage assembly, local zone reinforcement, wedge plate, wedges, inlet, outlet, couplers, duct, duct connections, and grout cap, used to construct a tendon of a particular size and type. The entire assembly must meet the system pressure testing requirement. Internal and external systems are considered independent of one another.

PRESTRESSING STEEL - The steel element of a post-tensioning tendon, which is elongated and anchored to provide the necessary permanent prestressing force.

SET - The total movement of a point on the strand just behind the anchoring wedges during load transfer from the jack to the permanent anchorages. Set movement is the sum of slippage of the wedges with respect to the anchorage head and the elastic deformation of the anchor components. For bars, set is the total movement of a point on the bar just behind the anchor nut at transfer and is the sum of slippage of the bar and the elastic deformation of the anchorage components.

SHEATHING - General term for the duct material surrounding the prestressing element to provide corrosion protection or conduit for installation.

SPECIAL BEARING PLATE - Any hardware that transfers tendon anchor forces into the concrete but does not meet the analytical design requirements. Covered by this definition are devices having single or multiple plane bearing surfaces, and devices combining bearing and wedge plate in once piece. They normally require confinement reinforcement.

STRAND - An assembly of several high strength steel wires wound together. Strands usually have six outer wires wound in long-pitch helix around a single straight wire of a similar diameter.

TENDON - A single or group of prestressing elements and their anchorage assemblies, which impart a compressive force to a structural member. Also included are ducts, grouting attachments, grout, and corrosion protection filler materials or coatings. The main prestressing element is usually a high strength steel member made up of a number of strands, wires, or bars.

TENDON SIZE - The number of individual strands of a certain strand diameter or the diameter of a bar.

TENDON TYPE - The relative location of the tendon to the concrete shape, internal or external.

WEDGE - A conically shaped device that anchors the strand in the wedge plate.

WEDGE PLATE - The hardware that holds the wedges of a multi-strand tendon and transfers the tendon force to the anchorage assembly (commonly referred to as anchor head).

WIRE - A single, small diameter, high strength steel wire, typically the basic component of strand.

XX. POST-TENSIONING GROUT RELATED DEFINITIONS.

ADMIXTURE - A material, usually a liquid or powder that is used as an ingredient of the cementitious grout and is added immediately before or during mixing.

BLEED - The autogenous flow of mixing water within or its emergence from, newly placed grout, caused by the settlement of the solid materials within the mass.

CONTAMINATION - Any foreign material found in a tendon at any point in time.

CAVITATION - Air trapped during the grouting process through an irregular flow of grout through the duct. Cavitation can occur when grouts are injected from high points in the tendon profile or by a poor combination of grouting rate and viscosity, in which the grout traps air as it moves to the low point and does not completely fill the duct.

FINAL SET - A degree of stiffening of the grout mixture greater than the initial set, indicating the time required for the grout to stiffen sufficiently to resist, to an established degree, the penetration of a weighted test needle.

FLUIDITY - A measure of time, expressed in seconds necessary for a stated quantity of grout to pass through the orifice of a flow cone.

GROUT - A mixture of cementitious materials and water with or without mineral additives or admixtures, proportioned to produce a consistency

that may be pumped without segregation of the constituents when injected into the duct to fill the space around the prestressing steel.

GROUT CAP - A device which contains the grout and forms a protective cover sealing the post-tensioning steel at the anchorage.

GROUT PIPE - A small diameter pipe usually of plastic attached at a grout vent (inlet or outlet).

GROUT VENT - See "VENT".

INITIAL SET - A degree of stiffening of the grout mixture less than the final set, indicating the time required for the grout to stiffen sufficiently to resist, to an established degree, the penetration of a weighted test needle.
INLET - Tubing or duct used for injection of the grout into the duct (see also "VENT").

OUTLET - Tubing or duct to allow the escape of air, water, grout, and bleed water from the duct (see also "VENT").

PERMEABILITY TO CHLORIDE - A measure of the grout's ability to resist chloride ion penetration.

PORT OR GROUT PORT - See "VENT".

POTABLE WATER - Water as defined by EPA (Environmental Protection Agency) drinking water standards.

PRESSURE RATING - The estimated maximum pressure that water in a duct or in a duct component can exert continuously with a high degree of certainty that failure of the duct or duct component will not occur (commonly referred to as working pressure).

RECHARGE - The ability of water, outside of the post-tensioning tendon, to migrate through some path and enter the tendon, usually through the anchorage or at a breach in the duct.

SET TIME - The lapsed time for the addition of mixing water to a cementitious mixture until the mixture reaches a specified degree of rigidity as measured by a specific procedure.

SETTING - The process, due to the chemical reactions, occurring after the addition of mixing water, which results in a gradual development of rigidity of a cementitious mixture.

THIXOTROPIC - The property of a material that enables it to stiffen in a short time while at rest, but to acquire a lower viscosity when mechanically agitated.

VOLUME CHANGE - The change in volume produced by continued hydration of cement, exclusive of effects of the applied load and change in thermal or moisture content.

VENT OR GROUT VENT - An attachment to a duct through which grout is injected (inlet) or released (outlet) - also, a special hole in the anchorage or bearing plate which serves the same purpose. Vents may

also be used for inspection of grout by inserting a probe or endoscope.

WATER-REDUCING ADMIXTURE - An admixture that either increases the slump of freshly mixed grout without increasing the water content or that maintains the slump with reduced amount of water due to factors other than air entrainment.

XX. QUALIFICATIONS AND INSPECTIONS. Provide a crew foreman as follows:

Perform all post-tensioning field operations under the direct on-site supervision (crew foreman) of a qualified post-tensioning and grouting technician. The crew foreman for post-tensioning tendons installation and stressing shall have a current PTI Certification, Level 2 Bonded Post-Tensioning – Field Installation/Field Specialist and three years verifiable job-site experience in bridge related post-tensioning operations. The crew foreman for grouting operations shall be an ASBI Certified Grouting Technician with a continuous minimum verifiable experience of five years. All stressing and grouting operations shall be conducted in the presence of the Agency.

XX. FABRICATION DRAWINGS. Fabrication Drawings are required for the integration of the post-tensioning system, reinforcement, and other embedded items, including those for the Contractor's means and methods of construction for cast-in-place components. The Contractor/Supplier shall submit detailed Fabrication Drawings in accordance with Section 105 that address the requirements of the Plans and Specifications as follows:

(a) A complete description of, and details covering, each of the prestressing systems to be used for permanent and temporary tendons, including, but not necessarily limited to:

(1) Designation of the specific prestressing steel, dimensions, details, and materials for all manufactured components such as anchorage devices, wedges, nuts, bar couplers, ducts, materials, and accessories according to the post-tensioning system to be used.

(2) Tendon profile and clearances, duct supports, connections of ducts, connections at temporary bulkheads and the like, complying with the Plans and the limitations of the selected post-tensioning system.

(3) Location and details of grout inlets and outlets, at anchorages, low-points, high-points, and other required inspection points and the direction of grouting.

(4) Size, type, connections, and sealing details for permanent grout caps.

(5) Protection system materials and application limits.

(6) Details covering assembly and installation of each type of prestressing tendon.

(7) Equipment, dimensions, and clearances to be used in the prestressing operations.

(8) Procedure and sequence of operations for prestressing and securing tendons.

(9) Procedure for releasing temporary or permanent prestressing steel elements.

(10) Parameters to be used to calculate the typical tendon force such as; expected friction coefficients, anchor set, and prestress steel relaxation curves.

(b) A table detailing the prestressing jacking sequence, jacking forces, and initial elongations of each tendon at each stage of erection for all prestressing.

(c) Complete details of the anchorage system for prestressing including certified copies of the reports covering tests performed on prestress anchorage devices as required herein, and details for any reinforcing steel needed due to stresses imposed in the concrete by anchorage plates.

(d) For the operation of grouting prestressing tendons; the materials and proportions for grout, details of equipment for mixing and placing grout, and methods of mixing and placing grout (also, locations and details of inlets and outlets for grouting and the direction of grouting).

(e) Calculations to substantiate the prestressing system and procedures to be used including stress-strain curves typical of the prestressing steel to be furnished, required jacking forces, elongation of tendons during tensioning, seating losses, short-term prestress losses, long term prestress losses, temporary overstress, and stresses in prestress anchorages including distribution plates and reinforcing steel needed in the concrete to resist stresses imposed by prestress anchorages. These calculations shall show a typical tendon force and anticipated losses from friction, wobble, anchor set, and anticipated adjustment for thermal affects.

(f) Details of the apparatus and method to be used by the Contractor for the testing of prestressing tendons by the Contractor.

(g) Calculations for post-tensioning shall be signed and sealed by a Professional Engineer registered in the State of Vermont.

XX. FUTURE TENDONS. Not used.

XX. CERTIFICATION OF POST-TENSIONING SYSTEMS. Only post-tensioning systems that are approved by the Agency shall be used. Suppliers seeking evaluation of their post-tensioning systems shall submit test results to the Agency and include certified test reports from an independent laboratory audited by AASHTO Materials Reference Laboratory (AMRL) which shows the post-tensioning system meets all the requirements specified herein.

Plastic components shall be tested in a certified independent laboratory accredited through the laboratory accreditation program of

the Geosynthetic Accreditation Institute (GAI) or the American Association for Laboratory Accreditation (A2LA). Certification of test reports may be performed by an independent laboratory located outside the U.S., if the independent laboratory is approved by the Agency. If any component of the post-tensioning system is modified or replaced, the appropriate component test and entire system test, if needed, shall be retested in accordance with the requirements herein and an updated application made to the Agency containing the test reports and revised system drawings. Before attempting to change post-tensioning system components contact the Agency for direction.

Certification test for the plastic shall be performed on a sample formed or cut from the finished product. The Agency shall be provided with certification that the plastic from the duct sample complies with all requirements of the specified cell class, stress crack rating, and the specified amount of antioxidant. The supplier shall certify to the Agency that the post-tensioning system being furnished is in compliance with all requirements stated herein.

