# SECTION 10
# PRESTRESSING

## 10.1 Description

Post-tensioning prestressed concrete members consist of the furnishing, installing, stressing and grouting of prestressing tendons. In this process, prestressing steel, which may be strands, wires or bars, is installed through preformed voids or ducts in the concrete, stressed up to a predetermined load and anchored directly against the hardened concrete, initially imparting stresses through end bearing. Grout is then injected into the ducts to completely fill all remaining voids and to seal the permanently stressed tendons.

This also includes furnishing and installing all the hardware and any other appurtenant items necessary for the particular prestressing system used, including but not limited to ducts, anchorage assemblies, supplementary steel reinforcing bars and grout used for pressure grouting ducts and all associated operations.

The submission of shop and working drawings and manuals shall be governed by the provisions of CMS and these special provisions.

## 10.2 Terminology

Post-Tensioning: The application of a compressive force to the concrete by stressing tendons or bars after the concrete has been cast and cured. The force in the stressed tendons or bars in transferred to the concrete by means of anchorages.

Post-Tensioning Scheme or Layout: The pattern, size and locations of post-tensioning tendons provided by the Designer on the Contract Plans.

Post-Tensioning System: A proprietary system where the necessary hardware (anchorages, wedges, strands, bars, couplers, etc.) is supplied by a particular manufacturer or manufacturers of post-tensioning components.

Tendon: A high strength steel member made up of a number of strands, wires or bars.

Strand: An assembly of several high strength steel wires wound together. Strands usually have six outer wires helically wound around a single straight wire of a similar diameter.

Wire: A single, small diameter, high strength steel member and, normally, the basic component of a strand, although some proprietary post-tensioning systems are made up of individual or groups of single wires.

Bar: Post-tensioning bars are high strength steel bars, normally available from 15 to 36mm diameter and usually threaded with very coarse thread.

Coupling: The means by which the prestressing force may be transmitted from one partial length prestressing tendon to another.

Anchorage: An assembly of various hardware components which secure a tendon at its ends after it has been stressed and imparts the tendon force into the concrete,

Anchor plate: That part of the anchorage which bears directly on the concrete and through which the tendon force is transmitted.

Wedges: A small conically shaped steel component placed around a strand to grip and secure it by wedge action in a tapered hole through a wedge plate.

Wedge Plate: A circular steel component of the anchorage containing a number of tapered holes through which the strands pass and are secured by conical wedges.

Set (Also Anchor Set or Wedge Set): Set is 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.

Anticipated Set: Anticipated set is that set which is assumed to occur in the design calculation of the post-tensioning forces immediately after load transfer.

## 10.3 Alternate Post-Tensioning Scheme/System

An alternate Post-Tensioning Scheme or system other than that shown on the plans may be submitted by the contractor for the Engineer's approval provided that the proposed alternate scheme/system fulfills the following requirements:

(1) The prestress system is a type described in 10.4

(2) The net compressive stress in the concrete after all losses is at least as large as that provided by the scheme shown on the Plans.

(3) The distribution of individual tendons at each cross section generally conforms to the distribution shown on the Plans.

(4) The ultimate strength of the structure with the proposed post-tensioning scheme meets the requirements of Section 9 of the AASHTO Standard Specifications for Highway Bridges, and shall be equivalent to the ultimate strength provided by the original design.

(5) Stresses in the concrete and prestressing steel at all sections and at all stages of construction meet the requirements of the Design Criteria noted on the Plans.

(6) All provisions of the Design Criteria noted on the Plans shall be satisfied.

(7) The Contractor fully redesigns and details, as required, the elements where the alternate post-tensioning scheme is proposed to be used.

(8) The contractor submits complete shop drawings including post-tensioning scheme and system reinforcing steel, and concrete cover; and design calculations (including short and long term prestress losses) for the Engineer's approval.

(9) Any alternate post-tensioning scheme or system approved by the Engineer, which results in a change in quantity from that shown on the plans, shall be paid based on the quantity actually used and accepted or the plan quantity, whichever is less, and at the unit bid price.

## 10.4 Materials

### 10.4.1 Prestressing Material

#### 10.4.1.1 Prestressing Steel

(a) Strand: Unless otherwise noted on the plans, strand shall be uncoated, 1860 MPa, low relaxation 7-wire strand conforming to the requirements of ASTM A 416

(b) Bar: Unless otherwise noted on the plans, bar shall be uncoated, 1035 MPa, high strength, coarse thread bar conforming to the requirements of ASTM A 722, Type II.

(c) Wires: Unless otherwise noted on the plans, wire shall be uncoated, low relaxation wire conforming to the requirements of ASTM A 421.

The proper use of strand, bars and wires is predicated upon the use of suitable accessory materials. Details for the use of these materials shall be furnished by the manufacturer in connection with shop and working drawings submittals.

#### 10.4.1.2 Bar and Tendon Couplers

For permanent applications, the use and location of bar and tendon couplers shall be subject to approval of the Engineer. Where bars are extended by the use of couplers, the assembled units shall develop at least 100% of the manufacturer's minimum specified ultimate tensile strength of the bar, tested in an unbonded state without exceeding the anticipated set. The coupling of tendons shall not reduce the elongation at rupture below the requirements of the tendon itself. Tendon couplers shall develop at least 100% of the minimum ultimate tensile strength of the tendon.

#### 10.4.1.3 Prestress Anchorages

All prestressing steel shall be secured at the ends by anchoring devices meeting the approval of the Engineer. The anchorages shall develop at least 100% of the minimum specified ultimate tensile strength of the prestressing steel, tested in an unbonded state without exceeding the anticipated set. Certified copies of test results for the anchorage system shall be supplied to the Engineer at no additional cost. The anchorage shall be so arranged that the prestressing force in the tendon may be verified prior to the removal of the stressing equipment.

The use of two part wedges which show any sign of slippage or failure to grip the tendon without exceeding the anticipated set, shall be immediately discontinued and the Contractor shall be required to furnish and use acceptable alternative three part wedges for anchoring post.tensioning strands at no additional cost to the Employer.

The anchoring devices shall effectively distribute tendon forces to the concrete. Such devices shall conform to the following requirements :

(a) The average bearing stress in the concrete created by the bearing plate shall not exceed the values as determined by the following equations:

At service load:

$$fcp = 0.6 f'c \sqrt{\left(\frac{Ab'}{Ab}\right)}$$

but not greater than 1.25f′c

At transfer laod:

$$fcp = 0.8 f'ci \sqrt{\left(\frac{Ab'}{Ab} - 0.2\right)}$$

but not greater than 1.25 f′ ci

Where fcp = Permissible concrete compressive stress

f′c = Compressive strength of concrete (28 days)

f′ ci = Compressive strength of concrete at time of initial prestress (transfer)

A′ b = Maximum area of the portion of the concrete anchorage surface that is geometrically similar to and concentric with the area of the anchorage

Ab = Bearing area of the anchorage

The stresses calculated at application of the post.tensioning force and at service load shall be limited to 35 and 43 Mpa, respectively, as absolute maximum values, even if the concrete strength is in excess of 27 Mpa at transfer (load application) and/or 35 MP at 28 days.

(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 or cause visible distortion of the anchorage plate when 100% of the ultimate strength of the tendon is applied. Certified test reports from an approved independent testing laboratory, verifying compliance with this requirement, shall be provided to the Engineer for each type and/or size of anchoring device.

Alternatively, anchorage devices which do not meet with either or both of the above requirements [(a) and (b)] may be accepted on the basis of new or previous tests performed in accordance with and meeting the requirements of the 1989 AASHTO Guide Specifications for the Design and Construction of Segmental Concrete Bridges, Division II, Section 4.2. Special Anchorage devices shall be incorporated in the structure at no additional cost.

