CUY-90-14.90

PID 77332/85531

APPENDIX ST-01

Structures Project Provisions
(Contract Document)

State of Ohio
Department of Transportation
Jolene M. Molitoris, Director

Innerbelt Bridge
Construction Contract Group 1 (CCG1)

Revision Date: April 28, 2010

Table of Contents

Specifications For QC/QA Concrete for Structures

.01 Description

This work consists of designing a concrete mix, providing an acceptable quality control plan, performing quality control sampling and testing, and performing quality assurance testing.

Use provisions of 511.08 thru 511.22 and 499.06 thru 499.09 except as modified by this specification or the DBT's accepted quality control plan. Place all superstructure concrete according to the Class HP requirements.

.02 Definitions and Referenced Specifications

ACI	American Concrete Institute
AMRL	AASHTO Materials Reference Laboratory
Acceptance Tests	Compressive strength and plastic air tests that are the DBT's responsibility to obtain samples, make specimens and have tested.
Arithmetic Mean (0)	The value obtained by adding individual values and dividing by the number of individual values to obtain an average.
Certified Laboratory	An AMRL - PCC accredited laboratory
DBT	Design Build Team as defined in the Project Scope.
f'c	Specified Design Strength at 28 days.
f'cr	Required average compressive strength at 28 days (ACI 301 4.2.3.3)
IQF	Independent Quality Firm as defined in the Project Scope.
ICQM	Independent Construction Quality Manager as defined in the Project Scope.
Lot	The total cubic yards (cubic meters) required in the structure of the same class of concrete.
OMM	ODOT Office of Materials Management
Permeability	A measurement of the concrete's resistance to the penetration of chloride

	ions. Tested according to AASHTO T277, as modified herein to approximate 90 day results. The value is reported in coulombs.
QA	Quality Assurance
QA Samples	Quality Assurance samples of concrete taken by the ICQM to verify results from the DBT's quality control and acceptance tests.
QC	Quality Control
QCP	Quality Control Plan
QC Samples	Quality Control samples taken by the DBT, or designee, in order to control the materials and processes and insure the delivery of concrete that meets this specification. May also include acceptance samples.
Standard Deviation (Sc)	The positive square root of the square of the difference between an individual sample value and the mean of the sample.
Sublot	Division of a Lot into 3 or more segments for the purpose of evaluating uniformity and consistency. For this specification, a sublot is defined as 50 cubic yards (40 cubic meters).
Substructure Concrete	Concrete used in the following bridge components: abutments, piers, footings, wingwalls, columns, pier caps, cast-in-place piles and backwalls.
Superstructure Concrete	Concrete used in the following bridge components: Decks supported on steel or concrete beams, girders or box sections; slab bridge decks; abutment and pier diaphragms encasing prestressed I-beam or box beam members; abutment diaphragms encasing steel beams or girders; intermediate diaphragms between prestressed I-beams; approach slabs; sidewalks; and deflector parapets.
Unacceptable material	Concrete which is placed but fails to meet strength or air content requirements.

Referenced Specifications:

ACI 301	Standard Specification for Structural Concrete
ASTM C31	Method of Making and Curing Concrete Test Specimens in the Field
ASTM C39	Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM C42	Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
ASTM C94	Standard Specification for Ready-Mixed Concrete
ASTM C143	Test Method for Slump of Portland Cement Concrete
ASTM C172	Method of Sampling freshly Mixed Concrete
ASTM C173	Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
ASTM C231	Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C989	Standard Specification for Ground Granulated Blast-Furnace Slag for use in Concrete and Mortars
ASTM C1064	Standard Test Method for Temperature of Freshly Mixed Portland Cement Concrete
ASTM C1240	Standard Specification for Silica Fume for use as a Mineral Admixture in Hydraulic Cement Concrete, Mortar and Grout
AASHTO T277	Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration - modified by this specification

.03 Materials

Coarse aggregate..703.02

1. Use sizes No. 8, 78, 7, 67, 57 either alone or in combination.
2. The maximum sodium sulfate soundness loss shall be 12 percent.
3. Unless accepted by the ICQM, use the same kind and color of aggregates for all concrete above the ground line in a given substructure or superstructure unit.

Fine aggregate...703.02
Portland cement ....701.01, 701.02, 701.04, 701.05 or blended cements*
Fly ash 701.13
Ground granulated blast furnace slag 701.11
Micro-silica...701.10
Air-entraining admixture 705.10
Chemical admixtures 705.12
High Molecular Weight Methacrylate Resin 705.15
Curing materials .... 705.05, 705.06 (white opaque) 705.07 type 1 or 1D
Joint filler - 1/4 (6 mm) ....711.28 or 705.03
Seals (preformed elastomeric compression joint)...705.11

* Obtain OMM acceptance before using blended cements. The ready-mix producer shall provide certification from the producer of the blended cement. Blended cements shall have specific defined limitations on percentages of blended materials and shall be comprised of components that meet the applicable specifications.

Provide a technical representative from either the admixture company or the concrete supplier to be in charge of dispensing admixtures. The representative shall act in an advisory capacity reporting to the DBT and the ICQM any operations or procedures considered to be detrimental to the integrity of the concrete. The technical representative shall be present during concrete placement unless waived by the DBT.

.04 Water

Provide water free of sewage, oil, acid, strong alkalis, vegetable matter, clay or loam. Water shall conform to ASTM C94. Concrete produced with either wash water or storm water shall use a reclaiming system monitoring the quality of the water to meet ASTM C94 and produce no more than 0.06% total chlorides by weight of cement into the concrete. The IQF will review and accept the reclaiming system.

.05 Concrete Mix Design

Develop concrete mix designs according to ACI 301, section 4, and as modified in this specification. Submit test data from a Certified Laboratory to the OMM.

Establish the maximum air content for the concrete mix design and produce concrete within 0.5% of that maximum for the submitted data. If the test values meet the requirements of this specification, this value becomes the maximum air content for the mix design and for acceptance at the project.

The Certified Laboratory shall mix the trial batch, sample and test the samples (ACI 301, 4.2.3.4.b). An ACI Grade I Technician may perform batching and sampling with the laboratory witnessing the process. The certified laboratory shall perform the compressive strength and permeability testing.

Determine the required average compressive strength (f'cr) according to ACI 301, section 4.2.3. If there is no field data available, select the over-design for the mix from ACI 301, Table 4.2.3.3b. Follow ACI 301 section

4.2.3.4.a., or 4.2.3.4.b when using field or laboratory data, respectively, to establish a mix design. Use field test data from previous ODOT projects under this specification or other sources accepted by the OMM.

Determine the mix permeability by testing in conformance with AASHTO T-277 except moist cure the permeability samples for 7 days at 73° F (23°C) followed by 21 days of moist curing at 100° F (38°C). Perform permeability testing at 28 days.

If the laboratory trial mix procedure is used to support the mix design, a single mix may be used if all requirements of this specification are met. Produce the trial mix using the maximum water and all admixtures required to achieve the maximum placement slump and maximum air. Record the slump and air, and produce the strength and permeability test samples from the same mix.

Use a cement or cementitious content meeting the minimums given in **TABLE 3**.

TABLE 1

CONCRETE MIX DESIGN REQUIREMENTS			
Concrete Use (Class)	Specified Compressive Strength (f’c) psi (MPa)	Design Permeability (P_d) ** Coulombs	Plastic Air Content %
Substructure(QSC1)	4000 (28.0)	< 2000	TABLE 2
Superstructure(QSC2)	4500 (31.0)	< 1500	TABLE 2
Project Specific(QSC3)	As per plan	< 1500	TABLE 2

** AASHTO T-277 modified

TABLE 2

AIR CONTENT LIMITATIONS				
	Design	AT POINT OF PLACEMENT	AT POINT OF DISCHARGE WHEN PUMPING CONCRETE	AT POINT OF SAMPLING FOR ACCEPTANCE
Aggregate Size	Design Air	Minimum Air	Minimum Air	Maximum Air
8, 7, 78	7%	5.0%	6.0%	Established by the Producer as tested for each mix design
67, 57	6%	4.0%	5.0%	

Blending coarse aggregate is acceptable. Report the production blend.

TABLE 3

CONCRETE MIX DESIGN LIMITATIONS	
Minimum Cementitious Content *	565 lbs/yd^3 (335 kg/m^3)**
Fly Ash	up to 25%
Ground Granulated Blast Furnace Slag	up to 30%***
Micro-Silica	up to 10%
The total combination of pozzolan materials shall not exceed their individual percentage nor total more than 50% of the total cementitious content	

* The cementitious content shown above is a minimum. The DBT is responsible for proportioning a mix that is workable and meets all of the requirements of this specification. To accomplish this, quantities above the minimum shown may be required.

** For Mass Concrete, as defined in the Project Scope, Minimum Cementitious Content shall be 500 lbs/yd^3

*** For Mass Concrete, as defined in the Project Scope, the maximum percentage of Ground Granulated Blast Furnace Slag shall be 50%.