All components of a system shall be stamped with the suppliers name, trademark model number, and size corresponding to catalog designation. Post-tensioning systems consist of an assembly of components for various sizes of strand or bars assembled and pressure tested. Post-tensioning systems will have to be developed and tested for both internal (corrugated duct) and external (smooth duct) applications for those shown on the Plans.

Prior to installing any post-tensioning hardware, the Contractor shall furnish the Agency with a certification from the supplier that the post-tensioning system chosen for the project meets the requirements of this provision and is an Agency-approved post-tensioning system. Upon completion of post-tensioning installation, the Contractor shall provide a certification that the post-tensioning system supplied was installed without modification and met the requirements of the Contract Documents.

The supplier may submit to the Agency for consideration post-tensioning system certifications by other U.S. agencies.

The following are approved post-tensioning systems for use on this project:

DSI 1-3/8” Threadbar PT Bar System 100	DYWIDAG Systems International Post Tensioning/Reinforcing Unit 320 Marmon Drive Bolingbrook, IL 60440 (630) 739-6155
Williams Form Engineering Corp R7P	Williams Form Engineering Corp. 280 Ann Street N.W. Grand Rapids, MI 49504 (616) 365-9220
VStructural LLC (VSL) 1-3/8” PT Bar System	VSL 7455 New Ridge Road Hanover, MD 21076 (888) 489-2687

XX. PRESTRESSING STEEL.

(a) Thread-Bar. Unless otherwise noted on the Plans, prestress bars shall be uncoated, Grade 150, high strength deformed thread bars, Type II, conforming to the requirements of ASTM A 722, "Standard Specification for Uncoated High Strength Steel Bar for Prestressing Concrete".

XX. THREAD-BAR COUPLERS. Thread-bar couplers shall meet the requirements of ASTM A 722. Bar couplers shall be used only at locations specifically shown on the Plans or approved by the Agency. A bar coupler shall develop at least 95 percent of the required ultimate strength of the bar with a minimum elongation of two percent when tested in the unbonded condition measured in 10 foot gauge lengths, without failure of the coupler or the thread-bar.

Testing of couplers shall be performed using samples of the prestressing bar to be used on the project. The test specimen shall be assembled in an unbonded state and during testing the anticipated set shall not be exceeded.

Only threaded type couplers shall be used with post-tensioning thread bars. Post-tensioning thread-bars shall be threaded into 1/2 the length of the coupler ± 1/4 inch so that when two bars are mated in a coupler, the length of each bar positively engaged in the coupler shall be half the coupler's length within the acceptable tolerances. No coupling or splicing will be permitted with strands.

XX. POST-TENSIONING ANCHORAGES. All prestressing steel shall be secured at the ends by means of permanent type anchoring devices. Prestress anchorages shall develop at least 95 percent of the actual ultimate tensile strength of the prestressing steel, when tested in an unbonded state, without exceeding the anticipated set.

(Paragraph deleted)

The anchorage system shall be so arranged that the prestressing force in the tendon may be verified prior to the removal of the stressing equipment.

For tendon anchorages, the design and furnishing of any reinforcement (in addition to the reinforcement shown on the Plans) which is needed to resist bursting and splitting stresses imposed on the concrete by the proposed anchorage system shall be the responsibility of the Contractor.

Prestress anchorage devices shall effectively distribute prestressing loads to the concrete and shall conform to the following requirements:

(a) Anchorages shall be designed so that the average concrete bearing stress is in compliance with the "AASHTO LRFD Bridge Design Specifications".

(b) Bending stresses in the plates or assemblies induced by the pull of the prestressing steel shall not exceed the yield point of the material in the anchorage plate when 95 percent of the ultimate

strength of the tendon is applied. Nor shall it cause visual distortion of the anchor plate.

The body of the anchorage shall be galvanized in accordance with ASTM A 123. Other components of the anchorage including nuts and local zone reinforcement are not required to be galvanized. The bearing surface and nuts shall be made from ferrous metal. All permanent anchorages shall be equipped with a permanent grout cap that is vented and bolted to the anchorage.

Permanent anchorages shall have a grout vent suitable for inspection from either the top or front of the anchorage. The vent shall facilitate the dual purpose of grouting or post-grouting inspection by drilling, if necessary, using a straight bit, and by insertion of a probe or endoscope. The geometry of the grout outlets must facilitate being drilled using a 3/8 inch diameter straight bit to facilitate both inspection directly behind the anchor plate.

Trumpets associated with anchorages shall be made from either ferrous metal or polypropylene plastic material conforming to the material requirements of corrugated plastic duct. The thickness of the trumpet at the transition location (choke point) shall not be less than the thickness of the duct. Alternately, the trumpet material may be a polyethylene or polyolefin containing antioxidant(s) with a minimum Oxidation Induction Time (OIT) according to ASTM D 3895 of not less than 20 minutes. Test the remolded finished polyolefin material for stress crack resistance using ASTM F 2136 at an applied stress of 348 psi resulting in a minimum failure time of 3 hours.

XX. PERMANENET GROUT CAPS. Anchorages shall be fitted with a permanent grout cap made from polymer or ASTM A 240 Type 316L stainless steel. The resins used in the polymer shall be either nylon Acrylonitrite-Butadiene-Styrene or polyester. For products made from nylon, the cell class of the nylon according to ASTM D 5989 shall be S-PA0141 (weather resistant), S-PA0231, or S-PA0401 (ultimate strength no less than 10,000 psi with UV stabilizer added). The cap shall have an "O" ring or precision fitted flat gasket seal against the bearing plate. The grout cap shall have a grout vent oriented to the top of the cap. Grout caps shall be rated for a minimum pressure of 150 psi. Use ASTM A 240 Type 316L stainless steel bolts to attach the grout cap to the anchorage. Certified test reports of the chemical analysis of stainless steel caps is required for verification.

XX. GROUT VENTS (INLETS AND OUTLETS), VALVES, AND PLUGS. All inlets and outlets shall be equipped with pressure rated mechanical shut-off valves or plugs. Grout vents at inlets and outlets, valves, vent plugs, or caps shall be rated for a minimum pressure rating of 150 psi. Grout vents (inlets and outlets) shall have a minimum inside diameter of 3/4 inch for strand and 3/8 inch for single bar tendons and four-strand duct. Dual mechanical shutoff valves shall be provided when performing vertical grouting.

All permanent attachments to anchorages and ducts for grout vents (inlets and outlets) and threaded vent plugs or caps shall be made of ASTM A 240 Type 316 stainless steel, nylon, or polyolefin materials. For products made from nylon, the cell class of the nylon according to ASTM D 5989 shall be S-PA0141 (weather resistant), S-PA0231, or S-

PA0401 (ultimate strength no less than 10,000 psi with UV stabilizer added). Products made from polyolefin shall contain antioxidant(s) with a minimum Oxidation Induction Time (OIT) according to ASTM D 3895 of not less than 20 minutes. The finished polyolefin material shall be tested to satisfy stress crack resistance using ASTM F 2136 at an applied stress of 348 psi with a minimum failure time of 3 hours.

Temporary items, not part of the permanent structure, may be made of any suitable material.

Grout vents (inlets and outlets) shall be provided at locations designated on the approved Fabrication Drawings.

XX. DUCTS AND PIPES. Only plastic duct, steel pipe, or a combination of plastic duct and steel pipe shall be used for ducts. All connectors, connections, and components of post-tensioning system hardware shall be air and water tight. Corrugated plastic duct shall be used for all internal post-tensioning systems except where steel pipe is required.

All duct material shall be sufficiently rigid to withstand loads imposed during placing of concrete and internal pressure during grouting while maintaining its shape, remaining in proper alignment, and remaining watertight.

The duct system, including splices and joints, shall effectively prevent entrance of cement paste or water into the system and shall effectively contain pressurized grout during grouting of the tendon.

The interior diameter of ducts for single bars shall be at least 1/2 inch greater than the nominal diameter of the bar measured across the upstanding deformations. For prestressing bars with couplers, the entire length of duct shall be 1/2 inch larger than the diameter of the coupler.

Steel pipe and plastic duct may be connected directly to each other when the outside diameters do not vary more than 0.08 inch. Use a reducer when the outside diameters of the steel pipe and plastic duct are outside of this tolerance.

Steel pipe which is embedded in a deviation block, beam, or diaphragm shall be bent to a uniform radius along a curve extending between tangent points located three inches inward from the face of the deviation block, beam, or diaphragm.

XX. SPECIFIC MATERIAL PROPERTIES OF DUCTS, PIPES, AND ATTACHMENTS.

(a) Galvanized Rigid Steel Pipe. Steel pipe shall be galvanized steel pipe conforming to the requirements of ASTM A 53, Type E, Grade B. The nominal wall thickness of the pipe shall not be less than that of Schedule 40 unless otherwise specified. The pipe shall be bent so as to accurately conform to the alignment of the tendon, taking into consideration the minimum bending radius shown in the Plans or Fabrication Drawings.

(b) Corrugated Plastic Duct (HDPP).

(1) Material for Corrugated Plastic Duct (HDPP). Plastic ducts

shall not be made from recycled material. Only seamless fabrication methods shall be used to manufacture ducts. Corrugated duct shall be manufactured from non-colored, unfilled polypropylene meeting the requirements of ASTM D 4101 "Standard Specification for Polypropylene Plastic Injection and Extrusion Materials" with a cell classification range of PP0340B14541 to PP0340B67884. The duct shall be white in color containing antioxidant(s) with a minimum Oxidation Induction Time (OIT) according to ASTM D 3895 of 20 minutes and contain a non-yellow light stabilizer. Duct shall have a minimum thickness as defined in the following table:

Duct Shape	Duct Diameter	Duct Thickness
Flat	any size	0.08 inches
Round	0.9 inches	0.08 inches
Round	2.375 inches	0.08 inches
Round	3.0 inches	0.10 inches
Round	3.35 inches	0.10 inches
Round	4.0 inches	0.12 inches
Round	4.5 inches	0.14 inches
Round	5.125 inches	0.16 inches
Round	5.71 inches	0.16 inches

(2) Minimum Bending Radius for Corrugated Plastic (HDPP). In addition to the component testing stated herein, the manufacturer shall establish, through testing, the minimum bending radius for the duct. The test shall consist of a modified duct wear test as described in Chapter 4, Article 4.1.7 of FIB Technical Report, Bulletin 7, titled "Corrugated Plastic Duct for Internal Bonded Post-Tensioning". The test apparatus shall be identical to the wear test apparatus with the same clamping force as a function of the number of strands in the duct; however, modify the procedure as follows: do not move the sample along the strand to simulate wear; the test duration will be 7 days. Upon completion of the test duration, remove the duct and the minimum wall thickness along the strand path must not be less than 0.06 inch for duct up to 3.35 inches in diameter and not less than 0.08 inch for duct greater than 3.35 inches in diameter.