10.4.1.4 Ducts

10.4.1.4.1 General

Unless specifically noted on the Plans or otherwise approved by the Engineer, ducts for post-tensioning shall conform to the requirements of this specification.

Ducts embedded in the concrete for prestressing steel shall be either galvanized ferrous metal, or high density virgin polyethylene, except that high density virgin polyethylene will not be allowed at locations where galvanized ferrous metal is designated on the plans, or when the radius of curvature is less than 9m.

Polyethylene ducts shall be sufficiently rigid to withstand placement of concrete, grouting and construction loads without damage or excessive deformation, while remaining mortar-tight Semirigid polyethylene ducts embedded in the concrete shall conform to ASTM D 3350 and have a wall thickness of 1.25 ± 0.25 mm. Internal ducts shall have a white coating on the outside, or shall be white material with ultra violet stabilizers added. Rigid polyethylene ducts used for external tendons shall be rigid pipe conforming to ASTM D 2447, ASTM F 714 or ASTM D 2239. For external use, the ducts shall have an outside diameter to wall thickness ratio of 21 or less.

Plastic material used shall not react with concrete or enhance corrosion of prestressing steel and shall be free of water soluble chloride.

10.4.1.4.2 Size of Ducts

Ducts for multi-strand, multi-bar or multi-wire tendons shall have a minimum size which provides an inside area at least 2.5 times the net area of the prestressing steel. Ducts for single strand, single bar or single wire tendons shall have an inside diameter at least 10mm larger than the nominal diameter of the strand, bar or wire.

10.4.1.4.3 Ferrous Metal Ducts

Ferrous metal duets shall be galvanized. Rigid metal ducts may be fabricated with either welded or interlocked seams. Ducts shall bend without crimping or flattening and shall have sufficient strength to maintain their correct alignment during placing of concrete. Joints between sections of ducts shall have positive metallic connections which do not result in angle changes at the joints.

10.4.1.4.4 Epoxy Coated Metal Ducts

Epoxy Coated Metal Ducts shall not be used.

10.4.1.4.5 Polyethylene (P.E) Ducts and Pipes

Ducts and pipes shall be sufficiently rigid to withstand placement of concrete, grouting and construction loads without damage or excessive deformation, while remaining watertight and shall be in accordance with ASTM D 2239 or ASTM D 3350 with a cell classification PE3454336 or ASTM D 1248, Type 3, Grade 34. Category 5.

Plastic material used shall not react with concrete or enhance corrosion of prestressing steel and shall be free of water soluble chloride.

Smooth pipes shall not be used in locations embedded in tile concrete. Smooth pipes are acceptable for use with external tendons.

Ducts, pipes and all connections shall be capable of withstanding the pressure required for flushing the ducts in the event of an aborted grouting operation.

10.4.1.4.6 Steel Pipes

'Where called for on the Plans, steel pipes shall conform to ASTM A 53, Grade B Schedule 40. The steel pipes shall be galvanized.

10.4.1.5 Grout Vents, Injection and Ejection Pipes

Vents shall be 21.3 mm minimum outside diameter standard pipe or suitable plastic pipe. Neither metallic nor plastic components, if selected and approved, shall react with the concrete or enhance corrosion of the prestressing steel. Plastic components shall be free of water soluble chlorides.

Grout injection pipes shall be fitted with positive mechanical shut-off valves. Vents and ejection pipes shall be fitted with valves or other devices capable of withstanding the grout pumping pressures.

10.4.1.6 Grout

Grout shall consist of portland cement and water, and may contain admixtures if approved by the Engineer. Portland cement shall be Type 11 complying with Section 701.02. Type III Portland cement will not be permitted. Cement used for grouting shall be fresh and shall not contain any lumps or other indication of hydration or "pack set". Water shall be potable, clean and free of injurious; quantities of substances known to be harmful to portland cement or prestressing-steel.

Admixtures, if used, shall impart the properties of low water content, good flow ability, minimum bleed and expansion if desired. Its formulation shall obtain no chemicals in quantities that may have harmful effects on the prestressing steel or cement. Admixtures containing chlorides in excess of 0.5% weight of admixture, assuming 0.45kg of admixture per sack (43 kg) of cement, fluorides, sulfites and nitrates shall not be used.

Aluminum powder of proper fineness and quantity or other approved gas evolving material which is well dispersed through the mixture may be used to obtain a maximum of 5% unrestrained expansion of the grout.

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

10.4.2 Samples for Testing

10.4.2.1 General

Testing shall conform to the applicable ASTM Specifications for the prestressing material used.

All material samples for testing shall be furnished by the Contractor at no additional cost.

Job site or site referred to herein shall be considered the location where the prestressing steel is to be installed whether at the bridge site or a removed casting yard.

10.4.2.2 Prestressing Steel and Components

Samples for testing shall be furnished as described below for each manufacturer of prestressing strand, bar, wire, bar and/or tendon couplers, and anchorage assemblies to be used on the project.

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

The following samples of materials selected by the Engineer at the plant or job site from the prestressing steel used for post-tensioning operations shall be furnished by the Contractor to the Engineer well in advance of anticipated use:

(a) For strand: one randomly selected sample, 1.5m long, per manufacturer, per size of strand, per shipment, with a minimum of one sample for every ten reels delivered.

(b) For bars: three randomly selected samples, 1.5m long, per manufacturer, per size of bar, per shipment, per heat (batch) of steel, with a minimum of one sample per shipment.

(c) For wire: one randomly selected sample, 1.5m long, per manufacturer, per size of wire, per heat of steel, per shipment, with a minimum of one sample for every ten coils delivered.

(d) For permanent couplers: three units of 0.5m lengths of bar/tendon, each equipped with one coupler and fabricated to fit the coupler, per manufacturer, per heat of coupler steel.

(e) For anchorage assemblies: two samples of each size, per manufacturer, per heat of steel.

One of each of the samples furnished to represent a lot shall be tested. The remaining sample(s), properly identified and tagged, shall be stored by the Engineer for future testing in the event of loss or failure of the component represented to meet minimum strength requirements. For acceptance of the lot represented, test results shall show that 100% of the guaranteed ultimate tensile strength has been met.

10.4.2.3 Lots and Identification

A lot is that parcel of components as described herein. All bars, anchorage assemblies and couplers of each size from each mill heat of steel, all wire from each manufactured coil and all strand from each manufactured reel to be shipped to the site shall be assigned an individual lot number and shall be tagged in such a manner that each such lot can be accurately identified at the job site. Records shall be submitted to the Engineer identifying assigned lot numbers with the heat, coil or reel of material represented. All unidentified prestressing steel, anchorage assemblies or bar couplers received at the site will be rejected. Also, loss of positive identification of these items at any time will be cause for rejection.

10.4.3 Release of Materials

The release of any material by the Engineer shall not preclude subsequent rejection if the material is damaged in transit or later damaged or found to be defective.

## 10.5 Testing by the Contractor

10.5.1 Tendon Modulus of Elasticity

This test will not be required if the Contractor can demonstrate to the satisfaction of' the Engineer, valid results for the tendon modulus of elasticity from previous projects. Such results must be for the same type of strand, size, material and complement of strands per tendon as required for this project and must have been performed under test conditions satisfactory to the Engineer.

10.5.2 In Place Friction Test

This test is intended to demonstrate that the friction characteristics, losses and resulting tendon forces are in agreement with the design assumptions.

For the purpose of verifying friction loss the Contractor shall test, in place, the first draped or horizontally curved tendon installed of each size and type which is at least 15 m long. Size is defined as the size and number off strands, bars or wires in each tendon: type is defined as to both prestressing and duct material and to the tendon function within the structure. Function is the general category of the tendon whether it is a cantilever tendon. continuity tendon, or continuous profiled tendon passing through one or more spans, etc. In this respect, the function of two or more tendons may be the same even though their actual profiles and lengths differ.