.06 Mix Design Documentation
Mix designs for each class of concrete required on the project shall include certified test data documenting results for the following:

1. Design Air Content
2. Maximum Air Content
3. Compressive Strength
4. Slump
5. Unit Weight
6. Yield
7. Aggregate Correction Factor
8. Specified Design Strength (*f'c*)
9. ACI required Over- Design Value
10. Permeability

Also include:

TABLE 4

Mix Design Data					
Material	**Design Weight (SSD)**	**Source**	**Type**	**Specific Gravity**	**Absorption (%)**
Fine Aggregate	Required	Required	Required	Required	Required
Coarse Aggregate 1	Required	Required	Required	Required	Required
Coarse Aggregate 2	Required	Required	Required	Required	Required
Cement ***	Required	Required	Required	Required	Not Applicable
Fly Ash	Required	Required	Required	Required	Not Applicable
GGBF	Required	Required	Required	Required	Not Applicable
Micro-silica	Required	Required	Required	Required	Not Applicable
Other	Required	Required	Required	Required	Not Applicable
Water	Required	Required	Not Applicable	Not Applicable	Not Applicable

Admixtures	**Type**	**Brand Name**	**Dosage Rate**
Admixture 1	Required	Required	Required
Admixture 2	Required	Required	Required
Admixture 3	Required	Required	Required
Admixture 4	Required	Required	Required
Water/Cementitious Ratio	Required		

*** If a blended cement is used, indicate the components of the blended cement and the proportions of those components.

Changing sources of materials from those tested for the design submittal may require retesting of the mix for acceptance. The ICQM will request certification that the source changes will not adversely affect the tested mix. The ICQM will require retesting when changing aggregate type; aggregate size; cement type; and pozzolan type or grade. Notify OMM of ICQM approved changes.

Test any workability issues in the trial process. The ICQM will require a new mix and retesting for unworkable mixes in the field. The ICQM will consider modifying aggregate weights by more than 3%, excluding adjustments for specific gravity or absorption changes, as a change to the mix design.

.07 Mix Design Acceptance

Submit one copy of the mix design and test data to the OMM at least 10 calendar days prior to placement. The OMM will review the mix design to ensure that the design parameters in **TABLE 1** are met; limitations in **TABLES 2** and **3** are not exceeded; and the design batching data in **TABLE 4** is included.

Also submit a copy of the mix design data to the ICQM at least 10 days before any concrete production. The ICQM will review the mix design for compliance with the plan requirements and for project information and control. Do not place concrete until the mix design has been accepted by the ICQM.

If a mix design previously accepted by OMM is to be used, the mix design data will be again submitted to the ICQM at least 10 days before any concrete production.

If changes in the source(s) of cement, fly ash, GGBF slag, micro-silica or aggregates are proposed for use in a previously accepted mix design, concurrently submit the request 10 days prior to production to both OMM and the ICQM. OMM will determine if a completely new mix design is required or if the existing mix can be accepted with the proposed modification of materials.

.08 Lot, Sublot And Random Load Determination For Strength And Permeability Acceptance
Use a single mix design for each lot.

Provide the ICQM with a proposed placement schedule and division of the concrete lot into a minimum of 3 sublots. The maximum size of each sublot shall be 50 yd^3. The ICQM will review and accept the sublot divisions. Use a sequential numbering system for lots and sublots (i.e. Lot 1: sublot 1, sublot 2, etc).

The ICQM will determine the random load from which the DBT will sample the concrete to perform acceptance testing.

The ICQM will:

1. Randomly choose a starting number from **TABLE 7**.
2. Multiply the starting number by the volume of the first sublot and round to the nearest whole number to determine an individual yardage. The DBT shall sample the load containing this individual yardage.
3. Determine the individual yardage and load to be sampled for the next sublots using the next sequential number in the random number table and repeating step 2 until all sublots for the given class of concrete are complete.
4. Inform the DBT of the sublot test locations at the beginning of the day's placement.

.09 DBT Quality Control Plan
Develop a QCP establishing the responsibilities, duties and frequency of quality control testing for both in-process quality control at the job site and at the concrete's source. Use either a certified laboratory to perform all quality control responsibilities or perform some of the sampling and testing with an ACI certified Grade 1 Field Testing Technician. The person performing the quality control testing shall immediately inform the DBT and ICQM of non-compliant test results before the load of concrete is rejected, retempered or discharged.

Use a certified lab to test compression samples and QA samples (Section .11).

Include with the QCP: **TABLE 10** for reporting plastic air acceptance results and **TABLE 9** for reporting compressive strength. The ICQM will establish documentation for other items, such as core results for in-place evaluation, if needed.

Submit a complete QCP to the ICQM for review and acceptance with the mix design submission. Include at least the following information:

1. The name of the certified laboratory. (Include AMRL accreditation)
2. Name and certification of all laboratory, and/or DBT's, technicians who will perform plant and/or field site sampling and testing. (Minimum: ACI Grade 1 Field Testing Technician certification)

3. Method of reporting test results for compressive strength and plastic air (minimum requirements: The certified laboratory shall furnish and certify all results using the QC/QA reporting forms, **TABLES 9** and **10**)
4. Test equipment calibration records
5. Method for field curing specimens
6. Methods for transporting samples to the certified laboratory
7. Certified laboratory curing procedures.
8. In-process quality control program establishing the method of:
   Raw materials certification and control
   Aggregate moisture controls performed at least daily
   Concrete delivery controls.
   Minimum required rate of concrete delivery for continuous placement
   Concrete plant controls
   Construction site controls
   Methods for curing and testing samples for form release/removal - See Section .11.
   Concrete placement procedures, equipment, finishing methods, curing methods, lighting, etc.
   Methods of protecting concrete if inclement weather or evaporation rate exceeds specification requirements
9. Proposed modifications to construction processes of 511 and 499.

Address, in the QCP, whether plant control includes quality control personnel monitoring the mixing process. Use the NRMCA Publication No 190, NRMCA Guideline Manual for Quality Assurance/Quality Control, as one possible source to model the Quality Control Plan.

Provide delivery tickets conforming to 499.08.

Establish the desired slump for each item and maintain that slump within ±1.5inches (38mm). Measure the slump when performing the air and compression testing (Section .10) to verify consistent results within the specified tolerance. If slump loss occurs before placement, replasticize with either water, if the maximum water/cementitious ratio is not exceeded, or an admixture to restore plasticity. Recheck the air content. Reject any loads that segregate.

.10 DBT Quality Control (QC) & Acceptance Testing
Perform air content QC testing at the point of discharge from the Ready Mix concrete truck. Use the following quality control procedures during the placement:

1. Test the air content on at least the first three (3) loads of concrete delivered for each day's placement. Ensure that the air content is stabilized and within the specified parameters for the mix design before extending the sampling and testing frequency.

2. Once the air content is stabilized to the ICQM's satisfaction, extend the sampling frequency to no more than one test for every three (3) loads of concrete delivered.

   If a load of concrete is tested and found to have an air content less than the minimum in TABLE 2 or above the maximum air established for the mix, do not accept and place that load unless it can be adjusted to be within the specified limits. Test at least the next three loads for air to ensure that the air content is stabilized to the ICQM's satisfaction. The sampling frequency may then be extended back to one test for every three (3) loads of concrete delivered.

3. For concrete delivered to the point of placement by means of pumping equipment, provide a hose at

the end of the line that is at least 0.5 inch (12 mm) smaller in diameter than the line on the boom to provide back pressure in the system and minimize the amount of air lost in the concrete. Obtain the ICQM's approval for methods to produce back pressure in the system other than the 0.5 inch (12 mm) smaller diameter hose. Provide a trial placement of concrete with pumping equipment at the most severe condition (e.g. the pump line boomed straight up and down), using the proposed method to prove to the ICQM's satisfaction that the method has acceptable air loss at the extreme position of the pump.

Obtain concrete samples at the point of placement without interrupting the continuous flow of concrete by passing the pump line over the sampling container. The ICQM will allow sampling of placed concrete prior to vibrator consolidation. For placed concrete, obtain samples from five different portions of the deposited concrete and then combine into one composite sample for test purposes. Do not reconfigure the pump boom to obtain the sample.

During the first three loads, test the concrete at the point of discharge and the point of placement to verify that the loss of air going through the pump does not exceed 1%. If the amount of air loss is not controlled to the ICQM's satisfaction, make adjustments to the pump setup that results in an air loss of less than 1%. If less than 1% loss cannot be achieved, test the air at the point of placement on every load and use the air limits for the point of placement in **TABLE 2**.

Placing concrete indirectly into the forms by a method other than pumping requires a similar evaluation of the air and appropriate controls to limit losses.

4. Provide the ICQM a signed copy of the plastic air results **(TABLE 10)** after each placement.

Any concrete with an air content above the maximum air or below the minimum air that is placed into the structure is unacceptable material for the amount of material represented by the sampling frequency. In accordance with CMS 106.07, test unacceptable material as follows:

1. For high air, core and test unacceptable material according to Section N. Unacceptable material with sufficient strength may be left in place.

2. For low air, take at least one (1) core for each represented load in the area where the unacceptable material was placed. Perform a petrographic analysis according to ASTM C457. Remove and replace unacceptable materials with a specific surface less than 600 in^2/in^3 and a spacing factor of more than 0.008 in. The Department will not permit the same private laboratory performing the QC testing to perform the petrographic analysis.

Perform the following quality control/acceptance sampling and testing for compressive strength from the load determined by the random number:

1. Sample each sublot by making one (1) set of three (3) - 6"x12" (150x300mm) quality control/acceptance compressive strength cylinders. Test two (2) of the cylinders at 28 days. If the results are within the acceptable range established in ASTM C39 – Section 10, report the two results and the average as the strength for the sublot and discard the third cylinder. If the results of the first two cylinders are not within the acceptable range of ASTM C39 – Section 10, test the third cylinder and average the two closest results and report as the strength for the sublot.

   Perform all required curing, transporting, capping and testing of the samples to conform to the applicable ASTM specifications. Report the actual test values for quality control/acceptance using

TABLE 9. If developing a maturity curve, provide the maturity curve to the ICQM prior to placement or removal of the falsework.