(3) Testing Requirements for Corrugated Plastic. The duct system components and accessories shall meet the requirements of Chapter 4, Articles 4.1 through 4.1.8 of FIB Technical Report, Bulletin 7, entitled "Corrugated Plastic Duct for Internal Bonded Post-Tensioning" as modified herein. (Copies of the technical report are available from the International Federation of Structural Concrete (FIB) at fib@epfl.ch .)

The requirements in FIB Technical Report, Bulletin 7, are modified as follows: the lateral load resistance test (FIB 4.1.4), shall be conducted without the use of a duct stiffener plate and using a load of 150 pounds for all

sizes; wear resistance of duct (FIB 4.1.7) must not be less than 0.06 inch for duct up to 3.35 inches in diameter and not less than 0.08 inch for duct greater than 3.35 inches in diameter; bond behavior of duct (FIB 4.1.8) must achieve 40% GUTS in a maximum length of 16 duct diameters.

To satisfy the intent of these tests, the results for static pull-out tests from previous projects utilizing identical duct and prestressing steel with similar concrete and grout material may be submitted to the Agency in lieu of executing new pull-out tests. However, if the previous results are unacceptable or if there is a significant difference in the materials used, then the Contractor shall provide results from new tests for this project.

(4) Corrugated Duct Connections and Fittings. All splices, joints, couplings, and connections between ducts and to anchorages shall be made using devices or methods (i.e. mechanical couplers) producing a smooth interior alignment with no lips or kinks. All connections and fittings shall be airtight. Duct tape is not permitted to join or repair duct connections. Connections and fittings shall be made from polyolefin materials containing antioxidant stabilizer(s).

XX. SHIPPING AND STORAGE OF DUCTS. Duct shall be furnished with end caps to seal the duct interior from contamination. Ducts shall be shipped in bundles which are capped and covered during shipping and storage. Ducts shall be protected against ultraviolet degradation, crushing, excessive bending, dirt contamination, and corrosive elements during transportation, storage, and handling. End caps supplied with the duct shall not be removed until the duct is incorporated into the bridge component. Duct shall be stored in a location that is dry and protected from the sun. Storage must be on a raised platform and completely covered to prevent contamination; if necessary, duct shall be washed before use to remove any contamination.

XX. MECHANICAL COUPLERS AND HEAT SHRINK SLEEVE REQUIREMENTS. Mechanical couplers shall be made from stainless steel, plastic, or a combination of these materials. Plastic resins for couplers shall meet the requirements for plastic ducts. ASTM A 240 Type 316 stainless steel shall be used for metallic components.

Heat shrink sleeves shall have uni-directional circumferential recovery and be manufactured specifically for the size of the duct being coupled, consisting of an irradiated and cross linked high density polyethylene backing for external applications. Furnish adhesive having the same bond value to steel and polyolefin plastic materials. The heat shrink sleeves shall have an adhesive layer that will withstand 150°F operating temperature, meeting the requirements of the following table:

Property	Test Method	Minimum Requirements	
		Internal Application	External Application
Minimum Fully Recovered Thickness		92 mils	111 mils

Peel Strength	ASTM D 1000	29 pli	46 pli
Softening Point	ASTM E 28	162°F	216°F
Lap Shear	DIN 30 672M	87 psi	58 psi
Tensile Strength	ASTM D 638	2,900 psi	3,480 psi
Hardness	ASTM D 2240	46 Shore D	52 Shore D
Water Absorption	ASTM D 570	Less than 0.05%	Less than 0.05%
Color		Yellow	Black
Minimum Recovery	Heat Recovery Test	33%	23%

XX. SYSTEM PRESSURE TEST REQUIREMENTS.

(a) General. For each family of post-tensioning systems, a pressure test shall be performed on an assembled system as defined herein. For each family of post-tensioning systems two assemblies shall be tested (largest and smallest) from the family. The post-tensioning assembly shall include at least one of each component required to make a tendon from grout cap to grout cap. If applicable, plastic duct to steel pipe connections and segment duct couplers shall be included.

(b) Grouting Component Assembly Pressure Test. The anchorage and grout cap shall be assembled with all required grouting attachments (grout tube, valves, plugs, etc.). The opening in the anchorage where the duct connects shall be sealed. Condition the assembly by maintaining a pressure of 150 psi in the system for 3 hours. After conditioning, the assembly must sustain a 150 psi internal pressure for 5 minutes with no more than 15 psi reduction in pressure. For systems using the same anchorages, grout caps, and grouting attachments as a previously approved system, the Grouting Component Assembly Pressure Test may include documentation from a previous submittal with written certification that the same components are being utilized in both anchorages.

(c) Internal Duct Systems. The assembly shall be tested for compliance with the requirements of Chapter 4, Article 4.2, Stage 1 and Stage 2 Testing contained in FIB Technical Report, Bulletin 7, titled "Corrugated Plastic Duct for Internal Bonded Post-tensioning". For bar systems modify the system test length to 15 feet.

(d) Acceptability from Previous Tests. To satisfy the intent of the above tests, results from previous projects utilizing identical ducts and similar concrete may be submitted to the Agency in lieu of executing new tests. However, if the previous results are unacceptable or if there is a significant difference in the materials used, then the Contractor shall provide results from new tests for this project.

XX. SAMPLING AND TESTING OF PRESTRESSING ELEMENTS. All testing shall be done in accordance with ASTM Specifications.

The following samples of materials, devices, and test certifications as designated by the Agency shall be furnished at no cost to the Agency.

(a) Three randomly selected samples, each five feet long, of post-

tensioning bar, per manufacturer, per size of bar, per heat of steel, with a minimum of one sample per shipment.

(b) If bar couplers are to be used, three samples with two specimens each consisting of four foot lengths of the specific prestressing bar coupled with a bar coupler from the materials to be used on the project.

(c) For each type of duct material intended for the project, one sample, four feet long, from each production lot or per 10,000 linear feet, whichever is greater.

With each sample of prestressing steel strand or bar furnished for testing, a certification shall be submitted to the Contractor stating the manufacturer's minimum guaranteed ultimate tensile strength for that sample.

The Agency reserves the right to reject any material or device which is determined to be defective or was damaged subsequent to testing.

XX. LOTS AND IDENTIFICATION (CONTRACTOR'S QUALITY CONTROL). A "Lot" is that parcel of components as described herein. The manufacturer of prestressing steel and bar couplers shall assign an individual number to each Lot of strand, wire, bar, or devices at the time of manufacture. All bars of each size and mill heat of steel shipped to the project shall be identified by tag or other acceptable means as to Manufacturer's Lot number. The Contractor shall be responsible for establishing and maintaining a procedure by which all prestressing materials and devices can be continuously identified with the manufacturer's Lot number. Items which at any time cannot be positively identified as to Lot number shall not be incorporated into the work.

The Contractor shall furnish manufacturer's certified reports covering the tests required by this Special Provision. A certified test report stating the guaranteed minimum ultimate tensile, yield strength, elongation, and composition shall be furnished for each lot of prestressing steel. When requested, typical stress-strain curves for prestressing steel shall be furnished. A certified test report stating strength when tested using the type prestressing steel to be used in the work shall be furnished for each Lot of prestress anchorage devices.

XX. TESTING OF PRESTRESSING TENDONS BY THE CONTRACTOR.

(a) General. The Contractor shall perform certain testing of prestressing tendons as specified herein. Re-evaluate the theoretical elongations shown on the Fabrication Drawings using the results of the tests as appropriate and correct as necessary. Submit revisions to the theoretical elongations to the Agency for approval.

(b) Tendon Modulus of Elasticity Test. One tendon modulus of elasticity test shall be performed in accordance with the following procedure.

For the purpose of accurately determining the tendon elongations

while stressing, two samples of each size of tendon shall be bench tested to determine the modulus of elasticity prior to stressing the initial tendon.

For the purpose of this test, the bench length between anchorages must be at least 40 feet and the tendon duct at least 2 inches clear of the tendon all around. The test procedure must consist of stressing the tendon at an anchor assembly with a load cell at the dead end. The test specimen shall be tensioned to 80% of ultimate in ten increments and then de-tensioned from 80% of ultimate to zero in ten decrements. For each increment and decrement, the gauge pressure, elongations, and load cell force shall be recorded. Elongations shall be noted at both ends and the central 30 feet, measured to an accuracy of ± 1/32 inch. Elongations shall be corrected for wedge set at the dead end.
The modulus is calculated as follows:

$$E = \frac{P \times L}{A \times d_L}$$

Where;

P = force in tendon;
L = distance between pulling wedges and dead end wedges or exact length in center 30 feet of the tendon;
A = cross sectional area of the tendon based nominal area;
d_L = strand elongation for load P.

If the bench test result varies from the modulus of elasticity used for the Fabrication or Working Drawings by more than 1%, adjustments shall be made to theoretical elongations.

If the source of prestressing steel changes during the project, additional test series or substantiation from previous projects, not to exceed one per source, will be required.

The apparatus and methods used to perform the test must be submitted to the Agency for approval. Tests must be conducted in the Agency's presence.

A test report entitled "Tendon Modulus of Elasticity Test" shall be prepared prior to installing the tendons.