The test procedure shall 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 tendon strength in eight equal increments and detensioned in eight equal decrements. For each increment and decrement, the gauge pressure, elongations and load cell force shall be recorded. Account shall be taken of any wedge seating in both the live end (i.e., back of jack) and the dead end (i.e., back of load cell) and of any friction within the anchorages, wedge plates and jack as a result of slight deviations of the strands through these assemblies. For long tendons requiring multiple jack pulls with intermediate temporary anchoring, care shall be taken to keep an accurate account of the elongation at the jacking end allowing for intermediate wedge seating and slip of the jack wedges.

The test shall be conducted using the lubricants required, if any, to meet the expected friction coefficient.

If, for the Contractor's expected friction coefficients, the elongations fall outside the +/- 7% range, the Contractor will be required to investigate the reason and make revisions to his post-tensioning operations such that the final tendon forces are in agreement with the Drawings.

In reconciling theoretical and actual elongations, the value of the expected friction and wobble coefficients shall not be varied by more than ±7%. Significant shortfall in elongations is indicative of poor duct alignments and/or obstructions for which the Contractor shall be required to correct or compensate in a manner to be proposed by the Contractor and reviewed and approved by the Engineer at no additional cost.

One successful friction test for each type and size of tendon will be required for the project.

If, during the course of routine stressing operations, there are irreconcilable differences between forces and elongations, or other difficulties, the Engineer reserves the right to require additional in-place friction tests.

The apparatus and methods used to perform the tests shall be proposed by the Contractor and be subject to the approval of the Engineer. Furthermore, the tests shall be conducted by the Contractor in the presence of the Engineer.

Correction or adjustment of elongations as a consequence of the results of the friction test are the responsibility of the originator of the stressing and elongation calculations.

10.5.3 Not Used

10.5.4 Tests Reports Required

Two test reports of the "Tendon Modulus of Elasticity Test" shall be submitted to the Engineer at least 30 days prior to installing the tendon.

Two test reports of the "In Place Friction Test" shall be submitted to the Engineer within 2 weeks after successful installation of the tested tendon.

10.5.5 Payment for Testing

Testing by the Contractor will not be paid for separately but shall be incidental to the price paid for the Prestressing items.

10.5.6 Application of Test Results

The theoretical elongations shown on the post-tensioning shop or working drawings shall be reevaluated by the Contractor using the results of the tests for Tendon Modulus of Elasticity and In Place Friction as appropriate and corrected as necessaly. Revisions to the theoretical elongations shall be submitted to the Engineer for approval.

10.6 Protection of Prestressing Steel

10.6.1 Shipping, Handling and Storage

All prestressing steel shall be protected against physical damage and corrosion at all times from manufacturer to final grouting or encasing in the 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 carefully inspected during use and lengths of strand containing broken wires shall be removed and discarded. The wire shall be bright and uniformly colored, having no foreign matter or pitting on its surface.

Prestressing steel shall be packaged in containers or shipping forms 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, or when permitted by the Engineer, may be applied directly to the steel. The corrosion inhibitor shall have no deleterious effect on the steel or the concrete or bond strength of steel to concrete. Inhibitor carrier type packaging material shall conform to the provisions of Federal Specification MIL-P-3420. Packaging or forms damaged from any causes shall be immediately replaced or restored to the original condition.

The shipping package or form shall be clearly marked with a statement that the package contains high-strength prestressing steel, the care to be used in handling, and type, kind and amount of corrosion inhibitor used, including the date when placed, safety orders and instructions for use. Low relaxation (stabilized) strand shall be specifically designated per requirements of ASTM A 416. All such strands not so designated shall be rejected.

10.6.2 During Installation in the Structure:

When acceptable prestressing steel for post-tensioning is installed in the ducts after completion of concrete curing and if stressing and grouting are completed within 7 calendar days after the installation of the prestressing steel, rust which may form during these 7 days will not be cause for rejection of the steel. Post-tensioning steel installed, tensioned and grouted in this manner, all within 7 calendar days, will not require the use of a corrosion inhibitor in the duct following installation of the prestressing steel.

For post tensioning steel installed in ducts prior to concrete placement, the above time shall be reckoned from the day of first installation in the ducts.

Post-tensioning steel installed as above but not grouted within 7 calendar days shall have an approved water soluble oil corrosion inhibitor (emulsified rust passivator) applied in the ducts and shall be subject to all the requirements in this Section pertaining to corrosion protection and rejection because of rust. The rusting of the strand will be evaluated based on the criteria stated in ASTM A 416.

Immediately prior to grouting, the water soluble oil shall be thoroughly flushed from the ducts with water.

Within 30 calendar days after installation of the post-tensioning steel, ducts shall be grouted in accordance with these specifications. Except when approved by the Engineer is writing. failure to grout tendons within the 30 calendar days specified shall result in stoppage of the affected work and no invoices shall be processed for payment of that affected work.

## 10.7 Fabrication

10.7.1 General

All post-tensioning anchorages, ducts, vent pipes, miscellaneous hardware, reinforcing bars, and other embedments shall be accurately and securely fastened at the locations shown on the Plans or on the approved Shop or Working Drawings or as otherwise approved by the Engineer.

10.7.2 Ducts

Ducts shall be adcurately aligned and positioned at the locations shown on the Plans or according to the approved Shop or Working Drawings or as otherwise approved by the Engineer. All internal ducts shall be securely fastened in position at regular intervals not exceeding 0.75m to prevent movement, displacement or damage from concrete placement and consolidation operations. The method and spacing of duct supports shall be shown on appropriate Shop Drawings. Ducts for external tendons shall be straight between connections to internal ducts at anchorages, diaphragms and deviation saddles and shall be supported at intermediate locations or dampers according to the plans or approved shop drawings.

All 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 the placing of any concrete commences.

The tolerance on the location of the ducts for the tendons shall be as specified below.

After installation in the forms, all ends of ducts, connections to anchorages. splices. vents and the like shall at all times be sealed to prevent the entry of water and debris.

10.7.3 Splices and Joints

At splices and joints, and connections to anchorages, ducts shall be smoothly aligned and secured with no lips or kinks. They shall be joined in a manner which positively prevents the entrance of cement paste and water from the concrete or unwanted leakaae of grout during, subsequent grouting operations.

10.7.4 Grout Vents, Injection and Ejection Pipes

All ducts or anchorage assemblies for permanent post-tensioning shall be provided with pipes or other suitable connections at each end for the injection of grout after prestressing. As a minimum, ducts shall be vented at the high points of the tendon profile when there is more than a 150mm variation in the vertical position of the duct. The Contractor may use additional injection and vent pipes when shown on the shop drawings.

All connections to ducts shall be made with metallic or plastic structural fasteners. Waterproof tape shall be used at all connections to include vent and grouting pipes. Vents shall be mortar tight, taped as necessary, and shall provide means for injection of grout through the vents and for sealing the vents.

Grout injection pipes shall be fitted with positive mechanical shut-off valves. Vents and ejection pipes shall be fitted with valves, caps or other devices capable of withstanding the grout pumping pressures.

All grout caps used must be installed to prevent entrapment of air or water voids and must provide 100% coverage of all tendons.

10.7.5 Tolerances

Post-tensioning ducts shall be positioned within the following tolerances

Vertical Position + / - 6 mm
Lateral Position + / - 13 mm

The entrance and exit angles of tendon paths at anchorages and / or at faces of concrete shall be within + / -3 degrees of desired angle measured in any direction.