2. Determine the concrete temperature according to ASTM C1064 from the same sample taken for compressive strength. Ensure compliance with 499.09 and 511.15.

Sample the concrete at the point of discharge unless the air is being tested at the point of placement as required by Section .10-3.

Provide strength results within 5 days of completion of test.

If the quality control person(s) fails to follow proper testing procedures; use adequate equipment; inform the DBT and ICQM of unacceptable material; or report results in a timely manner, the ICQM may have the quality control person(s) and/or company removed from the project and suspend work until an acceptable replacement can be provided.

.11 ODOT Quality Assurance
ODOT will perform QA sampling and testing as specified or as deemed necessary.

The ICQM will perform side by side testing with the DBT and compare results. If the difference between the ICQM's and the DBT's testing is greater than the tolerances listed below, the DBT and ICQM will determine the reason for slump or air content differences and make necessary adjustments. The ICQM may stop the placement until the reason for the difference is established and corrected. The ICQM will check one of the first three loads delivered. Once the results are within the tolerances listed below, the ICQM may reduce the QA sampling and testing frequency to 10% of the DBT's subsequent quality control/acceptance tests.

1. Slump - ±1 inch (25 mm)
2. Air Content - ±1%.

The ICQM will obtain compressive strength QA samples from the same location as the DBT's quality control/acceptance samples. The ICQM will obtain QA samples for every 10 sublots or at least one per lot. The ICQM will make four (4) - 6" x 12" (150 x 300 mm) cylinders for each sample. The ICQM will mark the cylinders with identification and the DBT shall take ownership for handling, shipping, curing, transporting and testing the specimens.

After fourteen (14) days curing, deliver two (2) of the QA cylinders to the ODOT Office of Materials Management at 1600 W. Broad Street, Columbus, OH during normal working hours. Continue to cure the other two (2) QA cylinders with the quality control/acceptance cylinders at the Certified Laboratory. The Certified laboratory shall test the two (2) QA cylinders with the quality control/acceptance cylinders and report the 28 day test results on the accepted QCP form. The report shall distinguish the QA cylinder results from the quality control/acceptance results, including the sublot.

The ICQM will verify that the ICQM tested QA, DBT tested QA and the matching quality control/acceptance test results are within 500 psi (3.9 MPa). Investigate the results with the ICQM to determine the reason for the difference greater than 500 psi (3.9 MPa). If no reason is determined, the ICQM will require the DBT to either non-destructively test or core the concrete represented by the cylinder tests to determine compressive strength. Hire an independent laboratory to perform this additional testing. The ICQM will witness the testing and evaluate the results. If found valid, use the cylinder acceptance results, or if cores were taken during the evaluation, use the core's test results to determine the compressive strength values.

The ICQM will reject a mix design when a single compressive strength quality control/acceptance test result drops below 88% of *f'c* or a lot of concrete has a Percent Acceptable Material below 75. If the mix design is rejected, develop a new mix design according to Section .03 and Section .05.

The ICQM will reject loads and stop placement when quality control processes do not control balling, segregation, inconsistent or variable concrete indicating poor quality control. Do not restart placement until the cause of the problem is determined and corrected.

.12 Curing And Loading
Perform all testing required in this section as part of the quality control program. Modify 511.17 as follows:

Cure all superstructure concrete according to the Class HP requirements.
Do not use the falsework removal and traffic loading Table 511.17-1. Do not remove falsework for structure concrete, QSC1, QSC2 or QSC3, or subject it to construction or erection loads until field cured compressive strength test cylinders or maturity results reach a strength of 85% of *f'c* or greater. If using flexural beams, obtain a center-point Modulus of Rupture of 650 psi (4.6 MPa) or greater before opening to traffic. Remove formwork according to 511.16. Do not shorten the minimum required Method A curing time regardless of strength test results. Allow formwork construction and placement of reinforcing steel if no motorized equipment applies loads to the concrete and field cured compressive strength is 60% of *f'c*.

Make enough additional compressive or flexural samples required to verify compliance with the strengths above and the following:

A. Obtain field cured samples out of the first and last QC sampled loads of continuously placed concrete for quantities of 500 cubic yards or less, and one extra set of specimens for each 500 cubic yards or fraction thereof. Take samples in equally spaced increments throughout the placement when QC samples are taken as directed by the ICQM.
B. Delays in placements of more than 4 hours are not considered continuously placed and shall be treated as separate placements.

The DBT may use maturity testing according to Department standards to determine the in-place strength of the concrete.

.13 Slipforming
Follow 511.11 except:
Reducing the established water /cementitious ratio or amount of admixture of an accepted mix to achieve the desired consistency will not require a new mix design. The Department will require separate mix designs conforming to Section .05 for adjustments to the mix beyond those permitted in Section .06. The Department will permit designating slipformed concrete as a separate lot.

.14 Reevaluation Of Strength
1. If a single compressive strength acceptance test result for a sublot of concrete is less than 88% of the specified *f'c,* the ICQM will evaluate and accept or reject the material as follows:

   The ICQM will determine the location for evaluating the strength of the sublot represented by the low compressive strength. Evaluate using either nondestructive testing or cores. Nondestructive testing may be used only to determine if further action is necessary. The ICQM will accept the concrete if nondestructive test results are greater than the specified *f'c*. Use the original cylinder results for calculating the compressive strength only if further testing confirms the original cylinder results are accurate. If further testing confirms the original results are not accurate, the ICQM will not use the original cylinder results or the sublot. The Department will require coring if the nondestructive test results are less than the specified *f'c*.

Core the concrete at locations determined by the ICQM. Provide the cores to the ICQM for testing by the Department. Patch core holes with approved patching material. If the core results indicate that the compressive strength of the concrete is below 88% *f'c*, submit a plan for corrective action to the ICQM and the Department for approval. If the corrective plan is not accepted, the DBT will remove and replace the unacceptable sublot at no cost to the Department.

2. If the Percent Acceptable Material for a lot of concrete is below 75%, submit a plan for corrective action to the ICQM and the Department for approval. If the corrective plan is not accepted, the ICQM will require the DBT to remove and replace the lot of unacceptable material at no cost to the Department.

Compressive Strength Example: A 420 yd^3 bridge deck using QSC2 concrete is placed. There are 8 sublots @ 50yd^3 and1 sublot @ 20 yd^3 for the lot. The compressive strength acceptance test results are as follows: 5060, 5820, 5210, 5930, 5740, 6130, 6560, 5040 and 7080 psi.

1. Calculate the Average Strength and Standard Deviation (S_c) as follows* :

SAMPLE	**COMPRESSION (X)**	**X - 0**	**$(X - 0)^2$**
1	5,060	-781	609,961
2	5,820	-21	441
3	5,210	-631	389,161
4	5,930	89	7,921
5	5,740	-101	10,201
6	6,130	289	83,521
7	6,560	719	516,961
8	5,040	-801	641,601
9	7,080	1239	1,535,121
Total	52,570	0	3,803,889
Avg. (0)	**5,841**		

Formula: $\mathbf{S_c = [\ni(x - 0)^2 / (n-1)]^2}$

$= [3,803,889 / (9-1)]^2$

$= [3,803,889 / 8]^2$

$\mathbf{S_c = 690}$

* This can also be calculated using standard computer programs. Make sure that the **<u>Sample</u> Std Dev** is used rather than the **<u>Population</u> Std Dev**.

2. Calculate the Quality Index (Q_{LLC}):

Formula: $\mathbf{Q_{LLC} = (0 - \mathit{f'c})/S_c}$

$= (5,841 – 4,500) / 690$

$= 1,341 / 690$

$= \mathbf{1.94}$

3. Determine the Percent Defective (PD_c) and then Percent Acceptable Material:

Go to **TABLE 8**; n = 9; Q_{LLC} = 1.94 (1.9 on the column on the left side of the table and 0.04 across the top row)

% Defective = 1.32, therefore

Percent Acceptable Material = 100 - 1.32 = **98.68 %**

TABLE 7

RANDOM NUMBERS					
0.889	0.848	0.612	0.806	0.774	0.115
0.745	0.127	0.317	0.867	0.645	0.212
0.697	0.138	0.236	0.447	0.651	0.436
0.123	0.326	0.775	0.467	0.419	0.725
0.807	0.121	0.369	0.778	0.796	0.570
0.653	0.529	0.688	0.887	0.449	0.419
0.524	0.161	0.899	0.155	0.526	0.722
0.192	0.897	0.798	0.244	0.205	0.180
0.654	0.174	0.133	0.262	0.380	0.828
0.127	0.796	0.608	0.102	0.428	0.194
0.615	0.385	0.102	0.782	0.589	0.113
0.333	0.309	0.692	0.559	0.860	0.421
0.562	0.497	0.210	0.220	0.592	0.850
0.346	0.789	0.523	0.368	0.716	0.193
0.564	0.621	0.804	0.641	0.183	0.351
0.649	0.521	0.850	0.189	0.332	0.736
0.403	0.510	0.562	0.670	0.881	0.723
0.792	0.203	0.318	0.608	0.107	0.572
0.454	0.682	0.521	0.588	0.141	0.110
0.703	0.634	0.846	0.826	0.475	0.313