To satisfy the intent of this test, results for modulus of elasticity from a previous project utilizing prestressing steel of the same grade, size, and from the same source may be used in lieu of new testing. If the previous results demonstrate a significant difference in the strands used, submit results from new tests for this project. If observed elongations of the tendons in the erected structure fall outside of the acceptable tolerances, tendon modulus of elasticity tests shall be performed as directed by the Agency.

XX. GROUT MATERIALS AND PROPERTIES.

(a) General. Grout for tendons shall consist of Portland cement and mineral admixtures for partial cement replacement, other

specified or approved admixtures which impart low water content, flow, fluidity, minimum bleeding, non-shrink and, when necessary, set retarding properties to the grout. Grout shall have enhanced corrosion-resisting properties, such as increased resistance to chloride penetration. There shall be no deliberate addition of materials containing chlorides. Grout shall be mixed using potable water.

Only commercial, pre-packaged, cement-based, enhanced grout mixtures, meeting the requirements of this Special Provision, shall be used subject to approval by the Agency. Grout shall be stored in a location that is both dry and convenient to the work. Storage in the open must be on a raised platform and with adequate waterproof covering to protect the material. On-site storage of grout is limited to a maximum period of one month.

Post-tensioning grout shall be formulated for proper use in either horizontal, vertical, or repair applications. Grout fluidity shall be strictly maintained by production grouting flow-cone testing.

The following products are approved for grouting of vertical and horizontal tendons:

Euco Cable Grout PTX	Euclid Chemical 19218 Redwood Road Cleveland, OH 44110 (800) 321-7628
Masterflow 1341	BASF C C Building Systems 889 Valley Park Drive Shakopee, MN 55379 (813) 240-6400
Sikagrout 300 PT	Sika Corporation 12414 Lobelia Terrace Bradenton, FL 34202 (941) 713-1376

(b) Characteristics of Prepackaged Grouts.

(1) Cement. Portland cement shall conform to requirements of AASHTO C 150 Type I or Type II. The cement shall be fresh and not contain lumps or other indication of hydration or "pack set". The Contractor shall furnish, for each shipment of cement, a manufacturer's report stating results of tests made on samples of the material taken during production or transfer and certifying compliance with the applicable requirements of AASHTO C 150.

(2) Cement Replacement in Prepackaged Grouts. The following cementitious materials may be used for cement replacement in order to enhance the corrosion resisting and durability characteristics of grout used for aggressive environments:

Silica Fume: 0 to 15% replacement by weight of Portland cement.

Fly-Ash (Class C): 0 to 30% replacement by weight of Portland cement.

Slag: 0 to 55% replacement by weight of Portland cement.

The water content shall be calculated for the total weight of cementitious material (cement plus replacement material) and expressed as water/cementitious ratio.

(3) Water. Water shall be potable, clean, and free of injurious quantities or substances (chlorides, sulfides, sulfates and nitrates) known to be harmful to Portland cement or prestressing steel. Water shall have chloride, sulfide, sulfate, and nitrate contents not greater than 500, 100, 650, and 13 ppm respectively.

Water used for grouting tendons shall be tested for the chemicals noted above at regular intervals not to exceed 120 days. Water shall be tested at the location where the water is placed into containers for the project. If the water is stored in containers which might contaminate it (e.g. unlined metal tanks), then the Agency can request that tests be performed on water coming from the storage tanks. The Contractor shall provide the Agency with copies of test reports for the stored water.

(4) Admixtures. Admixtures shall consist of chemicals that impart the following properties when incorporated into the grout mixture. These properties are low water content, good flow, fluidity, minimum bleeding (sedimentation of cement), expansion or non-shrink and, when necessary, increase in setting time. Any admixture containing chlorides, sulphites, fluorides, or nitrates shall not be used in the grout. The date of manufacture and shelf life shall be clearly stamped on each container. No admixture shall be used for which the shelf life recommended by the manufacturer has expired.

(5) Non-Shrink Properties and Expansion Agents. Grout shall have non-shrink properties. However, gas evolving expansion agents and/or additives containing free aluminum or other components which produce hydrogen, carbon dioxide, or oxygen gas shall not be used.

(6) Corrosion Inhibitors. Corrosion inhibiting chemical admixtures shall not be used.

(7) Chloride Ion Content. All constituent materials shall be such that the acid-soluble chloride ion content of the grout shall not exceed 0.08% by weight of Portland cement as measured by ASTM C 1152 "Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete."

(c) Required Physical Properties of Grout. Prepackaged grout shall meet or exceed the physical properties listed in Table 1 when mixed, prepared, and tested at a normal temperature of 65°F to

78°F in a laboratory approved by the Agency.

Prepackaged grout shall be tested in accordance with the requirements of Table 1. Prior to beginning grouting operations, the Contractor shall furnish the Agency with a report detailing the results of all laboratory testing, including the types and number of tests performed, test procedures, results, and comparison of results with specified values.

To satisfy the intent of the tests outlined in this Section, results from previous projects utilizing identical grouts may be submitted in lieu of executing new tests; or the prepackaged grout that has previously met the requirements of this Specification as independently certified by a laboratory approved by the Agency. However, if the previous results are unacceptable or if there is a significant difference in the materials used, then results from new tests for this project shall be submitted.

Table 1 - Physical Property Requirements for Prepackaged Grout

Physical Property	Requirement	Test Method
Water-Cementitious Material Ratio	Maximum 0.45	n/a
Grout Cube Strength	Min. 3,000 psi at 7 days Min. 5,000 psi at 28 days	ASTM C 942
Total Chloride Ions	Maximum 0.08% by weight of cementitious material	ASTM C 1152
Fine Aggregate (if utilized)	99% passing the No. 50 Sieve (300 micron)	ASTM C 136*
Volume Change @ 24 hours 28 days	 0.0% to + 0.1% 0.0% to + 0.2%	ASTM C 1090**
Expansion	≤ 2.0% for up to 3 hours	ASTM C 940
Wet Density – Laboratory	Report maximum and minimum obtained test value lb/ft^3	ASTM C 185
Wet Density – Field	Report maximum and minimum obtained test value lb/ft^3	ASTM C 138
Compressive Strength 28 day (Average of 3 cubes)	≥7,000 psi	ASTM C 942
Initial Set of Grout	Minimum 3 hours Maximum 12 hours	ASTM C 953
Fluidity Test*** Efflux Time from Flow Cone: Immediately after mixing	Minimum 20 Seconds Maximum 30 Seconds Or Minimum 9 Seconds Maximum 20 Seconds	ASTM C 939 ASTM C 939****
Fluidity Test*** Efflux Time from Flow Cone: 30 minutes after mixing with remixing	Maximum 30 Seconds Or Maximum 30 Seconds	ASTM C 939 ASTM C 939****

for 30 sec		
Bleed @ 3 hours	Maximum 0.0 percent	ASTM C 940*****
Permeability @ 28 days	Maximum 2500 coulombs at 30 V for 6 hours	ASTM C 1202******

*ASTM C 117 procedure shall be modified to use a #50 sieve. The percent passing the #50 sieve after washing the sieve shall be determined.

**ASTM C 1090 shall be modified to include verification at both 24 hours and 28 days.

***Adjustments to flow rates shall be achieved by strict compliance with the manufacturer's recommendations. The time of efflux is the time to fill a one liter container placed directly under the flow cone.

****Grout fluidity shall meet either the standard ASTM C 939 flow cone test or the modified test, as follows. The ASTM C 939 flow cone test shall be modified by filling the cone to the top instead of to the standard level. The efflux time shall be the time to fill a one liter container placed directly under the flow cone.

*****ASTM C 940 shall be modified to conform with the wick induced bleed test as follows:

(1) The wick shall be a 20 inch length of ASTM A 416 seven wire 0.5 inch diameter strand. The strand shall be degreased with acetone or hexane solvent and a wire brush to remove any surface rust on the strand before temperature conditioning. The strand shall be wrapped with 2 inch wide duct or electrical tape at each end prior to cutting to avoid splaying of the wires when it is cut.

(2) All the dry ingredients, mixing water, prestressing strand, and test apparatus shall be conditioned overnight at 65 to 75°F.

(3) The conditioned dry ingredients shall be mixed with conditioned mixing water and 800 ml of the resulting grout placed into a 1,000 ml graduate cylinder. The level of the top of the grout shall be recorded.

(4) The strand shall be inserted into the graduated cylinder, centered, and fastened so it remains essentially parallel to the vertical axis of the cylinder. The level of the top of the grout shall be recorded.

(5) The mixed specimen shall be stored at the temperature range specified in part (b) above.

(6) The level of the bleed water shall be measured every 15 minutes for the first hour and hourly for two successive readings thereafter.

(7) The amount of bleed water, if any, shall be calculated at the end of the three hour test period and the resulting expansion per 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.

******When evaluating grouts, the ASTM C 1202 procedure shall be modified to perform the test at 30 volts rather than 60 volts. Testing shall be performed on grout samples at 28 days of age. For grouts containing pozzolanic mineral admixtures, testing may be performed on grout samples at 90 days of age.

(d) Accelerated Corrosion Test Method (ACTM). An accelerated corrosion test shall be performed as outlined in Appendix B of the "Specification for Grouting of Post-Tensioning Structures" published by the Post-Tensioning Institute. The time to corrosion for both the grout being tested and the control sample using a 0.45 water-cement ratio neat grout shall be reported. A grout that shows a longer average time to corrosion in the ACTM than the control sample and the time to corrosion exceed 1,000 hours is considered satisfactory.

(e) Schupack Pressure Bleed Test. The Schupack pressure bleed test shall be performed as per ASTM C 1741. Acceptable bleed values are shown in Table 4.1(b) of the "Specification for Grouting of Post-Tensioning Structures" published by the Post-Tensioning Institute.

(f) Repair Applications. Repair applications are used to augment grouting operations which did not completely fill the duct or anchorage. Repairs may be made with the same grout approved for use in the tendons as long as the volume of the void is less than 0.5 gal. In all other cases, a non-sanded grout meeting the requirements of the Required Physical Properties of Grout Section with a modified maximum permeability of 2,800 coulombs (ASTM C 1202 at 30 volts) shall be used. Non-sanded grouts shall have 95% passing on the #100 sieve and 90% passing the #170 sieve as determined by ASTM C 33. Each sieve may be washed and dried before weighing in accordance with the procedure in ASTM C 117 modified for sieve size.