Angle changes at duct joints shall not be greater than + / - 3 degrees in any direction.

Anchorages shall be located within + / - 6 mm of desired position and + / - 25 mm along the tendon except that minimum cover requirements to ends of cut off tendons and anchor components must be maintained.

Anchorage confinement reinforcement in the form of spirals, multiple U shaped bars or links, shall be positioned to start within 13mm of the back of the main anchor plate, providing the anchorage is to be encased or sealed later in the construction, and shall be properly centered around the duct.

In the event of conflicts between the reinforcement and post-tensioning duct, in general, the position of the post-tensioning duct shall Prevail and the reinforcement shall be adjusted locally to the approval of the Engineer.

## 10.8 Placing Concrete

10.8.1 Precautions

The Contractor shall exercise great care when placing and consolidating concrete so as not to displace or damage any of the post-tensioning ducts, anchorage assemblies, splices and connections, reinforcement or other embedments.

10.8.2 Proving of Post-Tensioning Ducts

Upon completion of concrete placement the Contractor shall prove that the post-tensioning ducts are free and clear of any obstructions or damage and will be 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, be 6 mm smaller all around than the clear, nominal inside dimensions of the duct. No deductions to the torpedo section dimensions shall be made for tolerances allowed in the manufacture or fixing of the ducts. For straight ducts, it shall be at least 0.6m long. For curved ducts, the length shall be determined by the Contractor such that when both ends touch the outermost wall of the duct, the torpedo is 6mm clear of the innermost wall. If the torpedo will not travel completely through the duct, the member shall be rejected, unless a workable repair can be made to clear the cuts, all to the satisfaction of the Engineer. The torpedo shall be passed through the duct easily, by hand, without resorting to excessive effort or mechanical assistance.

10.8.3 Problems and Remedies

If the ducts or any part of the work is found to be deficient, it will be rejected. No remedial or repair work will be permitted without the approval of the Engineer.

## 10.9 Installing Tendons

Post-tensioning stands may be pushed or pulled through the ducts to make up a tendon. Pushing shall be done with care so as to avoid snaging on any lips or joints in the ducts. The Contractor shall take precautions by rounding off the end of the strand or fitting it with a smooth protective cap for this purpose.

Alternatively, stands may be assembled into the tendon which then may be pulled through the duct together using a special steel wire sock ("Chinese finger") or other device attached to the end. Also. the ends of the strands may be welded together for this purpose. If so, then the end of the bundle must be rounded for smooth passage and the entire welded end together with at least 0.75 m of tendon beyond the end of the last weld shall be cut off and wasted. Cutting shall be done with an abrasive saw or similar device. Flame cutting shall not be allowed.

When approved by the Engineer, in some special cases, such as small sized transverse tendons in the top of precast superstructure box girder segments, strands may be laid in the ducts prior to concrete placement. However, upon completion of concrete placement, the strands shall be moved back and forth to ensure that they are free and unobstructed by cement grout leakage or other damage. If any tendons so installed are found to be unusable for stressing due to cement grout entrapment, then the Engineer has the right to reject the concrete member and seek a replacement from the Contractor at no additional cost. Furthermore, the time requirements for corrosion protection shall commence from the time the strands were first placed in these ducts and not from the time of concrete placement, all in accordance with these specification.

Installation of tendons in ducts prior to concrete placement shall not be allowed for larger sized (i.e. seven 12.7mm diameter strands and larger) and longitudinal tendons in girders or cast-in-place work.

No permanent tendons shall be installed prior to the completion of testing as required by these specifications or Plans, except for the "In Place Friction Test" where only the tendon to be tested shall be installed prior to successful completion of the test.

## 10.10 Post-Tensioning Operations

10.10.1 General

Post-tensioning forces shall not be applied until the concrete has attained the specified compressive strength as determined by cylinder tests.

10.10.2 Stressing Tendons

All post-tensioning steel shall be tensioned by means of hydraulic jacks so that the post-tensioning force shall not be less than that required by the plans or approved shop drawings, or as otherwise approved by the Engineer. Monostrand jacks shall not be utilized for stressing tendons other than those tendons with four or fewer strands.

10.10.2.1 Maximum Stress at Jacking

The maximum temporary stress (jacking stress) in post.tensioning steel shall not exceed 80% of its specified minimum ultimate tensile strength. Tendons shall not be overstressed to achieve the expected elongation.

10.10.2.2 Initial and Permanent Stresses

The post-tensioning steel shall be anchored at initial stresses that will result in the long term retention of permanents stresses or forces of not less than those shown on the Plans or the approved shop drawings. Unless otherwise approved by the Engineer, the initial stress after anchor set shall 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 off 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.

10.10.2.3 Stressing Sequence

Except as noted otherwise on the Plans, the approved shop drawings or as approved by the Engineer, permanent post-tensioning tendons shall be stressed from both ends. The required force shall be applied at one end and subsequently at the other end or simultaneously at both ends.

Single end stressing is permitted when the following are satisfied:

(a) Space limitations prohibit two end stressing

(b) The calculated elongation of the post-tensioning steel at the second end is 13mm or less

(c) Single end stressing shall be applied at alternate ends of paired adjacent post-tensioning tendons to produce a symmetrical force distribution in agreement with the Plan design.

For construction in stages where some tendons are required to be stressed before others, the sequence of installation and stressing shall be 'a accordance with the Plans or approved shop drawings or as otherwise approved by the Engineer.

10.10.3 Stressing Equipment

Equipment for tensioning the tendons shall be furnished by the manufacturer of the post-tensioning system (tendons, hardware, anchorages, etc.).

10.10.3.1 Stressing Jacks and Gauges

Each jack used to stress tendons shall be equipped with a pressure gauge or determining the jacking pressure. The pressure gauge shall have an accurately reading dial at least 150mm in diameter.

10.10.3.2 Calibration of Jacks and Gauges

Each jack and its gauge shall be calibrated as a unit with the cylinder extension in the approximate position it will be in at the final jacking force. Calibration shall be done when the jack is connected to the equipment (pumps and gauges) in the identical configuration as will be used on the job site, i.e. with the same length hydraulic lines. Initial calibration of the jacks and gauges shall be performed by an independent laboratory using a proven load cell. For each jack and gauge unit used on the project, certified calibration charts shall be furnished by the Contractor from the independent laboratory prior to stressing the first tendon.

Certified calibration shall be made at the start of the work and at every 6 months thereafter, or as requested by the Engineer. At the option of the Contractor, calibrations subsequent to the initial calibration with a load cell may be accomplished by the use of a master gauge. 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 to a laboratory. 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 be calibrated by and shall remain in the possession of the Engineer for the duration of the project.

Any repair of the jacks, such as replacing seals or changing the length of the hydraulic lines, is cause for recalibration of the jacks using a load cell.

No extra compensation shall be allowed for the initial or subsequent calibrations or for the use and required calibrations of the master gauge.

10.10.4 Elongations and Agreement with Forces

The post-tensioning operation shall be so conducted that the forces being applied to the tendon and the elongation of the post-tensioning tendon can be measured at all times.

Elongations shall be measured to the nearest 1.5mm.

For the required tendon force, the observed elongation shall agree within ±7% of the theoretical elongation or the entire operation shall be checked and the source of error determined and remedied to the satisfaction of the Engineer before proceeding further. The tendon shall not be overstressed to achieve the theoretical elongation.

In the event that agreement between the observed and theoretical elongations at the required force falls outside the acceptable tolerances, the Engineer may, at his discretion and without additional compensation to the contractor, require additional tests for "Tendon Modulus of Elasticity" and/or "In Place Friction" in accordance with Sections 3.5.1 and 3.5.2.