TABLE 8: Estimated percent defective for compressive strength (PDc) **Sample size (n) = 2**										
Q	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
0.0	50.00	49.66	49.33	48.99	48.66	48.32	47.99	47.65	47.32	46.98
0.1	46.64	46.31	45.97	45.64	45.30	44.97	44.63	44.30	43.96	43.62
0.2	43.29	42.95	42.62	42.28	41.95	41.61	41.28	40.94	40.60	40.27
0.3	39.93	39.60	39.26	38.93	38.59	38.26	37.92	37.58	37.25	36.91
0.4	36.58	36.24	35.91	35.57	35.23	34.90	34.56	34.23	33.89	33.56
0.5	33.22	32.89	32.55	32.21	31.88	31.54	31.21	30.87	30.54	30.20
0.6	29.87	29.53	29.19	28.86	28.52	28.19	27.85	27.52	27.18	26.85
0.7	26.51	26.17	25.84	25.50	25.17	24.83	24.50	24.16	23.83	23.49
0.8	23.15	22.82	22.48	22.15	21.81	21.48	21.14	20.81	20.47	20.13
0.9	19.80	19.46	19.13	18.79	18.46	18.12	17.79	17.45	17.11	16.78
1.0	16.44	16.11	15.77	15.44	15.10	14.77	14.43	14.09	13.76	13.42
1.1	13.09	12.75	12.42	12.08	11.75	11.41	11.07	10.74	10.40	10.07
1.2	9.73	9.40	9.06	8.72	8.39	8.05	7.72	7.38	7.05	6.71
1.3	6.38	6.04	5.70	5.37	5.03	4.70	4.36	4.03	3.69	3.36
1.4	3.02	2.68	2.35	2.01	1.68	1.34	1.01	0.67	0.34	0.00

For values of Q greater than or equal to zero, the estimate of percent defective (PDc) is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100. Values of Q greater than what is on the table indicate that there is 0.00 % unacceptable material.

TABLE 8 (CONT.): Estimated percent defective for compressive strength (PDc)
Sample size (n) = 3

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.72	49.45	49.17	48.90	48.62	48.35	48.07	47.79	47.52
0.1	47.24	46.96	46.69	46.41	46.13	45.85	45.58	45.30	45.02	44.74
0.2	44.46	44.18	43.90	43.62	43.34	43.05	42.77	42.49	42.20	41.92
0.3	41.63	41.35	41.06	40.77	40.49	40.20	39.91	39.62	39.33	39.03
0.4	38.74	38.45	38.15	37.85	37.56	37.26	36.96	36.66	36.35	36.05
0.5	35.75	35.44	35.13	34.82	34.51	34.20	33.88	33.57	33.25	32.93
0.6	32.61	32.28	31.96	31.63	31.30	30.97	30.63	30.30	29.96	29.61
0.7	29.27	28.92	28.57	28.22	27.86	27.50	27.13	26.76	26.39	26.02
0.8	28.64	25.25	24.86	24.47	24.07	23.67	23.26	22.84	22.42	21.99
0.9	21.55	21.11	20.66	20.19	19.73	19.25	18.74	18.25	17.74	17.21
1.0	16.67	16.11	15.53	14.93	14.31	13.66	12.98	12.27	11.51	10.71
1.1	9.84	8.89	7.82	6.60	5.08	2.87	0.00	0.00	0.00	0.00

For values of Q greater than or equal to zero, the estimate of percent defective (Pdc) is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100. Values of Q greater than what is on the table indicate that there is 0.00 % unacceptable material.

TABLE 8 (CONT.): Estimated percent defective for compressive strength (PDc)
Sample size (n) = 4

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.76	49.33	49.00	48.67	48.33	48.00	47.67	47.33	47.00
0.1	46.67	46.33	46.00	45.67	45.33	45.00	44.67	44.33	44.00	43.67
0.2	43.33	43.00	42.67	42.33	42.00	41.67	41.33	41.00	40.76	40.33
0.3	40.00	39.67	39.33	39.00	38.67	38.33	38.00	37.67	37.33	37.00
0.4	36.67	36.33	36.00	35.67	35.33	35.00	34.67	34.33	34.00	33.67
0.5	33.33	33.00	32.67	32.33	32.00	31.67	31.33	31.00	30.67	30.33
0.6	30.00	29.67	29.33	29.00	28.67	28.33	28.00	27.67	27.33	27.00
0.7	26.67	26.33	26.00	25.67	25.33	25.00	24.67	24.33	24.00	23.67
0.8	23.33	23.00	22.67	22.33	22.00	21.67	21.33	21.00	20.67	20.33
0.9	20.00	19.67	19.33	19.00	18.67	18.33	18.00	17.67	17.33	17.00
1.0	16.67	16.33	16.00	15.67	15.33	15.00	14.67	14.33	14.00	13.67
1.1	13.33	13.00	12.67	12.33	12.00	11.67	11.33	11.00	10.67	10.33
1.2	10.00	9.67	9.33	9.00	8.67	8.33	8.00	7.67	7.33	7.00
1.3	6.67	6.33	6.00	5.67	5.33	5.00	4.67	4.33	4.00	3.67
1.4	3.33	3.00	2.67	2.33	2.00	1.67	1.33	1.00	0.67	0.33
1.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

For values of Q greater than or equal to zero, the estimate of percent defective (PDc) is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100. Values of Q greater than what is on the table indicate that there is 0.00 % unacceptable material.

TABLE 8 (CONT.): Estimated percent defective for-compressive strength (PDc)
Sample size (n) = 5

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.0	49.64	49.29	48.93	48.58	48.22	47.86	47.51	47.15	46.80
0.1	46.44	46.09	45.73	45.38	45.02	44.76	44.31	43.96	43.60	43.25
0.2	42.90	42.54	42.19	41.84	41.48	41.13	40.78	40.43	40.08	39.72
0.3	39.37	39.02	38.67	38.32	37.97	37.62	37.28	36.93	36.58	36.23
0.4	35.88	35.54	35.19	34.85	34.50	34.16	33.81	33.47	33.12	32.78
0.5	32.44	32.10	31.76	31.42	31.08	30.74	30.40	30.06	29.73	29.39
0.6	29.05	28.72	28.39	28.05	27.72	27.39	27.06	26.73	26.40	26.07
0.7	25.74	25.41	25.09	24.76	24.44	24.11	23.79	23.47	23.15	22.83
0.8	22.51	22.19	21.87	21.56	21.24	20.93	20.62	20.31	20.00	19.69
0.9	19.38	19.07	18.77	18.46	18.16	17.86	17.55	17.25	16.96	16.66
1.0	16.36	16.07	15.78	15.48	15.19	14.91	14.62	14.33	14.05	13.76
1.1	13.48	13.20	12.93	12.65	12.37	12.10	11.83	11.56	11.29	11.02
1.2	10.76	10.50	10.23	9.97	9.72	9.46	9.21	8.96	8.71	8.46
1.3	8.21	7.97	7.73	7.49	7.25	7.02	6.79	6.56	6.33	6.10
1.4	5.88	5.66	5.44	5.23	5.02	4.81	4.60	4.39	4.19	3.99
1.5	3.80	3.61	3.42	3.23	3.05	2.87	2.69	2.52	2.35	2.19
1.6	2.03	1.87	1.72	1.57	1.42	1.28	1.15	1.02	0.89	0.77
1.7	0.66	0.55	0.45	0.36	0.27	0.19	0.12	0.06	0.02	0.00

For values of Q greater than or equal to zero, the estimate of percent defective (PDc) is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100. Values of Q greater than what is on the table indicate that there is 0.00 % unacceptable material.

TABLE 8 (CONT.): Estimated percent defective for compressive strength (PDc)
Sample size (n) = 6

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.63	49.27	48.90	48.53	48.16	47.80	47.43	47.06	46.70
0.1	46.33	45.96	45.60	45.23	44.86	44.50	44.13	43.77	43.40	43.04
0.2	42.68	42.31	41.95	41.59	41.22	40.86	40.50	40.14	39.78	39.42
0.3	39.06	38.70	38.34	37.98	37.62	37.27	36.91	36.55	36.20	35.84
0.4	35.49	35.14	34.79	34.43	34.08	33.73	33.38	33.04	32.69	32.34
0.5	32.00	31.65	31.31	30.96	30.62	30.28	29.94	29.60	29.26	28.93
0.6	28.59	28.25	27.92	27.59	27.26	26.92	26.60	26.27	25.94	25.61
0.7	25.29	24.96	24.64	24.32	24.00	23.68	23.37	23.05	22.74	22.42
0.8	22.11	21.80	21.49	21.18	20.88	20.57	20.27	19.97	19.67	19.37
0.9	19.07	18.78	18.49	18.19	17.90	17.61	17.33	17.04	16.76	16.48
1.0	16.20	15.92	15.64	15.37	15.09	14.82	14.55	14.29	14.02	13.76
1.1	13.50	13.24	12.98	12.72	12.47	12.22	11.97	11.72	11.47	11.23
1.2	10.99	10.75	10.51	10.28	10.04	9.81	9.58	9.36	9.13	8.91
1.3	8.69	8.48	8.26	8.05	7.84	7.63	7.42	7.22	7.02	6.82
1.4	6.63	6.43	6.24	6.05	5.87	5.68	5.50	5.33	5.15	4.98
1.5	4.81	4.64	4.47	4.31	4.15	4.00	3.84	3.69	3.54	3.40
1.6	3.25	3.11	2.97	2.84	2.71	2.58	2.45	2.33	2.21	2.09
1.7	1.98	1.87	1.76	1.66	1.55	1.45	1.36	1.27	1.18	1.09
1.8	1.01	0.93	0.85	0.78	0.71	0.64	0.57	0.51	0.46	0.40
1.9	0.35	0.30	0.26	0.22	0.18	0.15	0.12	0.09	0.07	0.05
2.0	0.03	0.02	0.01	.0.00	0.00	0.00	0.00	0.00	0.00	0.00

For values of Q greater than or equal to zero, the estimate of percent defective (PDc) is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100. Values of Q greater than what is on the table indicate that there is 0.00 % unacceptable material.