(g) Acceptance by Previous Tests. To satisfy the intent of the tests outlined in the Grout Materials and Properties Section, results from previous projects utilizing identical grouts may be submitted to the Agency in lieu of executing new tests. However, if the previous results are unacceptable or if there is a significant difference in the materials used, then the Contractor

shall provide results from new tests for this project. Also, for pre-packaged grouts, the Agency may waive the requirements for these particular tests based upon satisfactory prior performance of the proposed grout material, mixing, and installation methods.

XX. GROUT SUPPLY QUALITY CONTROL. The Contractor shall provide to the Agency a copy of grout quality control data sheets from the Manufacturer for each lot number and shipment of grout material supplied to the site. Material with a total time from manufacture in excess of six months must be retested and certified by the supplier before use or be removed from the project and be replaced by approved materials. A lot is that parcel of material making up a particular shipment.

XX. EPOXY GROUT FOR ANCHORAGE POUR-BACKS. Pour-backs protecting post-tensioning anchorages shall be as specified herein.

The following products are approved for grouting anchorage pour-backs:

E3HP Epoxy Grout	Euclid Chemical 19218 Redwood Road Cleveland, OH 44110 (800) 321-7628
Sikadur 42 Grout Pak PT	Sika Corporation 12414 Lobelia Terrance Bradenton, FL 34202 (941) 713-1376
Masterflow 648 CP Plus (for use with standard aggregate load ration only)	BASF C C Building Systems 889 Valley Park Drive Shakopee, MN 55379 (813) 240-6400
Magmaflow Grout-Pak	Pilgrim Permacoat Inc 402 S. 22nd Street Tampa, FL 33605 (800) 637-3328
E-Bond 420 Grout System	E-Bond Epoxies Inc. 501 N E 33rd Street Fort Lauderdale, FL 33307 (954) 566-6555

(a) The material shall produce a low exothermic reaction and have flow and fill characteristics suitable for machine base plate applications. The material will be extended with the aggregate supplied by the manufacturer. Mix with the full aggregate loading unless the use of less aggregate is approved by the Agency.

(b) The material shall be factory pre-proportioned including factory supplied aggregate. Deliver products in original containers with manufacturer’s name, date of manufacture, product identification label, and batch numbers. Materials shall be within the manufacturer’s recommended shelf life. Store and condition the product in full compliance with manufacturer’s recommendations.

(c) The epoxy grout plus aggregate mix shall meet or exceed the specified physical properties stated herein as determined by the following standard ASTM test methods.

Property	Test Value	Test Method
Compressive Strength, Cubes (7 day cure at 77°F)	> 10,000 psi	ASTM C 579B
Tensile Strength at 7 days	> 2,100 psi	ASTM C 307
Flexural Strength (7 day cure at 77°F)	> 3,600 psi	ASTM C 580
Modulus of Elasticity (7day cure at 77°F)	< 2,100,000 psi	ASTM C 580
Coefficient of Thermal Expansion at 74 to 210° F	< 20 x 10^{-6} in/in/°F	ASTM C 531
Peak Exotherm, Specimen, 12 x 12 x 3 in.	< 150°F	ASTM D 2471
Slant Shear at 7 days (Bond Strength to Concrete)	> 3,000 psi	ASTM C 882
Thermal Compatibility	5 Cycles Passed	ASTM C 884
Linear Shrinkage at 7 days	0.025%	ASTM C 531
Flowability and Bearing Area	90% Contact area	ASTM C 1339
Gel Time, Specimen 12 x 12 x 3 in.	< 4:00 (hr.)	ASTM D 2471

XX. ELASTOMERIC COATING SYSTEM. Not used.

XX. PROTECTION OF PRESTRESSING STEEL.

(a) Before Installation of Tendons in Ducts. All prestressing steel shall be protected against physical damage at all times from manufacture to grouting or encasing in concrete. Prestressing steel that has sustained physical damage at any time shall be rejected. Any reel that is found to contain broken wires shall be rejected and the reel replaced. The wire must be bright and uniformly colored, having no foreign matter or pitting on its surface.

Prestressing steel shall be packaged in containers for protection of the steel 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. The corrosion inhibitor shall have no deleterious effect on the steel or concrete or bond strength of steel to concrete. Inhibitor carrier type packaging material shall conform to the provisions of Federal Specifications MIL-P-3420. Packaging or forms damaged from any cause shall be immediately replaced or restored to original condition.

The prestressing steel shall be stored in a manner which will at all times prevent the packing material from becoming saturated with water and allow a free flow of air around the packages. If the useful life of the corrosion inhibitor in the package expires, it shall immediately be rejuvenated or replaced.

At the time the prestressing steel is installed in the work, it

shall be free from loose rust, loose mill scale, dirt, paint, oil, grease, or other deleterious material. Removal of tightly adhering rust or mill scale will not be required. Prestressing steel that has experienced rusting to the extent it exhibits pits visible to the naked eye shall not be used in the work.

The shipping package shall be clearly marked with the heat number and with a statement that the package contains high-strength prestressing steel and care is to be used in handling, and the type, kind, and amount of corrosion inhibitor used, including the date when placed, safety orders, and instructions for use shall also be marked on the package or form. Specifically designate low relaxation (stabilized) strands per requirements of ASTM A 416. Strands not so designated will be rejected.

(b) After Installation of Tendons in Ducts. After installation in the ducts, prestressing steel shall be protected from corrosion and the duct system shall be sealed to prevent moisture intrusion from the time of tendon installation to the time of grouting. In addition, all grout vents shall be closed or plugged at all times during the period prior to grouting, except that low-point drainage vents shall remain open and point downward.

Grouting shall proceed as soon as possible after installation and stressing of the tendons. To minimize the adverse effects, the time from installing the tendons in an unstressed condition to grouting after stressing shall not exceed the following periods without approval of the Agency:

Very damp atmosphere (RH > 70%) or over salt water - 7 calendar days

Moderate to dry atmosphere (40% < RH < 70%) -20 calendar days

Very dry atmosphere (RH < 40%) – 40 calendar days

In this context, the "RH" is the average annual relative humidity for the site. For this project, the maximum time shall be 20 calendar days.
Any light surface discoloration or corrosion forming during this period shall not be cause for rejection of the prestressing steel.

Flushing of grout is not permitted and vacuum grouting is required to repair all voids and blockages. Flushing of ducts is only permitted if a lubricant is required to reduce the friction. When flushing is permitted by the Agency, use flush water containing slack lime (calcium hydroxide) or quicklime (calcium oxide) in the amount of 0.17 lb/gal.

Except when waived by the Agency in writing, failure to grout tendons within the time limit specified above will result in stoppage of the affected work as directed by the Agency.

(c) Tendon Protection Between Installation and Stressing. Measures shall be taken to protect the prestressing steel when there is a

period of more than 24 hours between installation of the tendons in ducts and stressing. Bare strand projecting out of an anchorage shall be wrapped in continuous plastic sheeting and sealed using waterproof tape extending from the tendon anchorage, and the anchorage opening shall be sealed with plastic and waterproof tape in a sufficient manner to prevent moisture intrusion. All grout vents shall be closed or plugged, all duct connections shall be sealed, and drainage vents shall be open, pointing downward.

(d) Use of Temporary Corrosion Inhibitors. The use of temporary corrosion inhibitors will not be permitted for this project.

xx. INSTALLATION OF DUCTS, GROUT INJECTION PORTS, AND OUTLET VENTS.

(a) General. All post-tensioning anchorages, ducts, inlet and outlet pipes, miscellaneous hardware, reinforcing bars, and other embedded items shall be accurately and securely fastened, at locations shown on the Plans or on the approved Fabrication Drawings, or as otherwise approved by the Agency. Ducts for tendons shall be made using the minimum number of duct splices possible.

(b) Tolerances. In their final position post-tensioning ducts shall be within the following tolerances:

Table of Duct Position Tolerances		
Tolerances	Vertical Position (Inches)	Lateral Position (Inches)
Horizontal tendons in slabs or in slab regions of larger members	±1/4	± 1/2
Longitudinal draped super-structure tendons in webs: Tendon over supports or in middle third of span	±1/4	±1/4
Tendon in middle half of web depth	±1/2	±1/4
Longitudinal, generally horizontal, superstructure tendons usually in top or bottom of member	±1/4	±1/4
Horizontal tendons in substructures and foundations	± 1/2	± 1/2
Vertical tendons in webs	Longitudinal position ±1	Transverse position ±1/4
Vertical tendons in pier shafts	±1/2	±1/4

In all other cases, tendons shall not be out of position by more than ± 1/4 inch in any direction.

Entrance and exit angles of tendon paths at anchorages and/or at faces of concrete shall be within ± 3 degrees [± 5%] of desired angle measured in any direction and any deviations in the alignment shall be accomplished with smooth transitions without any kinks.

Angle changes at duct joints must not be greater than ± 3 degrees [± 5%] in any direction and must be accomplished with smooth transitions without any kinks.

Anchorages shall be located within ± 1/4 inch of desired position laterally and ± 1 inch along the tendon except that minimum cover requirements must be maintained.

Anchorage confinement reinforcement in the form of spirals, multiple U shaped bars, or links shall be properly centered around the duct and start within 1/2 inch of the back of the main anchor plate.

If conflicts exist between the reinforcement and post-tensioning duct, the position of the post-tensioning duct shall prevail and the reinforcement shall be adjusted locally with the Agency's approval.

(c) Ducts. Ducts shall be accurately aligned and located as shown on the Plans or according to the approved Fabrication Drawings and as required herein. All internal ducts shall be secured in position at regular intervals not exceeding 30 inches for steel pipes, 24 inches for round plastic duct, and 12 inches for flat ducts to prevent movement, displacement, or damage from concrete placement and consolidation operations. Any additional mild reinforcing or other devices required to support post-tensioning ducts shall be supplied by the Contractor at no additional expense to the Agency.