10.10.5 Friction

The Contract Plans were prepared based on the assumed friction and wobble coefficients and anchor set noted on the Plans. The contractor shall submit calculations and show a typical tendon force diagram, after friction, wobble and anchor set losses, on the shop drawings based upon the expected actual coefficients and values for the post-tensioning system to be used. These coefficients and values shall be given on the shop drawings.

If, in the opinion of the Engineer, the actual friction significantly varies from the expected friction, the Contractor shall revise his post-tensioning operation such that the final tendon force is in agreement with the Plans.

When friction must be reduced, water soluble oil or graphite may be used as a lubricant subject to the approval of the Engineer. Lubricants shall be flushed from the duct as soon as possible after stressing is completed by use of water pressure. These ducts shall be flushed again just prior to the grouting operations. Each time ducts are flushed, they shall be immediately blown dry with oil-free air.

10.10.6 Wire Failures in Post-Tensioning Tendons

Multi strand Post-tensioning tendons having wires which fail by breaking or slippage during stressing may be accepted provided the following conditions are met:

(a) The completed structure shall have a final post-tensioning force of at least 98% of the design total post-tensioning force.

(b) For precast or cast-in-place segmental construction and for any similar construction that has members post-tensioned together across a common joint face, at any stage of erection, the post-tensioning force across a mating joint shall be at least 98% of the post-tensioning required for that mating joint for that stage of erection.

(c) Any single tendon shall have no more than a 5% reduction in cross-sectional area of post-tensioning steel due to wire failure

As an exception, any of the above conditions may be waived as approved by the Engineer, when conditions permit the Contractor to propose acceptable alternative means of restoring the post-tensioning force lost due to wire failure.

10.10.7 Cutting of Post-Tensioning Steel

Post-tensionjng steel shall be cut by an abrasive saw within 20 to 40mm away from the anchoring device. Flame cutting of post-tensioning steel is not allowed.

10.10.8 Record of Stressing Operations

The Contractor shall keep a record of the following post-tensioning operations for each tendon installed:

(a) Project name, number
(b) Contractor and/or subcontractor
(c) Tendon location, size and type
(d) Date tendon was first installed in ducts
(e) Coil/reel number for strands or wires and heat number for bars and wire
(f) Assumed and actual cross-sectional area
(g) Assumed and actual Modulus of elasticity
(h) Date stressed
(i) Jack and Gauge numbers per end of tendon
(j) Required jacking force

(k) Gauge pressures
(l) Elongations (anticipated and actual)
(m) Anchor sets (anticipated and actual)
(n) Stressing sequence (i.e. tendons before and after this)
(o) Stressing mode (one end/two ends/simultaneous)
(p) Witnesses to stressing operation (Contractor and inspector)
(q) Date grouted. days from stressing to grouting, grouting pressure applied and injection end.

Any other relevant information shall also be recorded. The Contractor shall provide the Engineer with a complete copy of all stressing and grouting operation records.

## 10.11 Grouting Operations

### 10.11.1 General

Within 30 calendar days after installation of the post-tensioning steel, ducts shall be grouted in accordance with these specifications. Except when approved by the Engineer in writing, failure to guout tendons within the 30 calendar days specified shall result in stoppage of the affected work and no invoices shall be processed for payment of the affected work.

After stressing and prior to grouting, tendons shall be protected against corrosion or harmful of debris by temporarily plugging or sealing all openings and vents until the tendon is grouted.

When stressing has been completed and the stressed tendons have been accepted by the Engineer the annular space between the tendons and the duct shall be grouted.

### 10.11.2 Equipment

The grout mixer shall be capable of continuous mechanical mixing and shall produce a grout free of lumps and undispersed cement. The equipment shall be able to pump mixed grout in a manner which will comply with all the provisions specified herein. Accessory equipment which will provide for accurate solid and liquid measures shall be provided to batch all materials.

Grout pumps shall be positive displacement type and shall be able to produce an outlet pressure of at least 1 MPa Pumps shall have seals adequate to prevent oil, air or other foreign substances entering into the grout and to prevent loss of grout or water. A pressure gauge having a full scale reading of no more than 2 MPa shall be placed at some point in the grout line between the pumping outlet and the duct inlet. The grouting equipment shall contain a screen having clear openings of 3.35 mm maximum size to screen the grout prior to its introduction into the grout pump. If grout with an additive is used, a screen opening of 4.75 mm is satisfactory. This screen shall be easily accessible for inspection and cleaning. The grouting equipment shall utilize a gravity feed to the pump inlet from a hopper attached to and directly over it. The hopper must be kept at least partially full at all times during the pumping operation to prevent air from being drawing into the post-tensioning duct. Under normal conditions, the grout equipment shall be capable of continuously grouting the longest tendon on the project in not more than 20 minutes.

10.11.3 Mixing

Water shall be added to the mixer first, followed by Portland cement and admixture, or as required by the admixture manufacturer. Mixing shall be of such duration as to obtain a unifoim thoroughly blended grout, without excessive temperature increase or loss of properties of the admixture. The grout shall be continuously agitated until it is pumped. Water shall not be added to increase flowability which has decreased by delayed use of the grout. Proportions of the materials shall be based on tests made on the grout before grouting is begun or may be selected based on prior documented experience with similar materials and equipment and under comparable field conditions (weather, temperature, etc.). The water content shall be the minimum necessary for proper placement and shall not exceed the water-cement ratio of 0.45 or approximately 19 liters of water per sack (43 kg) of cement. The water content required shall be established for a particular brand of cement based on tests. The pumpability of the grout may be determined by the Engineer in accordance with the U. S. Corps of Engineers Method CRD-C79. When this method is used, the efflux time of the grout sample immediately after mixing shall not be less than 11 seconds. The flow cone test does not apply to grout which incorporates a thixotropic additive.

10.11.4 Grout Injection

All grout vents and high point vent opening shall be open when grouting starts. Injection and ejection vents shall be provided with positive shut-offs. Grout shall be allowed to flow from the first vent after the injection vent until any residual flushing water or entrapped air has been removed, at which time the vents shall be closed. Remaining vents shall be closed in sequence in the same manner.

The pumping pressure at the injection vent shall not exceed 1 MPa for oval dusts nor 1.7 MPa for circular ducts. However; normal operations shall be performed at approximately 500 KPa. If the actual grouting pressure exceeds the maximum allowed, the injection vent shall be closed and the grout shall be injected at the next vent which has been, or is ready to be, closed as long as a one way flow is maintained. Grout shall not be injected into a succeeding vent from which grout has not yet flowed. If this procedure is used, then the vent which is to be used for injection shall be fitted with a positive shut-off When one-way flow of grout cannot be maintained as outlined above, the grout shall be immediately flushed out of the duct with water.

Grout shall be pumped through the duct and continuously wasted at the ejection vent until no visible slugs of water or air are ejected. To ensure that the tendon remains filled with grout, the ejection and injection vents shall be closed in sequence, respectively, under pressure when the tendon duct is completely filled with grout. The positive shut-offs at the injection and ejection vents shall not be removed or opened until the grout has set.

10.11.5 Temperature Restriction

The temperature of the grout shall not be above 32°C during mixing or pumping. If necessary, mixing water shall be cooled.

**10.12 Protection of End Anchorages**

Within 54 hours after grouting is completed, exposed end anchorages, strands and other metal accessories shall be cleaned of rust, misplaced mortar, grout and other such materials immediately following the cleaning operation, a heavy unbroken coating of an epoxy bonding compound shall be applied to all such dry metal surfaces. Epoxy bonding compound shall conform to AASHTO M 233 Class III.