TABLE 8 (CONT.): Estimated percent defective for compressive strength (PDc) Sample size (n) = 7										
Q	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
0.0	50.00	49.63	49.25	48.88	48.50	48.13	47.75	47.38	47.01	46.63
0.1	46.26	45.89	45.51	45.14	44.77	44.40	44.03	43.65	43.28	42.91
0.2	42.54	42.17	41.80	41.44	41.07	40.70	40.33	39.97	39.60	39.23
0.3	38.87	38.50	38.14	37.78	37.42	37.05	36.69	36.33	35.98	35.62
0.4	35.26	34.90	34.55	34.19	33.84	33.49	33.13	32.78	32.43	32.08
0.5	31.74	31.39	31.04	30.70	30.36	30.01	29.67	29.33	28.99	28.66
0.6	28.32	27.98	27.65	27.32	26.99	26.66	26.33	26.00	25.68	25.35
0.7	25.03	24.71	24.39	24.07	23.75	23.44	23.12	22.81	22.50	22.19
0.8	21.88	21.58	21.27	20.97	20.67	20.37	20.07	19.78	19.48	19.19
0.9	18.90	18.61	18.33	18.04	17.76	17.48	17.20	16.92	16.65	16.37
1.0	16.10	15.83	15.56	15.30	15.03	14.77	14.51	14.26	14.00	13.75
1.1	13.49	13.25	13.00	12.75	12.51	12.27	12.03	11.79	11.56	11.33
1.2	11.10	10.87	10.65	10.42	10.20	9.98	9.77	9.55	9.34	9.13
1.3	8.93	8.72	8.52	8.32	8.12	7.92	7.73	7.54	7.35	7.17
1.4	6.98	6.80	6.62	6.45	6.27	6.10	5.93	5.77	5.60	5.44
1.5	5.28	5.13	4.97	4.82	4.67	4.52	4.38	4.24	4.10	3.96
1.6	3.83	3.69	3.57	3.44	3.31	3.19	3.07	2.95	2.84	2.73
1.7	2.62	2.51	2.41	2.30	2.20	2.11	2.01	1.92	1.83	1.74
1.8	1.65	1.57	1.49	1.41	1.34	1.26	1.19	1.12	1.06	0.99
1.9	0.93	0.87	0.81	0.76	0.70	0.65	0.60	0.56	0.51	0.47
2.0	0.43	0.39	0.36	0.32	0.29	0.26	0.23	0.21	0.18	0.16
2.1	0.14	0.12	0.10	0.08	0.07	0.06	0.05	0.04	0.03	0.02
2.2	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00

For values of Q greater than or equal to zero, the estimate of percent defective (PDc) is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100. Values of Q greater than what is on the table indicate that there is 0.00 % unacceptable material.

TABLE 8 (CONT.): Estimated percent defective for compressive strength (PDc)
Sample size (n) =8

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.62	49.24	48.86	48.49	48.11	47.73	47.35	46.97	46.59
0.1	46.22	45.84	45.46	45.08	44.71	44.33	43.96	43.58	43.21	42.83
0.2	42.46	42.08	41.71	41.34	40.97	40.59	40.22	39.85	39.48	39.11
0.3	38.75	38.38	38.01	37.65	37.28	36.92	36.55	36.19	35.83	35.47
0.4	35.11	34.75	34.39	34.04	33.68	33.33	32.97	32.62	32.27	31.92
0.5	31.57	31.22	30.87	30.53	30.18	29.84	29.50	29.16	28.82	28.48
0.6	28.15	27.81	27.48	27.15	26.82	26.49	26.16	25.83	25.51	25.19
0.7	24.86	24.54	24.23	23.91	23.59	23.28	22.97	22.66	22.35	22.04
0.8	21.74	21.44	21.14	20.84	20.54	20.24	19.95	19.66	19.37	19.08
0.9	18.79	18.51	18.23	17.95	17.67	17.39	17.12	16.85	16.57	16.31
1.0	16.04	15.78	15.51	15.25	15.00	14.74	14.49	14.24	13.99	13.74
1.1	13.49	13.25	13.01	12.77	12.54	12.30	12.07	11.84	11.61	11.39
1.2	11.17	10.94	10.73	10.51	10.30	10.09	9.88	9.67	9.47	9.26
1.3	9.06	8.87	8.67	8.48	8.29	8.10	7.91	7.73	7.55	7.37
1.4	7.19	7.02	6.85	6.68	6.51	6.35	6.19	6.03	5.87	5.71
1.5	5.56	5.41	5.26	5.12	4.97	4.83	4.69	4.56	4.42	4.29
1.6	4.16	4.03	3.91	3.79	3.67	3.55	3.43	3.32	3.21	3.10
1.7	2.99	2.89	2.79	2.69	2.59	2.49	2.40	2.31	2.22	2.13
1.8	2.04	1.96	1.88	1.80	1.72	1.65	1.58	1.51	1.44	1.37
1.9	1.31	1.24	1.18	1.12	1.07	1.01	0.96	0.91	0.86	0.81
2.0	0.76	0.72	0.67	0.63	0.59	0.55	0.52	0.48	0.45	0.42
2.1	0.39	0.36	0.33	0.30	0.28	0.26	0.23	0.21	0.19	0.17
2.2	0.16	0.14	0.13	0.11	0.10	0.09	0.08	0.07	0.06	0.05
2.3	0.04	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.00

For values of Q greater than or equal to zero, the estimate of percent defective (PDc) is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100. Values of Q greater than what is on the table indicate that there is 0.00 % unacceptable material.

TABLE 8 (CONT.): Estimated percent defective for compressive strength (PDc)
Sample size (n) =9

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.62	49.24	48.85	48.47	48.09	47.71	47.33	46.95	46.57
0.1	46.18	45.80	45.42	45.04	44.66	44.29	43.91	43.53	43.15	42.77
0.2	42.40	42.02	41.64	41.27	40.89	40.52	40.15	39.77	39.40	39.03
0.3	38.66	38.29	37.92	37.55	37.19	36.82	36.46	36.09	35.73	35.37
0.4	35.00	34.64	34.29	33.93	33.57	33.21	32.86	32.51	32.15	31.80
0.5	31.45	31.10	30.76	30.41	30.07	29.72	29.38	29.04	28.70	28.36
0.6	28.03	27.69	27.36	27.03	26.70	26.37	26.04	25.72	25.39	25.07
0.7	24.75	24.43	24.11	23.80	23.49	23.17	22.86	22.56	22.25	21.94
0.8	21.64	21.34	21.04	20.75	20.45	20.16	19.87	19.58	19.29	19.00
0.9	18.72	18.44	18.16	17.88	17.61	17.33	17.06	16.79	16.53	16.26
1.0	16.00	15.74	15.48	15.23	14.97	14.72	14.47	14.22	13.98	13.73
1.1	13.49	13.26	13.02	12.79	12.55	12.32	12.10	11.87	11.65	11.43
1.2	11.21	10.99	10.78	10.57	10.36	10.15	9.95	9.75	9.55	9.35
1.3	9.16	8.96	8.77	8.59	8.40	8.22	8.04	7.86	7.68	7.51
1.4	7.33	7.17	7.00	6.83	6.67	6.51	6.35	6.20	6.04	5.89
1.5	5.74	5.60	5.45	5.31	5.17	5.03	4.90	4.77	4.64	4.51
1.6	4.38	4.26	4.14	4.02	3.90	3.78	3.67	3.56	3.45	3.34
1.7	3.24	3.14	3.03	2.94	2.84	2.75	2.65	2.56	2.47	2.39
1.8	2.30	2.22	2.14	2.06	1.98	1.91	1.84	1.76	1.70	1.63
1.9	1.56	1.50	1.44	1.37	1.32	1.26	1.20	1.15	1.10	1.05
2.0	1.00	0.95	0.90	0.86	0.82	0.77	0.73	0.70	0.66	0.62
2.1	0.59	0.55	0.52	0.49	0.46	0.43	0.41	0.38	0.36	0.33
2.2	0.31	0.29	0.27	0.25	0.23	0.21	0.20	0.18	0.17	0.15
2.3	0.14	0.13	0.11	0.10	0.09	0.08	0.08	0.07	0.06	0.05
2.4	0.05	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.01	0.01
2.5	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00

For values of Q greater than or equal to zero, the estimate of percent defective (PDc) is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100. Values of Q greater than what is on the table indicate that there is 0.00 % unacceptable material.