For external tendons, ducts shall be straight between connections to internal pipes at anchorages, diaphragms, and deviation saddles and shall be supported at intermediate locations, as required, according to the Plans or approved Fabrication Drawings.

All duct alignments, including curves and straight portions, shall be smooth and continuous with no lips, kinks, or dents. This also applies to curves in pre-bent steel pipe.

All ducts shall be carefully checked and repaired as necessary before placing any concrete.

After installation of ducts, until grouting is complete, all ends of ducts, connections to anchorages, splices, and vents (inlets and outlets) shall remain sealed at all times. An absolute seal shall be provided of anchorage and duct termination locations by

using plumber's plugs or equal. Grout vents (inlets and outlets) shall be installed with plugs or valves in the closed position. Low point drainage outlets shall be left open. The use of duct tape shall not be permitted. Ducts shall be carefully inspected and repaired before placing of the concrete is started. Care shall be exercised during placement of the concrete to avoid displacing or damaging the ducts.

All splices, joints, couplings, vent connections (inlets and outlets), and valves shall be part of the approved post-tensioning system. Approved shrink-sleeve material may be used to repair duct. The use of duct tape to repair or seal duct shall not be permitted.

(d) Grout Vents (Inlets and Outlets) and Drains. Grout pipes shall be installed on each duct to serve as injection or evacuation vents during grouting and to allow the escape of air, water, grout, and bleed water. Drainage vents, point downward, shall be provided at low points of tendon profile to allow any accumulated moisture to be drained prior to installing tendons.

The length of an inlet or outlet shall be sufficient to extend out of the concrete to allow for proper closing. At all high points the outlet shall connect at the uppermost part of the duct profile.

Inlets and outlets shall be placed at locations shown on the Plans, on the approved Fabrication Drawings, and/or the approved Grouting Operation Plan (below). Locations shall be as follows:

(1) At the top of each tendon anchorage.

(2) At top of each grout cap.

(3) At each high point of the duct profile when the vertical distance between the highest and lowest point is more than 20 inches.

(4) At all low points. The vent (outlet) shall be free draining.

(5) At major changes in the cross-section of the duct.

(6) At each side of post-tensioning bar-couplers.

(7) At a distance of approximately 3 ft. from each high point in the direction of grout flow.

(8) For external tendons, provide vents as close to the inside face of the diaphragm as practical, located on the top of the duct.

(9) At other locations required by the Agency.

Grout pipes shall extend a sufficient distance out of the concrete member to allow for proper closing of valves.

(e) Care and Protection of Ducts, Vents, Anchorages, and Blockouts. Care shall be taken to ensure that all ducts, anchorages, blockouts, openings, and vents are kept clean and free of debris, fuel, oils, other contaminants, and site trash at all times prior to and after installing the tendons. Temporary plugs, seals, and covers shall be used. Minor damage to ducts may be repaired by removing the local damage and splicing duct or couplers onto the intact section (prior to the placing of concrete). Repair of major duct damage requires the removal and replacement of the entire duct section.

Connections from grout hose to inlet and ejection ports and to vents shall be kept free from dirt and be airtight.

(f) Placing Concrete. Methods used to place and consolidate concrete shall not displace or damage any of the post-tensioning ducts, anchorage assemblies, splices and connections, reinforcement, or other embedded items. Duct splices shall be made so as to prevent duct kinks during concrete placement. Suitable mandrels shall be used as needed to maintain duct alignment and shape.

(g) Proving of Post-Tensioning Ducts after Placing Concrete. Upon completion of concrete placement, longitudinal post-tensioning ducts shall be proven to be free and clear of any obstructions or damage and able to accept the intended post-tensioning tendons by passing a torpedo through the ducts. The torpedo shall have the same cross-sectional shape as the duct and be 1/4 inch smaller all around than the clear, nominal inside dimensions of the duct. No deductions shall be made to the torpedo section dimensions for tolerances allowed in the manufacture or fixing of the ducts. For straight ducts, the torpedo shall be at least 2 feet long. For curved ducts, the torpedo length shall be determined so that when both ends touch the outermost wall of the duct, the torpedo is 1/4 inch clear of the innermost wall. If the torpedo will not travel completely through the duct, the Agency may reject the member, unless a workable repair is made to clear the duct. The torpedo must pass through the duct easily, by hand, without resorting to excessive effort or mechanical assistance.

(h) Problems and Remedies. The Agency will reject ducts or any part of the work found to be deficient. No remedial or repair work shall be performed without the Agency's approval.

(i) Installing Tendons. If a tendon duct has been contaminated with chlorides, it shall be thoroughly flushed using lime treated potable water before placing the prestressing strands. The last two gallons of flushing water shall be tested for presence of chlorides and oils. Chlorides in the water must be less than 600 ppm. If chloride levels exceed 600 ppm, flushing shall continue until the chloride level is below 250 ppm. Oil-free compressed air shall then be blown through the duct to remove any excess water.

All bars shall be cut using an abrasive saw or an approved plasma cutter. Flame cutting is not allowed.

Permanent tendons shall not be installed before the completion of

testing as required by this Special Provision or the Plans.

xx. POST-TENSIONING OPERATIONS.

(a) General.

(1) Concrete Strength. Post-tensioning shall only be applied when the concrete has attained the required compressive strength, as noted on the Plans, and as determined from test cylinders cured under the same conditions as the structural concrete.

(2) Stressing Tendons. All post-tensioning steel shall be tensioned with hydraulic jacks so that the post-tensioning force is not less than that required by the Plans or approved Fabrication Drawings, or as otherwise approved by the Agency. Monostrand jacks shall not be used to stress tendons with five or more strands.

(3) Maximum Stress at Jacking. The maximum temporary stress (jacking stress) in post-tensioning steel shall not exceed 80% of the specific minimum ultimate tensile strength. Tendons shall not be overstressed to achieve elongation.

(4) Initial and Permanent Stress. The post-tensioning steel must be anchored at initial stresses that will result in the long term retention of permanent stresses or forces of no less than those shown on the Plans or the approved Fabrication Drawings. Unless otherwise approved by the Agency, the initial stress after anchor set must not exceed 70% of the specified ultimate tensile strength of the post-tensioning steel.

Permanent stress and permanent force are the stress and force remaining in the post-tensioning steel after all losses, including long term creep and shrinkage of concrete, elastic shortening of concrete, relaxation of steel, losses in the post-tensioning steel from the sequence of stressing, friction and unintentional wobble of the ducts, anchor set, friction in the anchorages, and all other losses peculiar to the post-tensioning system.

(5) Stressing Sequence. Except as noted on the Plans, approved Fabrication Drawings, or Erection or Post-Tensioning Manual, the permanent post-tensioning tendons shall be stressed from one end.

For construction in stages where some tendons are required to be stressed before others, install and stress tendons in accordance with the Plans or approved Fabrication Drawings or as otherwise approved by the Agency.

(b) Stressing Jacks. When stressing tendons, only use equipment furnished by the supplier of the post-tensioning system (tendons, hardware, anchorages, etc.)

(1) Stressing Equipment. Each jack shall be equipped with a

pressure gauge having an accurate reading dial at least six inches in diameter for determining the jack pressure.

(2) Calibration. Prior to use for stressing on the project, each jack and its gauge shall be calibrated as a unit. Initial jack calibration shall be done, using a proven load cell, by the post-tensioning supplier or by an independent testing laboratory, approved by the Agency. The calibration shall consist of three test cycles with the cylinder extension of the jack in various positions (i.e. 2 inch, 4 inch, 8 inch stroke). At each pressure increment, the forces from each test cycle shall be averaged to obtain an average force. Calibration shall be done with the cylinder extension approximately in the position that it will be when applying the final jacking force and with the jacking assembly (jack, pump, hoses, etc.) set up in an identical configuration to that which will be used at the job site (i.e. same length hydraulic lines). Load cells used for calibration shall have been calibrated within the last 12 months. Certified calibration calculations and a calibration chart, both in English units of measure, shall be furnished to the Agency for each jack and gauge unit. Documentation denoting the load cell(s) calibration date and tractability to NIST (National Institute of Standards and Technology) along with the jack/gauge calibration shall be provided.

Recalibration of each jack shall be done at six month intervals and at other times when requested by the Agency. At the option of the Contractor, calibrations subsequent to the initial laboratory calibration may be accomplished by the use of a master gauge. The master gauge shall be calibrated at the same time as the initial calibration of the jacks, and shall be part of the unit for each jack. The data recorded during the initial calibrations shall be furnished to the Agency for use in the field. The master gauge shall be supplied by the Contractor in a protective waterproof container capable of protecting the calibration of the master gauge during shipment. The Contractor shall provide a quick-attach coupler next to the permanent gauge in the hydraulic lines which enables the quick and easy installation of the master gauge to verify the permanent gauge readings. The master gauge shall remain in the possession of the Agency for the duration of the project.

If a jack is repaired or modified, including replacing the seals or changing the length of the hydraulic lines, the jack shall be recalibrated by the approved testing laboratory. No extra compensation will be allowed for the initial or subsequent jack calibrations or for the use and required calibration of a master gauge.

(c) Stressing of Tendons. The tensioning process shall be so conducted that tension being applied and the elongation of the post-tensioning steel may be measured at all times. A permanent record shall be kept of gauge pressures and elongations at all times and shall be submitted to the Agency. The post-tensioning

force may be verified as deemed necessary by the Agency.

Do not overstress the tendons to achieve the theoretical elongation. Elongations shall be measured to the nearest 1/16 inch.

The anchor force for all permanent post-tensioning bars shall be verified with a lift-off after initial stressing operations. The resulting lift-off shall be within ±7% of the expected final anchor force as specified in the Plans.

(d) Friction. The Plans were prepared based on the assumed friction and wobble coefficients and anchor set noted on the Plans. Calculations shall be submitted to show a typical tendon force diagram, after friction, wobble and anchor set losses, on the Fabrication Drawings based upon the expected actual coefficients and values for the post-tensioning system used. These coefficients and values shall be shown on the Fabrication Drawings.