Tight fitting forms shall be installed and held in place securely against the previously placed concrete. Alter application of the epoxy bonding agent, the void between the form and the anchorage shall be filled with a non-shrink grout mix to protect the anchorage. This non-shrink grout shall be in accordance with CMS 705.20. The non-shrink grout shall be placed within the "tack time' period the epoxy bonding agent/compound. All work described in this and the preceding paragraph shall he accomplished within the designated 54 hour time period.

Only non-chloride bearing non-shrink grout mixes shall be used for anchorage protection After grout patches have been finished and cured, two heavy brush coats of bituminous protective coating material conforming with ASSHTO M-115 shall be applied in a manner and thickness recommended by the manufacturer. The bituminous protective coating shall be applied only to anchorages which are not exposed to the exterior of the structure or where further concrete encasement does not occur.

# SECTION 18
# BEARING DEVICES / HORIZONTAL RESTRAINTS

*Replace Section 18.2 with the following :*

## 18.2 Horizontal Restraints (Shock Transmission Units)

### 18.2.1 GENERAL

Horizontal Restraints shown on the plans as shock transmission units (STU's) shall be designed and furnished in conformance with the details shown on the plans and these specifications.

The Contractor shall submit complete working drawings for the STU's to the Engineer in accordance with the provisions in "Working Drawings" of these specifications, The working drawings shall show complete details of the STU's and anchorage components.

The work shall consist of furnishing the materials. services, labor, tools, equipment, and incidentals necessary for the design, fabrication, inspection, testing, and shipping to the job site, of the STU's as specified, and as shown on the plans.

The STU's shall be incorporated integrally with the horizontal restraint. They shall be designed to :

1. Allow longitudinal movements due to thermal, creep and shrinkage effects without transmitting significant forces;
2. Transmit inertial loading as shown on the plans due to the design seismic event, wind loads, stream loads, and any other horizontal load capable of producing a superstructure velocity greater than 0.01 m / sec.

The STU's shall comprise a double acting piston within a cylinder filled with silicone putty having appropriate flow characteristics. Oil filled devices will not be permitted.

The STU's shall meet the force, stroke and other performance requirements shown on the plans, and given herein. The STU's shall be capable of operating reliably over the life of the structure with a minimum of maintenance. The STU's shall fit within the dimensional envelope shown on the plans and the serviceable components shall be easily inspectable and replaceable. The entire device shall be removable.

The STU's shall be supplied complete with all anchorage components, including hardware and brackets, needed to permanently secure them in place.

### 18.2.2 QUALIFIED SUPPLIERS.

The Contractor is required to identify their intended supplier of the STU's within 120 days following the Notice to Proceed. The supplier shall be required to submit a detailed schedule of submittals documenting their capability and intended approach of complying with the Contract requirements.

The STU's shall be products which have a proven successful performance record. The Contractor shall submit for the approval of the Engineer full details of the proposed STU's, This shall include lists of projects in which the proposed product has been incorporated in similar structures and climatic conditions. The Contractor shall submit substantiating information on previously installed STU's of the same type supporting the durability and maintenance records, certified by the manufacturer.

The final selection of the STU's supplier is contingent upon the acceptance by the Engineer of this submittal.

18.2.3 DESIGN REQUIREMENTS

Design of the STU's shall be in general accordance with the AASHTO LRFD Bridge Design Specifications, 1994; and the following requirements:

**General Requirements** - Design of the STU's shall consider the following general requirements. The STU's shall fit within the dimensional envelope shown on the plans.

The design of the STU's shall provide for quick adjustment of their length within plus or minus 5mm to compensate for errors in the positioning of the STU brackets.

STU's having the same manufacturer's part number shall be functionally and physically interchangeable.

**Temperature and Environmental Design Requirements** - Design of the STU's shall consider the following temperature and environmental design requirements:

The STU's shall be designed to operate over an ambient temperature range of 0$^{o}$C to 60$^{o}$C.

The STU's shall be designed for a relative humidity of 100 percent, and for condensation due to temperature change.

The STU's shall be designed for probable combinations of the following atmospheric elements: rain, snow, sleet, hail, ice, fog, smoke, wind, ozone, sunshine, sand, dust, and salt atmosphere.

**Seismic Design Requirements** - The STU's shall be designed to meet the performance requiremenls shown on the plans.

**Thermal Excitation** - The STU's shall be designed to withstand stroking due to the seasonal thermal movement of the bridge, as shown on the plans.

The stroke requirements for seismic excitation, shown on the plans, already consider the offset of he STU's due to thermal movement of the bridge.

**Traffic Excitation** - The STU's shall be designed to withstand vibrations induced by traffic on the bridge, as shown on the plans.

**Wind Excitation** - The STU's shall be designed to withstand vibrations induced by movement of the bridge during high winds. The STU's shall be designed for the following duty cycle:

1. Seventy-five millimeter double amplitude vibration, at 1 Hz for 10,000 cycles per year.

**Factors of Safety** -- The STU's shall be designed to withstand the following internal pressures:

1. Proof pressure equal to 200 percent of the maximum operating pressure.
2. Burst pressure equal to 250 percent of the maximum operating pressure.

The STU's shall be designed with a factor of safety of 2.0 times the design loads, for yield of materials and with a factor of safety of 2.5 times the design loads for failure of materials.

18.2.4 MATERIALS

Materials for STU's shall be as listed below. All materials shall be subject to the approval of the Engineer. At the request of the Engineer, the manufacturer shall submit samples of the materials used.

Structural steel shall conform to the requirements of ASTM A36 or ASTM A572: weathering steels shall not be used.

Structural bolts, nuts, and washers shall conform to the requirements of ASTM A325 Type 1 or 2 and shall be mechanically galvanized in accordance with ASTM B695.

Castings shall be carbon steel casting conforming to ASTM A27, Grade 450-240, Class I.

Only those materials that are non-nutrient to fungus shall be used in the STU's.

Non-metallic packings, seals, wipers and gaskets shall be of non-age control materials.

Piston rods, and other metal parts that slide relative to a seal shall not be plated.

Materials shall be corrosion resistant or suitably treated to resist corrosion from environmental conditions. Materials exposed to atmospheric or internal pockets of air or gas shall be suitably protected against corrosion.

Other materials shall meet the requirements of the Standard Specifications and these specifications.

**Maximum Operating Temperatures** - The STU's shall operate below a maximum operating temperature that will not degrade their performance or longevity.

**Functional Life** - The STU's shall have a functional life of 40 years. The STU's shall be essentially maintenance free. Where maintenance is required, the STU's shall be designed for ease of maintenance and repair. The STU's shall be designed for ease of removal and replacement, with few special tools needed.

The STU's shall be designed to guarantee a minimum reuse of one maximum credible seismic event before requiring refurbishment.

18.2.5 SUBMITTALS.

The Contractor shall submit working drawings, an installation manual, an inspection and maintenance manual, and test reports for the STU's, in accordance with these specifications, for review and approval by the Engineer.

**Working Drawings** - Working drawings shall be subject to approval insofar as the details affect the character of the finished work and for compliance with design requirements applicable to the construction when specified or called for, but details of design will be left to the Contractor who shall be responsible for the successful construction of the work.

Approval of working drawings shall not operate to waive any of the requirements of the plans and specifications or relieve the Contractor of any obligation thereunder, and defective work, materials and equipment may be rejected notwithstanding the approval.

Fabrication of the STU's shall not be started until the working drawings have been approved like working drawings shall include the following:

1. STU identification and nomenclature.
2. Plans, elevations and sections of the STU's; showing dimensions, weights. and methods of assembly.
3. Complete details of all components of the STU's, showing dimensions, materials and processes.
4. Sources, part numbers, and specifications for component parts of the STU.
5. Details of all welds.
6. Lifting locations and mechanisms, and mounting and connecting hardware.