TABLE 8 (CONT.): Estimated percent defective for compressive strength (PDc)
Sample size (n) =10

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.0	49.62	49.23	48.85	48.46	48.08	47.70	47.31	46.93	46.54
0.1	46.16	45.78	45.40	45.01	44.63	44.25	43.87	43.49	43.11	42.73
0.2	42.35	41.97	41.60	41.22	40.84	40.47	40.09	39.72	39.34	38.97
0.3	38.60	38.23	37.86	37.49	37.12	36.75	36.38	36.02	35.65	35.29
0.4	34.93	34.57	34.21	33.85	33.49	33.13	32.78	32.42	32.07	31.72
0.5	31.37	31.02	30.67	30.32	29.98	29.64	29.29	28.95	28.61	28.28
0.6	27.94	27.60	27.27	26.94	26.61	26.28	25.96	25.63	25.31	24.99
0.7	24.67	24.35	24.03	23.72	23.41	23.10	22.79	22.48	22.18	21.87
0.8	21.57	21.27	20.98	20.68	20.39	20.10	19.81	19.52	19.23	18.95
0.9	18.67	18.39	18.11	17.84	17.56	17.29	17.03	16.76	16.49	16.23
1.0	15.97	15.72	15.46	15.21	14.96	14.71	14.46	14.22	13.97	13.73
1.1	13.50	13.26	13.03	12.80	12.57	12.34	12.12	11.90	11.68	11.46
1.2	11.24	11.03	10.82	10.61	10.41	10.21	10.00	9.81	9.61	9.42
1.3	9.22	9.03	8.85	8.66	8.48	8.30	8.12	7.95	7.77	7.60
1.4	7.44	7.27	7.10	6.94	6.78	6.63	6.47	6.32	6.17	6.02
1.5	5.87	5.73	5.59	5.45	5.31	5.18	5.05	4.92	4.79	4.66
1.6	4.54	4.41	4.30	4.18	4.06	3.95	3.84	3.73	3.62	3.52
1.7	3.41	3.31	3.21	3.11	3.02	2.93	2.83	2.74	2.66	2.57
1.8	2.49	2.40	2.32	2.25	2.17	2.09	2.02	1.95	1.88	1.81
1.9	1.75	1.68	1.62	1.56	1.50	1.44	1.38	1.33	1.27	1.22
2.0	1.17	1.12	1.07	1.03	0.98	0.94	0.90	0.86	0.82	0.78
2.1	0.74	0.71	0.67	0.64	0.61	0.58	0.55	0.52	0.49	0.46
2.2	0.44	0.41	0.39	0.37	0.34	0.32	0.30	0.29	0.27	0.25
2.3	0.23	0.22	0.20	0.19	0.18	0.16	0.15	0.14	0.13	0.12
2.4	0.11	0.10	0.09	0.08	0.08	0.07	0.06	0.06	0.05	0.05
2.5	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01
2.6	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00

For values of Q greater than or equal to zero, the estimate of percent defective (PDc) is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100. Values of Q greater than what is on the table indicate that there is 0.00 % unacceptable material.

TABLE 8 (CONT.): Estimated percent defective for compressive strength (PDc)
Sample size (n) >10

Q	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
0.0	50.00	49.60	49.20	48.80	48.40	48.01	47.61	47.21	46.81	46.41
0.1	46.02	45..62	45.22	44.83	44.43	44.04	43.64	43.25	42.86	42.47
0.2	42.07	41.68	41.29	40.90	40.52	40.13	39.74	39.36	38.97	38.59
0.3	38.21	37.83	37.45	37.07	36.69	36.32	35.94	35.57	35.20	34.83
0.4	34.46	34.09	33.72	33.36	33.00	32.64	32.28	31.92	31.56	31.21
0.5	30.85	30.50	30.15	29.81	29.46	29.12	28.77	28.43	28.10	27.76
0.6	27.43	27.09	26.76	26.43	26.11	25.78	25.46	25.14	24.38	24.51
0.7	24.20	23.89	23.58	23.27	22.95	22.66	22.36	22.06	21.77	21.48
0.8	21.19	20.90	20.61	20.33	20.05	19.77	19.49	19.22	18.94	18.67
0.9	18.41	18.14	17.88	17.62	17.36	17.11	16.85	16.60	16.35	16.11
1.0	15.87	15.62	15.39	15.15	14.92	14.69	14.46	14.23	14.01	13.79
1.1	13.57	13.35	13.14	12.92	12.71	12.51	12.30	12.10	11.90	11.70
1.2	11.51	11.31	11.12	10.93	10.75	10.56	10.38	10.20	10.03	9.85
1.3	9.68	9.51	9.34	9.80	9.01	8.85	8.69	8.53	8.38	8.23
1.4	8.08	7.93	7.78	7.64	7.49	7.35	7.21	7.08	6.94	6.81
1.5	6.68	6.55	6.43	6.30	6.18	6.06	5.94	5.82	5.71	5.59
1.6	5.48	5.37	5.26	5.16	5.05	4.95	4.85	4.75	4.65	4.55
1.7	4.46	4.36	4.27	4.18	4.09	4.01	3.92	3.84	3.75	3.67
1.8	3.59	3.51	3.44	3.36	3.29	3.22	3.14	3.07	3.01	2.94
1.9	2.87	2.81	2.74	2.68	2.62	2.56	2.50	2.44	2.39	2.33
2.0	2.28	2.22	2.17	2.12	2.07	2.02	1.97	1.92	1.88	1.83
2.1	1.79	1.74	1.70	1.66	1.62	1.58	1.54	1.50	1.46	1.43
2.2	1.39	1.36	1.32	1.29	1.25	1.22	1.19	1.16	1.13	1.10
2.3	1.07	1.04	1.02	0.99	0.96	0.94	0.91	0.89	0.87	0.84
2.4	0.82	0.80	0.78	0.75	0.73	0.71	0.69	0.68	0.68	0.64
2.5	0.62	0.60	0.59	0.57	0.55	0.54	0.52	0.51	0.49	0.48
2.6	0.47	0.45	0.44	0.43	0.41	0.40	0.39	0.38	0.37	0.36
2.7	0.35	0.34	0.33	0.32	0.31	0.30	0.29	0.28	0.27	0.26
2.8	0.26	0.25	0.24	0.23	0.23	0.22	0.21	0.21	.20	.19
2.9	.19	.18	.18	.17	.16	.16	.15	.15	.14	.14

3.0	.13	.13	.13	.12	.12	.11	.11	.11	.10	.10

For values of Q greater than or equal to zero, the estimate of percent defective (PDc) is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100. Values of Q greater than what is on the table indicate that there is 0.00 % unacceptable material.

TABLE 9	QC/QA ACCEPTANCE TEST RESULTS	SHEET		OF	

PROJECT NO		BRIDGE NO		REF NO		QUANTITY		CLASS		JMF #		PLACEMENT DATE	

DBT		PRODUCER / LOCATION		CERTIFIED LABORATORY / LOCATION	

QC or QA	LOAD	LOCATION	SPECIMEN NO	SUB LOT SIZE	BATCH TICKET NO	BATCH SIZE	BATCH WT	UNIT WT	YIELD	AGGREGATE MOISTURE FINE	AGGREGATE MOISTURE COARSE
	STRENGTH 1		STRENGTH 2		STRENGTH AVG		AIR		SLUMP		
QC or QA	LOAD	LOCATION	SPECIMEN NO	SUB LOT SIZE	BATCH TICKET NO	BATCH SIZE	BATCH WT	UNIT WT	YIELD	AGGREGATE MOISTURE FINE	AGGREGATE MOISTURE COARSE
	STRENGTH 1		STRENGTH 2		STRENGTH AVG		AIR		SLUMP		
QC or QA	LOAD	LOCATION	SPECIMEN NO	SUB LOT SIZE	BATCH TICKET NO	BATCH SIZE	BATCH WT	UNIT WT	YIELD	AGGREGATE MOISTURE FINE	AGGREGATE MOISTURE COARSE
	STRENGTH 1		STRENGTH 2		STRENGTH AVG		AIR		SLUMP		
QC or QA	LOAD	LOCATION	SPECIMEN NO	SUB LOT SIZE	BATCH TICKET NO	BATCH SIZE	BATCH WT	UNIT WT	YIELD	AGGREGATE MOISTURE FINE	AGGREGATE MOISTURE COARSE
	STRENGTH 1		STRENGTH 2		STRENGTH AVG		AIR		SLUMP		
QC or QA	LOAD	LOCATION	SPECIMEN NO	SUB LOT SIZE	BATCH TICKET NO	BATCH SIZE	BATCH WT	UNIT WT	YIELD	AGGREGATE MOISTURE FINE	AGGREGATE MOISTURE COARSE
	STRENGTH 1		STRENGTH 2		STRENGTH AVG		AIR		SLUMP		
QC or QA	LOAD	LOCATION	SPECIMEN NO	SUB LOT SIZE	BATCH TICKET NO	BATCH SIZE	BATCH WT	UNIT WT	YIELD	AGGREGATE MOISTURE FINE	AGGREGATE MOISTURE COARSE
	STRENGTH 1		STRENGTH 2		STRENGTH AVG		AIR		SLUMP		
QC or QA	LOAD	LOCATION	SPECIMEN NO	SUB LOT SIZE	BATCH TICKET NO	BATCH SIZE	BATCH WT	UNIT WT	YIELD	AGGREGATE MOISTURE FINE	AGGREGATE MOISTURE COARSE
	STRENGTH 1		STRENGTH 2		STRENGTH AVG		AIR		SLUMP		
QC or	LOAD	LOCATION	SPECIMEN NO	SUB LOT SIZE	BATCH TICKET	BATCH SIZE	BATCH WT	UNIT WT	YIELD	AGGREGATE MOISTURE FINE	AGGREGATE MOISTURE COARSE

QA					NO						

	STRENGTH 1		STRENGTH 2		STRENGTH AVG		AIR		SLUMP	

Signature from Certified laboratory	Date	Signature from DBT	Date

TABLE 10	**QC/QA PLASTIC AIR AND SLUMP RESULTS**				SHEET		OF
PLACEMENT DATE		CLASS OF CONCRETE		MINIMUM AIR		MAXIMUM AIR	
				See TABLE 2		Established for mix	
NAMES OF TECHNICIANS PERFORMING QC TESTS							
METHOD OF REDUCING AIR LOSS IF PUMPED							
LOAD	SLUMP	AIR @ DISCHARGE	AIR @ PLACMENT	LOAD	SLUMP	AIR @ DISCHARGE	AIR @ PLACMENT
Signature from Certified laboratory			Date	Signature from DBT			Date

Item 513 Structural Steel Members, Modular Expansion Joint Systems, Level UF

.01 DESCRIPTION

Furnish all materials, services, labor, tools, equipment and incidentals necessary to design, fabricate, inspect, test and install modular expansion joints in accordance with the contract documents. All requirements of 513, UF Level Fabrication apply, unless modified by these notes.