If, in the opinion of the Agency, the actual friction significantly varies from the expected friction, revise post-tensioning operations so the final tendon force is in agreement with the Plans.

(e) Cutting of Post-Tensioning Steel. Post-tensioning steel shall be cut by an abrasive saw or an approved plasma-cutter within 3/4 to 1-1/2 inches away from the anchoring device. Flame cutting of prestressing steel is not allowed.

(f) Record of Stressing Operations. The Contractor shall keep a record of the following post-tensioning operations for each tendon installed:

(1) Project name, Project ID.

(2) Contractor and/or subcontractor.

(3) Tendon location, size and type.

(4) Date tendon was first installed in ducts.

(5) Reel number for strands and heat number for bars.

(6) Tendon cross-sectional area.

(7) Modulus of elasticity.

(8) Date stressed.

(9) Jack and Gauge numbers per end of tendon.

(10) Required jacking force.

(11) Gauge pressures.

(12) Elongations (theoretical and actual).

(13) Anchor sets (anticipated and actual).

(14) Lift-Off Values.

(15) Stressing sequence (i.e. tendons to be stressed before and after).

(16) Stressing mode (one end/two ends/simultaneous).

(17) Witnesses to stressing operation (Contractor and Agency).

(18) Date grouted.

Any other relevant information shall be recorded. A complete copy of all stressing and grouting operations shall be provided to the Agency.

(g) Cleaning and Flushing Tendons. Tendons shall not be flushed with water except as directed by the Agency.

If flushing is to be performed as directed by the Agency, the inside of the duct system shall be flushed with water (under pressure) to remove all traces of the contaminants. Following the flushing operation, water shall be totally drained from within the duct system and it shall be blown out with compressed oil-free air to the extent necessary to dry the prestressing steel and inside surfaces of the ducts. The waste fluid flushed from the duct system shall be captured and disposed of properly.

(h) Tendon Protection. Within four hours after stressing, install grout caps and seal all other tendon openings. If acceptance of the tendon is delayed, all tendon openings and open ends of the anchorages shall be temporarily sealed. If tendon contamination occurs, the tendon shall be removed and replaced.

(i) Re-Use of Temporary Post-Tensioning Bars. Post-tensioning bars used to apply temporary post-tensioning may be reused as temporary bars if they are undamaged and in accordance with the supplier’s recommendations.

xx. GROUTING.

(a) General. After post-tensioning and anchoring of a tendon has been completed and accepted, the annular space between the prestressing steel and the duct shall be grouted in accordance with this Special Provision. Also grout all empty ducts. The interval between post-tensioning and grouting shall be limited as specified above. Immediately after post-tensioning, all grout vents, anchorages, and duct connections of each tendon shall be temporarily sealed to prevent entrance of air and water until just prior to tendon grouting.

At least six weeks before grouting commences, the Contractor shall submit to the Agency for review and approval a "Grouting Operation Plan". Written approval of the plan by the Agency is required before grouting proceeds. Any adjustments to the plan

as a result of trials or mock-ups shall be incorporated. Grouting operations shall be under the supervision of a qualified and experienced person, acceptable to the Agency.

At a minimum the Grouting Operation Plan shall address the following:

(1) Names and proof of training for the grouting crew and the crew supervisor in conformance with this specification.

(2) Type, quantity, and brand of materials used in grouting including all certifications required.

(3) Type of equipment furnished, including capacity in relation to demand and working condition, as well as back-up equipment and spare parts.

(4) General grouting procedure.

(5) Duct pressure test and repair procedures.

(6) Method to be used to control the rate of flow within ducts.

(7) Theoretical grout volume calculations.

(8) Mixing and pumping procedures.

(9) Direction of grouting.

(10) Sequence of use of the inlets and outlet pipes.

(11) Procedures for handling blockages.

(12) Procedures for possible post grouting repair.

(13) Contractor's QC forms that are to be signed daily by Grout Supervisor.

Before grouting operations commence, a joint meeting shall be held with the Contractor, Grouting Crew, and Agency to discuss and understand the grouting operation plan, required testing, and corrective procedures.

(b) Supplies. Before grouting operations start, an adequate supply of water and compressed air for clearing and testing the ducts, mixing, and pumping the grout shall be provided. Where water is not supplied through the public water supply system, a water storage tank of sufficient capacity must be provided.

A sufficient supply of grout material shall be available to complete the planned grouting operation.

(c) Equipment.

(1) General. Grouting equipment shall consist of measuring devices for water, a high-speed shear colloidal mixer, a storage hopper (holding reservoir), and a pump with all the

necessary connecting hoses, valves, and pressure gauge. Pumping equipment shall have sufficient capacity to ensure that the post-tensioning ducts to be grouted can be filled and vented without interruption at the required rate of injection in not more than 30 minutes.

An air compressor and hoses with sufficient output to perform the required functions shall be provided.

(2) Mixer, Storage Hopper. A high speed shear colloidal mixer shall be provided capable of continuous mechanical mixing to produce a homogeneous and stable grout free of lumps and un-dispersed cement. The colloidal grout machinery will have a charging tank for blending and a holding tank. The blending tank must be equipped with a high shear colloidal mixer. The holding tank must be kept agitated and at least partially full at all times during the pumping operation to prevent air from being drawn into the post-tensioning duct.

Water shall be added during the initial mixing by use of a flow meter or calibrated water reservoir with a measuring accuracy equal to one percent of the total water volume.

(3) Grout Pumping Equipment. Grout pumping equipment capable of continuous operation shall be provided which will include a system for circulating the grout when actual grouting is not in progress.

The equipment will be capable of maintaining pressure on completely grouted ducts and will be fitted with a valve that can be closed off without loss of pressure in the duct.

Grout pumps will be positive displacement type and will provide a continuous flow of grout and will be able to maintain a discharge pressure of at least 145 psi.
Pumps will have seals adequate to prevent oil, air, or other foreign substances entering the grout and to prevent loss of grout or water. The capacity will be such that an optimal rate of grouting can be achieved.

A pressure gauge having a full scale reading of no more than 300 psi will be placed at the duct inlet. If long hoses (in excess of 100 feet) are used, two gauges shall be provided, one at the pump and one at the inlet.

The diameter and rated pressure capacity of the grout hoses must be compatible with the pump output.

(4) Vacuum Grouting Equipment. Vacuum grouting equipment and experienced operators shall be provided at the job site within 48 hours notice and shall consist of the following:

a. Volumeter for the measurement of void volume.

b. Vacuum pump with a minimum capacity of 10 cfm and equipped with a flow-meter capable of measuring

amount of grout being injected.

c. Manual colloidal mixers and/or dissolvers (manual high speed shear mixers), for voids less than 20 liters in volume.

d. Standard colloidal mixers, for voids 20 liters and greater in volume.

Test shall be performed to confirm the accuracy of the volume-measuring component of the vacuum grouting equipment each day before using the vacuum grouting equipment. Either water or grout shall be used for testing standard testing devices with volumes of 0.5 gal and 6.5 gal and an accuracy of equal to or less than 4 oz. One test shall be performed with each device. The results must verify the accuracy of the void volume-measuring component of the vacuum grouting equipment within 1% of the test device volume and must verify the accuracy of the grout volume component of the vacuum grouting equipment within 5% of the test device volume. The Agency shall be present when any tests are performed.

(5) Availability of Testing Equipment. Equipment for field-testing shall be available at the job site.

(6) Stand-by Equipment. During grouting operations, a stand-by grout mixer and pump shall be provided.

(d) Field Trial and Mockup Tests.

(1) General. The Contractor shall perform field trial tests and field mockup tests at the same time using the same materials, personnel, and equipment used in production grouting. The Contractor shall submit to the Agency, at least 4 weeks before scheduled start of the field mockup tests, a detailed written plan covering test setup, materials, ducts, inlets, outlets, anchorages, prestressing element, grouting, and dissection procedures. The Agency shall be present when any tests are performed.

(2) Field Trial Tests. The following tests shall be performed on the grout as described in Table 1 of this Specification:

a. Strength test (ASTM C 942).

b. Volume change test (ASTM C 1090).

c. Pumpability and fluidity test (ASTM C 939 Modified).

d. Schupack pressure bleed test (ASTM C 1741).

(3) Field Mockup Tests. The field mockup should follow the inclined tube test setup per EN 445, "Grout for Prestressing Tendons – Test Methods", American National Standards Institute. Not less than 3 days after grouting, the Contractor shall dissect the test specimen for a

thorough examination of grout, prestressing steel, and the duct. Special attention shall be given to the examination of the tendon high points for bleed pockets, soft grout, segregation, or corrosion. A report describing the trial test (including any variations from the test plan) and its findings shall be submitted to the Agency for approval a maximum of 2 weeks after dissection. The report shall document all voids in the grout with respect to size, location, and any presence of free moisture or corrosion.

(4) Test Acceptance. The Agency shall determine whether the results of the mockup test satisfy the acceptance requirements. Additional tests may be required by the Agency.

(e) Grouting Operations.

(1) General. Tendons shall be grouted in accordance with the procedures set forth in the approved grouting operation plan. All empty ducts shall also be grouted.

(2) Temperature Considerations. The maximum grout temperature must not exceed 90°F at the grout inlet. Chilled water and/or pre-cooling of the bagged material to maintain mixed grout temperature below the maximum allowed temperature shall be used. Grouting operations shall be prohibited when the temperature of the grout is below 45°F. Grouting operations shall be prohibited when the ambient temperature is below 40°F or is 40°F and falling. Grouting operations shall be prohibited if freezing temperatures are forecasted within the next two days and it is expected the concrete temperature surrounding the duct will fall below 40°F. When it is anticipated that the ambient temperature will fall below 32°F, ducts shall be kept free of water so as to avoid freeze damage to ducts.

(3) Mixing and Pumping. The grout shall be mixed with a metered amount of water to produce a uniformly blended, homogeneous grout. The mix shall be continuously agitated until grouting is complete.

(4) Injecting Grout. All grout outlets shall be opened before starting the grouting operation. Tendons shall be grouted in accordance with the Grouting Operations Plan.