**Installation Manual** - The Contractor shall submit an installation manual for the STUs for review and approval by the Engineer. Fabrication of the STU's shall not be started until the installation manual has been approved. The installation manual shall include the following:

1. The method of installation of the STU's including installation sequence and setting diagram
2. The method of adjustment of the STU's for temperature change as shown on the plans, and for errors in the positioning of the STU brackets.
3. Temporary and permanent attachment of the STU's to the bridge; including the installation and securing in place of the pins connecting the STU's to the STU brackets shown on the plans
4. Requirements for storage of the STU's and details of temporary support of the STU's for shipping and handling.

**Inspection and Maintenance Manual.**--The Contractor shall submit an inspection and maintenance manual for the STU's for review and approval by the Engineer. Fabrication of the STU's shall not be started until the inspection and maintenance manual has been approved. The inspection and maintenance manual shall include the following:

1. Inspection requirements for the STU's, including the recommended frequency of inspection. The manual shall include the specific observations to be made, and the acceptable range of values.

2. Maintenance requirements for the STU's, including the recommended frequency of maintenance.

**Test Reports.**--The Contractor shall submit the following test reports for review and approval by the Engineer:

1. After the working drawings have been approved, certified mill test reports, showing conformance of all materials to the standards referenced in these specifications. Fabrication of the STU's shall not be started until the test reports have been approved.

2. Proposed test procedures including a description of the test equipment. Testing of the STU's shall not be started until the test procedures have been approved.

3. Report on the pre-producuion testing specified below. Installation of the STU's shall not be started until the test report has been approved.

4. Report on the production testing specified below, No STU shall be installed until its report has been approved,

18.2.6 FABRICATION.

The STU's shall be fabricated in accordance with the dimensions, shapes, designs, and details shown in the approved working drawings and in conformance with these specifications. All fabrication processes shall be subject to the approval of the Engineer. The Contractor shall give the Engineer at least 2 weeks notice before beginning fabrication or testing.

Final fabrication and assembly of the STU's shall be at facilities owned and operated by the manufacturer; the manufacturer being the entity that designs, fabricates, and installs (or advises the Contractor on the installation of) the STU's; or final fabrication and assembly of the STU's shall be under the direct supervision of an employee of the manufacturer, with five or more years of experience in the fabrication of similar devices.

**Corrosion Protection** - Materials subject to deterioration when exposed to the environment shall he protected against such deterioration in a manner that will not interfere with the performance of the STU's. Piston rods, in particular, shall be protected from direct exposure to the environment by a scaled cover able to accommodate the full stroke of the STU.

Protective coatings that will crack, ship, or scale with age or extremes of climate and environmental conditions shall not be used.

Hot-dip galvanizing shall be in accordance with AASHTO M111. Zinc Coatings on Product Fabricated from Rolled, Pressed, and Forged Steel Shapes, Plates Bars and Strip.

**Fusion Welding** - Fusion welding shall be in accordance with approved standards. Weld design shall be based on the function and strength of assemblies. Fillet welds shall not be used on plates greater in thickness than 3mm without the approval of the Engineer. Weld quality shall be specified on the manufacturer's drawings with proper acceptance standards and inspection methods. All welds shall he non-destructive tested using ultrasonic or magnetic particle testing as directed by the Engineer.

**Resistance Welding** - Resistance welding shall be in accordance with MIL-W-6858 and

**Resistance Welding** - Resistance welding shall be in accordance with MIL-W-6858 and MIL-W45223, as applicable.

**Welders Certification** - Certification tests for welders shall be in accordance with MIL-STD-248

**Brazing** - The brazing of steel, copper, copper alloys and nickel alloys shall conform MIL-B-7883.

**Soldering** - Soldering shall be in accordance with approved standards. Insulation material shall not be damaged during soldering, and parts fastened thereto shall not be loosened. Mechanical assemblies shall not depend on soft-solder for mechanical strength.

**Finish** - The STU's shall be finished as recommended by the manufacturer and as approved by the Engineer.

**Workmanship.**– The STU's, including all parts and accessories, shall be fabricated and finished in a thoroughly workmanlike manner. Particular attention shall be given to neatness and thoroughness of soldering, wiring, making of parts and assemblies, welding and brazing, plating, finished, riveting, machining and screwing assemblies. All parts shall be free of burrs and sharp edges, and any damage, defect or foreign material which might detract from the functioning or appearance of the STU's.

**Safety** - The design of the STU's shall be such that all possible sources of danger to personnel or equipment during assembly, disassembly, testing operation and maintenance are minimized. Where required, precautionary measures shall be prominently and clearly indicated on the equipment.

**Change Control** -- Any changes in the design of the STUs. or any changes in, or substitutions of materials, dimensions, or fabrication methods, after initial approval by the Engineer, shall also be submitted to the Engineer for review and approval. The manufacturer shall exercise change control over his suppliers.

**Identification Marking** - The STU's shall be marked for identification in accordance with with MIL-STD-130. Each STU shall be marked with a unique serial number including the STU type, as defined herein, and otherwise in accordance with the manufacturer's standard practice.

18.2.7 TESTING.

The STU's shall be tested before they will be accepted by the Engineer, in accordance with the following requirements. The manufacturer shall submit certification that all testing equipment has been calibrated in accordance with an appropriate standard.

1. Dynamic, cyclic tests on a hydraulic servo controlled actuator test stand. The test STU shall be mounted in a horizontal position in the test stand, and subjected to imposed velocities from near zero to the (scaled) peak design velocity, at various strokes and frequencies. The dynamic, cyclic tests shall be conducted at $0^{\circ}C$, the mean ambient temperature, and at $60^{\circ}C$, after conditioning the STU at the test temperature for at least four hours prior to the test.

2. Drop testing using a heavyweight drop hammer, from near zero to the (scaled) peak design velocity.

3. The manufacturer shall submit a test report with the force-velocity relationship at each test stroke, frequency, and temperature, including the raw data. The report shall compare the results of the dynamic, cyclic testing and the drop testing. Differences of 10% or less between the results of the dynamic, cyclic testing and the drop testing will be considered acceptable.

The test results shall be used as an indication of the behavior of the production STU's, including their dependence on stroke, frequency, and temperature, and to provide a basis for correlating dynamic, cyclic testing with drop testing.

**Pre-Production Damper Testing -** The first production STU of each type shall be tested for conformance to the requirements of this special provision. The pre-production STU tests shall he performed at room temperature, and shall include the following:

1. The STU shall be proof tested at an internal pressure of 125% of the maximum operating pressure for a minimum of 120 seconds.

2. The STU shall be cycled through its full stroke for a minimum of 120 cycles. The test velocity shall be much smaller than the peak design velocity, depending on the capacity of the test apparatus.

3. The STU shall be mounted in a horizontal position in a hydraulic actuator test stand, and subjected to imposed velocities from near zero to the peak design velocity, in 5 inch/second increments. Measurements of force, displacement and velocity shall be accurately recorded and force-velocity plots constructed. Two tests shall be made at each velocity, at different stroke positions. Thc full range of stroke of the STU shall be covered during the test series.

   or

4. Using a heavyweight drop hammer, the STU shall be subjected to imposed velocities from near zero to the peak design velocity, in 125mm/second increments, in compression. Measurements of force. displacement and velocity shall be accurately recorded and force-velocity plots constructed. Two tests shall be made at each velocity, at different stroke positions. The full range of stroke of the STU shall be covered during the test series. The sequence of tests shall be repeated with the STU acting in tension.

The pre-production testing shall be used to determine the force-velocity relationship of the STU's and to verify the soundness and leak proof nature of their construction under proof loading and cyclic testing. The Engineer will accept the STU's if the following test criteria are met.