.02 DESIGN

1. Prepare and check the design under the authority of an Ohio Registered Professional Engineer. The Registered Engineer shall seal, sign and date the design calculations and shop drawings.
2. Include design calculations with the submission of shop drawings.
3. Provide a detailed installation procedure and include any specific manufacturers notes necessary for completion of the work.
4. Design and test the modular joint components, joint armor and anchorages according to the National Cooperative Highway Research Program (NCHRP) Report # 402 Appendix A and B.
5. Design temporary and field connections to the bridge to accommodate adjustments for roadway geometry and varying temperature.
6. Design for the movement for the full ambient temperature range for a cold climate as specified by AASHTO LRFD Bridge Design Specifications.
7. Supply support bar bearings to transfer the load from the support bars to the joint armor.
8. Supply equalization springs to counter the compression forces from the sealing elements and maintain equal expansion properties for each sealing element across the joint.
9. Supply control springs which work longitudinally to maintain equidistant spacing between transverse separation beams.
10. Supply separation beams/ transverse dividers/center beams to limit total horizontal movement in any individual strip seal.

11. Supply a strip seal type seal connected to matching retainers connected to the joint armor and the separation beams. Do not exceed 3.15 inches of total horizontal movement in any individual strip seal.

12. Supply removable and replaceable neoprene seals, support bar bearings and equalization springs.

13. Set seals and retainers 1/8" lower than the roadway surface.

14. Design and fabricate the modular joint as a continuous full length member without field splices, unless phased construction or excessive lengths (greater than 70'-0") prohibits monolithic fabrication.

.03 MATERIALS

1. Supply structural steel meeting ASTM A709 grade 50. Supply separation beams/ transverse dividers/ center beams, edge beams and joint armor meeting Charpy V Notch impact requirements per ASTM A709 Table S1.2 zone 2 temperature range. Supply Tube sections meeting ASTM A501 or A500 grade B.
2. Supply ASTM A240, type 304 stainless steel, 13 gage minimum thicknesses with No. 8 finish for sliding surfaces in contact with PTFE.
3. Supply testing and reports by the manufacturer or an independent testing laboratory for all Elastomeric, PTFE, Urethane and preformed fabric materials used in all bearings and springs. The submission of material certification and testing data shall be per501.06 except the submissions are to be sent to and accepted by the Independent Quality Firm (IQF). These materials shall be tested according to the National Cooperative Highway Research Program (NCHRP) Report # 402 Appendix A Guideline for Durability Testing of Springs and Bearings for MBEJ.
4. Supply strip seals conforming to ASTM D5973. Submit certified test data from the manufacturer or an accredited laboratory per 501.06 except submissions are to be sent to and accepted by the IQF. Per D5973 Section 8, lot size is one sample per joint. A sample is a piece 4 feet long with all manufactures' markings. The seal and retainer are an integral system supplied by one manufacturer.
5. Seal Retainers: Extrude, hot roll or machine, steel retainers into a solid shape. Retainers manufactured from bent plate or built up pieces are not acceptable. The internal dimensions of the retainer shall be specified by the manufacturer to achieve positive seal anchorage.
6. Separation beams/ transverse dividers/center beams shall be a solid, non welded machined or extruded steel section.
7. Lubricant - Adhesive Shall be one part moisture curing polyurethane compound meeting the requirements of ASTM D4070 and as specified by the seal manufacturer.
8. Hardware shall be ASTM A325 type one, galvanized or A449 galvanized.

.04 FABRICATION

1. The modular joints shall be fabricated according to 513.
2. Shop assembled the modular joint with all components except, neoprene seals, per 513.24 except that full assembly is required with phased construction.
3. Joints in Strip Seals: No joints are allowed.
4. Joints in Retainers: Welds are water tight, partial penetration welds around the outer periphery of the abutting surfaces. Make splices only in compression zones of the joint armor. Grind flush all welds in contact with the seal and joint armor. Do not use short pieces of retainers less than 6'-0" long, unless required at curbs or sidewalks. Do not provide additional splices in retainers at curb or sidewalk sections other than required for geometry.
5. Shop or field welds of center beams and joint armor shall be complete penetration welds, ground to provide smooth transitions and be 100 % ultrasonically tested per AASHTO/ AWS Bridge Welding Code, with tension acceptance criteria.
6. The Separation beams/ transverse dividers/center beams to support bar connections shall be complete penetration welds, ground to provide smooth transitions and be 100% ultrasonically tested per AASHTO/AWS Bridge Welding Code, with tension acceptance criteria.
7. Temporary Supports: Fabricator designed and installed supports are required to support shipping, erection and construction forces without damage to the steel armor or coatings. These supports shall be adjustable for field temperature setting.

.05 COATING

1. Galvanize or metalize all steel surfaces and components, except at stainless steel and PTFE sliding surfaces. These coatings may be mixed on one assembly, if all similar components of the assembly have the same coating type.
2. Provide a galvanized coating per ASTM A123, with a minimum thickness of 4 mils. Clean excessive galvanizing as necessary to achieve mechanical movement and seal installation.
3. Provide a metalized coating per 516.03.
4. Prior to shipping, retainer grooves shall be protected from construction debris by the installation of backer rods or other effective masking techniques.

.06 INSTALLATION

1. Provide a joint manufacturer's technical representative to physically oversee the fabrication, installation, adjustment and testing during all operations. Where special instructions are not

contained herein or elsewhere in these notes, direction for the installation shall be according to the recommendations of the technical representative.

2. Coordinate and schedule the technical representative.

3. Install the superstructure supporting units before installing the modular joint. Position the joint to match roadway geometry, superstructure connections and temperature opening. Take care to maintain exact alignment of adjacent ends of the armor and separation beams/ transverse dividers/center beams for field welded units. Provide temporary supports as directed by the manufacturer to maintain the proper positioning. For Phased construction, the DBT's methods for installation and temporary supports shall achieve separation of the phases and unrestricted temperature movement.

4. Perform concrete placement using vibration and hand work as necessary to achieve consolidation and eliminate air voids.

5. Place the deck concrete first. Check the abutment or adjacent span side of the modular joint for alignment and temperature adjustment. Temperature shall be measured at the underside of the concrete deck at each end and mid-span to achieve the average super structure temperature. Place the backwall or adjacent span concrete second. The manufacturer's representative shall check that temperature movement has not caused any damage to the bond between the joint and the concrete.

6. Examine seal retainers for soil or defects that can damage the seal. Repair any defects as directed by the Manufacturer's technical representative.

7. Solvent clean the neoprene seal elements and the retainer grooves to remove oil, grease or other soil immediately prior to installing the seals. Install seals using procedures and adhesive specified by the joint manufacturer. Keep the bonding surfaces clean, dry and warmer than 45^{o} F.

8. Test the installed modular joint for leaks. Flood the total expansion joint length with water for a period of not less than one hour. Cover the entire joint system by either ponding or flowing water. Locate any points of leakage and take any and all measures necessary to stop the leakage. Perform a second water test after all repairs have been made. Continue this cycle until no leakage is observed.

Specifications for Cast-In-Place Concrete Overlay

SPECIFICATIONS FOR CAST-IN-PLACE CONCRETE OVERLAY

.01 Description
This work shall consist of furnishing the necessary labor, materials and equipment to overlay concrete bridge decks in accordance with the contract documents; furnishing, placing, finishing, texturing and curing of a micro silica modified concrete (MSC) overlay or a superplasticized dense concrete (SDC) overlay; and all other operations necessary to complete this work according to these specifications.

The overlay surface shall be finished to a dimension "T" above the surface of the bridge deck. The dimension "T" shall be:

- 1¼ inches minimum for micro-silica modified concrete
- 1¾ inches minimum for superplasticized dense concrete.

.02 Micro-silica Modified Concrete Materials
The materials for micro-silica modified concrete shall conform to the following requirements:
Fine aggregate (natural sand)..703.02*
Coarse aggregate (No.8) 703.02*
Portland cement, Type I or IA ....701.04** or 701.01
Water..499.02
Chemical admixture... .....705.12, ASTM C 494, Type A or D
Air-entraining admixture 705.10
Superplasticizing admixture .... ….705.12, ASTM C 494, Type F

(High Range Water Reducer)
Curing materials..705.05 or 705.06, White opaque
Micro-silica admixture...701.10

* Deleterious material shall not exceed one-half the requirement for superstructure aggregate. Deleterious material is clay lumps, shale, soft, friable, or laminated particles, vegetable matter, or other objectionable material. Sodium sulfate soundness loss shall not exceed that specified for superstructure concrete in 703.02.

** Only one brand of cement shall be used for each bridge deck overlay unless otherwise permitted by the Independent Quality Firm (IQF).

Note:
The Design Build Team (DBT) shall obtain a written statement from the manufacturer of the chemical admixtures verifying the compatibility of the combination of materials and the sequence in which they are combined. The manufacturer shall further designate a technical representative from their company or the ready-mix supplier to be in charge of the dispensing of the admixture products. The technical representatives shall act in an advisory capacity and shall report to the DBT and IQF any operations and procedures which are considered by the representative as being detrimental to the integrity of the placement. The manufacturer's technical representative shall be present during concrete placement unless his presence is waived by the IQF.