Unless approved otherwise by the Agency, grout shall be pumped at a rate of 16 feet to 50 feet of duct per minute. Normal grouting operations shall be conducted at a pressure range of 10 psi to 50 psi measured at the grout inlet; the maximum pumping pressure of 145 psi at the grout inlet for round ducts and 75 psi for flat ducts in deck slabs shall not be exceeded.

Grout pumping methods shall ensure complete filling of the ducts and complete encasement of the steel. Grout must flow from the first and subsequent outlets until any residual water or entrapped air has been removed prior to

closing the outlet.

Grout shall be pumped through the duct and continuously discharged at the anchorage and grout cap outlets until all free water and air has been discharged and the consistency of the grout is equivalent to that of the grout being pumped into the inlet. The anchorage outlet shall be closed and a minimum of 2 gallons of grout shall be discharged from the grout cap into a clean receptacle. The grout cap outlet shall then be closed.

After all outlets have been bled and sealed, the grout pressure shall be raised to not less than 50 psi and not more than 75 psi and the inlet valve sealed. Wait two minutes to determine if any leaks exist. If leaks are present, they shall be fixed using methods approved by the Agency. The above process shall be repeated until no leaks are present. If no leaks are present, the pressure shall be reduced to 50 $\pm$ 10 psi and a minimum of five minutes shall elapse for any entrapped air to flow to the high points. After the minimum five minute period has expired, the pressure shall be raised as needed to discharge grout at each high point outlet to eliminate any entrapped air or water. The process shall be completed by locking-off at a pressure of 30 psi.

If the actual grouting pressure exceeds the maximum allowed, the inlet will be closed and the grout will be pumped at the next outlet, which has just been, or is ready to be, closed as long as a one-way flow is maintained. Grout will not be pumped into a succeeding outlet from which grout has not yet flowed. If this procedure is used, the outlet/inlet which is to be used for pumping will be fitted with a positive shut-off and pressure gage.

When complete grouting of the tendon cannot be achieved by the steps stated herein, the grouting operation shall stop. After waiting 48 hours, the tendon shall be filled with grout in accordance with the Post-Grouting Sealing of Grout Vents section.

All waste grout and liquids shall be captured and disposed of properly.

(f) Grout Testing During Grouting Operations. Acceptance testing for grout physical properties shall be performed during grouting operations.

The following minimum number of production tests shall be carried out in the field in accordance with Table 1 in the Required Physical Properties of Grout Section:

(1) One pressure bleeding test per day (ASTM C 940). The sample shall be taken at the mixer.

(2) Two wet density tests per day or when there is a visual or apparent change in the characteristics of the grout at the mixer and one at the duct outlet (ASTM C 138).

(3) One strength test per day (ASTM C 942).

(4) Two fluidity test (flow cone) – one at the mixer and one at the duct outlet (ASTM C 939 Modified), repeat testing every 2 hours of grouting operations. The efflux time shall be within 5 seconds of the values established during laboratory testing.

Grout materials shall be conditioned as required to limit the grout temperature at the inlet end of the grout hose to 90°F. Prior to performing repair grouting operations, grout materials shall be conditioned as required to limit the grout temperature at the inlet end of the grout hose to 85°F. The temperature of the grout at the inlet end of the grout hose shall be checked hourly.

(g) Construction Traffic and Operations Causing Vibrations. During grouting and for a period of 4 hours upon completion of grouting, eliminate vibrations from all sources such as moving vehicles, jackhammers, compressors, generators, pile driving operations, soil compaction, etc., that are operating within 300 feet down-station and 300 feet up-station of the ends of the span in which grouting is taking place.

(h) Post-Grouting Inspection. Unless grout caps are determined to have voids by sounding, caps shall not be drilled. Drilling equipment shall automatically shut-off when steel is encountered. Inspection shall be performed in the presence of the Agency. Within 48 hours of completion of the inspections, all voids shall be filled using the vacuum injection grouting process.

If tendon grouting operations were prematurely terminated prior to completely filling the tendon, then the duct shall be drilled into and voided areas explored with an endoscope. Probing shall not be allowed. The location and extent of all voided areas shall be determined. Grout inlets shall be installed as needed and the voids filled using volumetric measuring vacuum grouting equipment.

(i) Post-Grouting Sealing of Grout Vents. Shut off valves shall not be opened at injection or evacuation vent pipes, nor shall pipes or caps be removed until the grout has set and inspection of vents has been accepted.

Intermediate grout vent pipes (inlets and outlets) along an internal tendon (including rigid steel pipes in diaphragms) shall be installed straight to facilitate possible drilling and inspection for complete grout filling using, if necessary, an endoscope. Place threaded plastic caps in all inlet/outlet locations required in the Plans. The inlet/outlet locations shall be repaired as shown on the Plans using the same approved epoxy grout as used for the anchorage pour-backs. The surface to receive the epoxy material shall be prepared in strict compliance

with the manufacturer's recommendations.

(j) Record of Grouting Operations. The Contractor shall keep a record of all grouting operations for each tendon installed, stressed, and grouted. This shall include, but shall not necessarily be limited to, the following:

(1) Tendon or group of tendons grouted in one continuous operation.

(2) Date grouted.

(3) Number of days from stressing to grouting, per tendon.

(4) Type of grout mix and additives.

(5) Fluidity of grout (flow-cone) per batch for both newly mixed and 30 minute, rested grout.

(6) Density of grout per batch of fresh mix.

(7) Location of injection vent and direction of grout flow (note - injection vent may not necessarily be at an end anchorage).

(8) Applied grouting pressure during normal pumping and maximum pressure sustained for two minutes after closing all vents grouting.

(9) Theoretical volume of grout anticipated in order to fill the duct or ducts.

(10) Actual quantity of grout in place in the duct(s) after grouting (for one grout mixing and injection operation, this is the quantity mixed less the quantity wasted at the vents, less the quantity remaining in the mixer and injection equipment).

(11) Summarize any difficulties encountered and corrective action taken.

(12) Witnesses to grouting operation (Contractor and Agency).

Within 72 hours, the Contractor shall provide the Agency with a complete copy of all tendon stressing and grouting operations.

xx. PROTECTION OF POST-TENSIONING ANCHORAGES. After acceptance of grouting, all miscellaneous material (tie wire, tape, plastic, etc.) used for temporary protection or sealing shall be removed prior to carrying out further work to protect anchorages.

Details for anchor protection shall be shown on the Fabrication Drawings in accordance with the Plans and the following requirements.

(a) Installation of Anchor Protection. Anchorage protection shall be installed within seven days from the satisfactory completion of the grouting. The application of the elastomeric coating may be delayed for up to 90 days after grouting. Use plastic or

stainless steel threaded caps to plug all grout inlets/outlets.

(1) Pour-Backs. An approved epoxy grout compound meeting the requirements of the Epoxy Grout for Anchorage Pour-Backs Section shall be used to construct pour-backs at anchorages.

All laitance, grease, curing compounds, surface treatments, coatings, and oils shall be removed by grit blasting or water blasting the substrate surface using a minimum 10,000 psi nozzle pressure. Surfaces shall be flushed with potable water and blown dry. Surfaces must be clean, sound and without any standing water. In case of dispute, ACI 503 shall be used for substrate testing and a minimum of 175 psi tension (pull-off value) shall be attained.

The epoxy shall be mixed and placed per manufacturer's current standard technical guidelines. All pour-backs shall be constructed with leak proof forms to create neat lines. The epoxy compound may require pumping for proper installation. Forms shall be constructed so as to maintain a liquid head to insure intimate contact with the concrete surface. Vents shall be provided as needed to allow for the escape of air to insure complete filling of the forms. Pour-backs shall provide a minimum cover over the grout cap of 1-1/2 inches for anchors in the superstructure and 3 inches for anchors in the substructure.

(b) Anchors at Surfaces Exposed to Weather Action. The following applies to anchors in expansion joint diaphragms, at ends of girders under expansion joint devices or strip seals, substructures, or other similar surfaces directly exposed to weather or potential run-off or leakage. The protection of the anchors at these locations shall be as follows:

(1) Permanent grout cap.

(2) Encapsulating epoxy grout pour-back.

Concrete details under the expansion joint shall incorporate a drip flange (not a v-groove) to provide a positive, protective edge for the top of the elastomeric seal coat.

xx. METHOD OF MEASUREMENT. The quantity of Special Provision (Post-Tensioning) to be measured for payment will be on a lump sum basis for each component specified in the complete and accepted work.

xx. BASIS OF PAYMENT. The accepted quantity of Special Provision (Post-Tensioning) will be paid for at the Contract lump sum price. Payment will be full compensation for making required Working Drawing submittals; furnishing, installing, stressing, and grouting all permanent post-tensioning tendons; anchorage assemblies and associated supplemental reinforcing steel required by the supplier; post-tensioning system hardware which is not embedded in concrete; ducts; flushing lubricants or contaminants from the ducts (if required); grout and grouting; all testing; protection of post-tensioning anchorages, vents, inlets, and outlets; and all labor, materials, tools, equipment,

and incidentals necessary to complete the work.

Anchorage components, ducts, and similar items of post-tensioning system hardware embedded within precast or cast-in-place concrete will be deemed to be included in the cost of the precast components or cast-in-place concrete.

If the Contractor constructs the structure with an accepted alternate not detailed on the Plans, payment will be at the Contract lump sum price bid.

Permanent post-tensioning strand or bar tendons which are an integral part of individual precast concrete units will be paid for under this item and will not be considered incidental to the cost of the precast concrete units.

When all Fabrication Drawings have been submitted and approved, a payment of 15 percent of the Contract lump sum price will be allowed. Further payments totaling 70 percent of the Contract lump sum price will be paid on a pro-rated basis for the duration of the work. The remaining 15 percent of the Contract lump sum price will be paid following successful placement, stressing, grouting, inspection, protection, approval, and acceptance by the Engineer.

Payment will be made under:

Pay Item	Pay Unit
900.645 Special Provision (Post-Tensioning, Pier Cap)	Lump Sum
900.645 Special Provision (Post-Tensioning, Pier Sub-Cap)	Lump Sum