1. There is no visible leakage from the test STU, or other sign of physical deterioration either during or after the tests. There is no sign of yielding or permanent deformation.

2. The force-velocity relationship, from the actuator testing or the drop testing, meets the specified relationship within ±15%, over the range of strokes, frequencies, and temperatures included in the test.

**Production Damper Testing** - Each production STU shall be tested for conformance to the requirements of this special provision. The production STU tests shall be performed at room temperature, and shall include the following:

1. The STU shall be proof tested at an internal pressure of 125% of the maximum operating pressure. for a minimum of 120 seconds.

2. The STU shall be mounted in a horizontal position in a hydraulic actuator test stand, and subjected to an imposed velocity of 75% of the peak design velocity, with the STU at the mid-stroke position.

   or

3. Using a heavyweight drop hammer, the STU shall be subjected to an imposed velocity of 75% of the peak design velocity, in both compression and tension, with the STU at the mid-stroke position.

The Engineer will accept the STU's if the following test criteria are met:

1. There is no visible leakage from the test STU, or other sign of physical deterioration, either during or after the tests. There is no sign of yielding or permanent deformation.

2. The force-velocity relationship, from the actuator testing or the drop testing, meets the specified relationship within ±15%.

18.2.8 SHIPPING, HANDLING, AND STORAGE.

The STU's shall be shipped to the job site and handled and stored in accordance with the manufacturers recommendations and the following requirements:

1. The STU's shall be lifted only at the lifting locations and using the lifting mechanisms shown on the working drawings.

2. The STU's shall be shipped in protective packaging.

3. Damage to a STU during shipping or handling will be cause for rejection of the STU.

4. Damage to the STU corrosion protection system shall be repaired to the satisfaction of the Engineer.

5. The STU's shall be stored off the ground, on dunnage, and protected from construction activity and exposure to the elements.

18.2.9 QUALITY CONTROL AND ASSURANCE.

Quality control and assurance shall be in accordance with the following:

**Control of Quality** - The manufacturer shall establish and maintain a manufacturing and processing control system including written process specifications and procedures to insure that manufacturing, process specification and testing are accomplished in accordance with at least one of the following:

1. Control of Quality MIL-Q-9858A. The manufacturer shall provide and maintain a system that complies with U.S. Specification MIL-Q-9858A, "Quality Program Requirements."

2. Control of Quality MIL-I-45208A. The manufacturer shall provide and maintain a system that complies with U.S. Specification MIL-I-45208A, "Inspection System Requirements"

3. Control of Quality ISO 9001. The manufacturer shall provide and maintain a system that complies with the U.S. requirements of the International Standards Organization (ISO) 9001 model for quality assurance in design, development, production, installation and servicing.

**Manufacturing Process Control** - The manufacturer shall maintain a system for manufacturing process control, including the following:

1. Raw material tractability.
2. Specific raw material tractability.
3. Special process certification tractability.
4. Detailed manufacturing instructions that identify by operation and machine the work performed.
5. Inspection instructions.
6. In process and final detail component inspection instructions with actual dimensions.

**Part Information** - The manufacturer shall provide specific instructions for detail part marking providing for one way backward tractability to the information listed in "Manufacturing Process Control" of these specifications. This information shall be readily retrievable and shall be combined into one inclusive document that is controlled and approved by quality assurance personnel at the manufacturer's facility.

**Calibration** - All devices used to measure, gage, test, inspect or otherwise examine items to determine compliance with these specifications or other contractual requirements shall be calibrated in accordance, with MIL-STD - 120 and MIL-STD-45662A, to a calibrated measurement standard which has a known valid relationship to the National Institute of Standards and Technology (NIST).

## 18.2.10 INSTALLATION

Lock-up devices shown on the plans as shock transmission units (STU's) shall be installed in conformance with the details shown on the plans and these specifications; and in accordance with the installation manual provided by the manufacturer of the STU's,

During installation of the STU's, the Contractor shall utilize the services of a qualified technician. employed by the manufacturer of the STU's. The technician shall be present on the job site during installation of the STU's. The Contractor shall follow the recommendations of the manufacturer's technician, when approved by the Engineer.

The manufacturer's technician shall advise the Contractor regarding installation of the STU's, and certify to the Engineer that proper procedures are being followed. Certification to the Engineer shall be in writing, signed and dated by the manufacturer's technician.

The STU's shall be installed between the STU brackets shown on the plans. The length of the STU's shall be set equal to the distance between the brackets, measured immediately before installation. The distance between the brackets varies with the temperature of the bridge, as shown on the plans.

All debris interfering with the free action of the STU's shall be removed. The Contractor shall protect the STU's from damage. After installation, the STU's shall be protected from construction loads.

18.2.12 PERFORMANCE

The Contractor shall provide a ten-year written guarantee of the satisfactory operation and durability of the STU's. Cracked welds, broken bolts, fatigue or other cracks in steel components or welds, gross leakage of fluid, or breakdown of the corrosion protection, shall constitute unsatisfactory operation and durability of the STU's. The Contractor shall repair or replace the STU's, or parts thereof, at the Contractor's expense, as necessary to restore them to full serviceability, within the period of the guarantee. The guarantee shall extend ten years from the date of completion of the contract.

The manufacturer of the STU's shall certify the bearings to have a functional life of at least 40 years and furthermore shall clearly specify any routine inspection and maintenance operations that are considered critical to ensure the specified longivity of the STU's.

## 18.3 Pot Bearings

***Replace section 18.3.1 with the following :***

18.3.1 GENERAL

Pot bearings shall be furnished conforming to the following requirements and as indicated on the Drawings.

The bearings shall be adequate for the vertical, longitudinal and transverse loads shown on the Drawings and to adequately provide for the rotational and translational movement requirements shown on the Drawings.

18.3.1.1 QUALIFIED SUPPLIERS.

All bearings supplied shall be furnished by the same manufacturer. Manufacturers of bearings shall have not less than five years recent experience in successfully manufacturing high quality bearings similar to those to be furnished under the Contract.

The Contractor is required to identify their intended supplier of the Pot Bearings within 120 days following the Notice to Proceed. The supplier shall be required to submit a detailed schedule of submittals documenting their capability and intended approach of complying with the Contract requirements.

The Pot Bearings shall be products which have a proven successful performance record. The Contractor shall submit for the approval of the Engineer full details of the proposed Pot Bearings. This shall include lists of projects in which the proposed product has been incorporated in similar structures and climatic conditions. The Contractor shall submit substantiating information on previously installed Pot Bearings of the same type supporting the durability and maintenance records, certified by the manufacturer.

The final section of the Pot Bearing supplier is contingent upon the acceptance by the Engineer of this submittal.

***Add new paragraph at the end of Article 18.3.5.2.1 as follows :***

18.3.5.2.1 Testing by Manufacturer

Testing shall be as specified and shall be considered as incidental to the item.

***Add new Article 18.3.7 as follows :***

18.3.7 PERFORMANCE.

The Contractor shall provide a ten-year written guarantee of the satisfactory operation and durability of the Pot Bearings. Cracked welds, broken bolts, fatigue or other cracks in steel components or welds, tearing or failure of the sliding surfaces or break down of the corrosion protection shall constitute unsatisfactory operation and durability of the Pot Bearings. The Contractor shall repair or replace the Pot Bearings, or parts thereof, at the Contractor's expense, as necessary to restore them to full serviceability, within the period of the guarantee. The guarantee shall extend ten years from the date of completion of the contract.

The manufacturer of the Pot Bearings shall certify the bearings to have a functional life of at least 40 years and furthermore shall clearly specify any routine inspection and maintenance operations that are considered critical to ensure the specified longevity of the Pot Bearings.