.03 Superplasticized Dense Concrete Materials

The materials for superplasticized dense concrete shall conform to the following requirements:

Fine aggregate (natural sand)..703.02*
Coarse aggregate (No. 8) 703.02*
Portland cement, Type I or IA** .... 701.04 or 701.01
Water...499.02
Chemical admixture...705.12, ASTM C 494, Type A or D
Air-entraining admixture 705.10
Superplasticizing admixture ....705.12, ASTM C 494, Type F

(High Range Water Reducer)
Curing materials...705.05 or 705.06, White opaque

* Deleterious material shall not exceed one half the requirement for superstructure aggregate. Deleterious material is clay lumps, shale, soft, friable, or laminated particles, vegetable matter, or other objectionable material. Sodium sulfate soundness loss shall not exceed that specified for superstructure concrete in 703.02.

** Only one brand of cement shall be used for each bridge deck overlay unless otherwise permitted by the IQF.

Note:

The DBT shall obtain a written statement from the manufacturer of the superplasticizing admixture verifying the compatibility of the combination of materials and the sequence in which they are combined. The manufacturer shall further designate a technical representative from the ready-mix supplier or his company to be in charge of dispensing the admixture products. Operations and procedures which are considered by the designated representative as being detrimental to the integrity of the overlay shall not be permitted.

.04 Mixers

Concrete shall be mixed in a central mixing plant or by a ready-mixed concrete truck capable of discharging concrete having a maximum water-cementitious ratio of 0.36. Mixing equipment shall meet the requirements of 499.06(B). Admixtures shall be introduced into the concrete in such a manner that will disperse them throughout the entire load. Batch plants shall meet the requirements of 499.06(A) and shall be located such that the maximum time required from start of mixing to completion of discharge of the concrete at the site of work shall not exceed 90 minutes.

.05 Finishing Machine Rail and Supports

Finishing machines shall be supported by rail and supports made of steel. Rail shall be furnished in sections not less than 10 feet in length and be of sufficient cross-section so that the weight of the finishing machine causes zero vertical deflection while in motion. Rail shall be straight with no sections exceeding a tolerance of 1/8 inch in 10 feet in any direction. Rail supports shall be screw-type adjustable saddles and shall be of sufficient number under the rail so that near zero vertical deflection occurs under the weight of the finishing machine.

.06 Proportioning and Mixing of Micro-silica Modified Concrete

All required characteristics of the mix, i.e. air entrainment and slump, shall be adjusted off the deck before placement of the overlay begins. The components of the micro silica modified concrete shall be combined into a workable mixture of uniform composition and consistency. They shall be proportioned as follows:

QUANTITIES OF MATERIAL PER CUBIC YARD (DRY WEIGHTS)*

Type of Coarse Aggregate	Coarse Aggregate lb	Fine Aggregate lb	Cement lb	Micro Silica lb	Maximum Water-Cementitious Ratio^^
Gravel	1355	1355	700	50	0.36
Limestone	1370	1355	700	50	0.36
Slag	1190	1355	700	50	0.36

* The specific gravities used for determining the above weights are: natural sand 2.62, gravel 2.62, limestone 2.65, slag 2.30 and micro silica 2.20.

^^ The water cementitious ratio shall be calculated based upon the total cementitious material. Cementitious material shall include Portland cement and microsilica (solids).

The proportions of coarse and fine aggregate shall be adjusted to provide the maximum amount of course aggregate possible and still provide a workable and finishable mix. The DBT may modify the mixes shown by adjusting the coarse and fine aggregates up to 100 pound each, unless otherwise accepted by the IQF.

The batch weights previously described shall be corrected to compensate for the moisture contained in the aggregate at the time of use. A chemical admixture (705.12, Type A or D) shall be used. The transit mixer charge shall be limited to 3/4 of its rated capacity or 6 cubic yards, whichever is the smaller, unless a larger size is accepted by the IQF.

The specified cementitious content shall be maintained and a maximum water-cementitious material ratio of 0.36 shall not be exceeded. Any admixture added at the job site shall be mixed a minimum of 5 minutes at mixing speed. After all components have been added, the slump range shall be 6 inches plus or minus 2 inches. The air content of plastic concrete at the time of placement shall be 8 plus or minus 2 percent.

The use of Micro-silica admixture in dissolvable bags shall not be allowed.

If a slump loss occurs after mixing and before placement, the charge may be retempered with the admixture to restore plasticity. The slump range and air content shall be rechecked to ensure conformance to the allowable values. The load shall still be placed within the 90 minute limitation as per Section D – Mixers. If the consistency of the charge after retempering is such as to cause segregation of the components, this shall be cause for rejection of the load.

<u>.07 Proportioning and Mixing of Superplasticized Dense Concrete.</u>

The SDC mix shall be proportioned and mixed in accordance with 499 of the CMS except as modified herein.

All required characteristics of the mix, i.e. air entrainment and slump, shall be adjusted off the deck before placement of the overlay begins. The components for superplasticized dense concrete shall be combined into a workable mixture of uniform composition and consistency. They shall be proportioned as follows:

QUANTITIES OF MATERIAL PER CUBIC YARD, DRY WEIGHTS*

Type of Coarse Aggregate	Coarse Aggregate lb	Fine Aggregate lb	Cement lb	Maximum Water-Cement Ratio^^
Gravel	1300	1300	825	0.36
Limestone	1315	1300	825	0.36
Slag	1140	1300	825	0.36

* The specific gravities used for determining the above weights are: natural sand 2.62, gravel 2.62, limestone 2.65 and slag 2.30.

The batch weights previously described shall be corrected to compensate for the moisture contained in the aggregate at the time of use. A chemical admixture (705.12, Type A or D) shall be used. The transit mixer charge shall be limited to 3/4 of its rated capacity or 6 cubic yards (4.6 m^3), whichever is the smaller, unless a larger size is accepted by the IQF.

The specified cement content shall be maintained and a maximum water-cement ratio of 0.36 shall not be exceeded. If superplasticizing admixture is added at the job site, the load shall be mixed a minimum of 5 minutes at mixing speed. After all of the superplasticizer has been added, the slump range shall be 6 ± 2 inches. The air content of fresh unvibrated SDC at the time of placement shall be 8 ± 2 percent. Two compressive cylinders shall be made for every other ready-mix truck load of SDC incorporated into the work.

If a slump loss occurs after addition and mixing of the superplasticizing admixture and before placement of the SDC overlay, the charge may be "re-tempered" with the admixture to restore plasticity. The slump range and air content shall be rechecked to ensure conformance to the allowable values. If the consistency of the charge after "re-tempering" is such as to cause segregation of the components, this shall be cause for rejection of the load.

.08 Test Slab

At the option of the IQF, the DBT shall make one or more trial batches of overlay material of the size to be hauled at least 4 days before the overlay is to be placed. He shall cast one or more small test slabs demonstrating the ability to finish and texture the concrete in accordance with Section K – Placing, Consolidating and Finishing. These slabs shall be 8 feet long, a width which is wide enough to accommodate the tinning equipment and 1 1/4 inch thick.

.09 Preparation Prior to Overlay Placement

Not more than 24 hours prior to placing the overlay, all surfaces to which the overlay is to bond, including the faces of barriers up to a height of at least 1 inch above the proposed overlay surface shall be blast cleaned. Suitable blast methods may include high pressure water blasting [10,000 psi min], water blasting [less than 10,000 psi] with abrasives in the water, abrasive blasting with containment, or vacuum abrasive blasting. All surfaces to which the overlay is to bond shall be made free of laitance and all other contaminants detrimental to achieving an adequate bond.

Bridge scuppers shall be cleaned of all foreign matter and plugged prior to placement of the overlay. Following overlay placement, scuppers shall be unplugged to permit free drainage of water from the deck surface.

.10 Finishing Machine Dry Run

After the screed rails have been set to proper profile and prior to placing the overlay, the DBT shall check the finishing machine clearance to assure the IQF that the specified nominal thickness of overlay will be attained over the entire deck.

.11 Placing, Consolidating and Finishing

The deck surface which will contact the overlay shall be cleaned with compressed air, wetted, and kept wet for at least one hour immediately prior to placing the overlay. Any standing water shall be removed prior to placement of the overlay. The overlay shall be placed, consolidated and finished to the plan surface.

Contamination of the wetted deck by construction equipment or from any other source shall be prevented by placement of a clean 4-mill polyethylene sheet (or any other covering as accepted by the IQF) on the surface of the prepared deck.

After the overlay material has been consolidated and finished, it shall be textured transversely to provide a random pattern of grooves spaced at 3/8 inch to 1 3/4 inch centers with 50 percent of the spacings being less than 1 inch. Grooves shall be approximately 0.15 inches deep and 0.10 inches wide. A strip of surface 9 to 12 inches wide adjacent to barriers shall not be textured.

At the DBT's option an evaporation retardant may be used after finishing, or after texturing, or both. This material shall not be finished into the plastic concrete at any time. Only products specifically marketed for such usage shall be utilized. The evaporation retardant shall be applied as per the manufacturer's written recommendations and shall consist of a fine mist using a suitable sprayer. Application in a stream shall not be allowed. The wet burlap cure of Section M – Curing Application shall follow this operation as closely as possible.

The DBT shall stencil the date of construction (month and year) and the letters "MS" for micro-silica modified or "SD" for superplasticized dense into the overlay before it takes its final set. The date and letters shall be located in the right-hand corner of the deck at the forward abutment. It shall be placed parallel to the edge of the overlay and centered at 12 inches in from both the edge of the overlay and end finish. The numerals shall be 3 to 4 inches in height, 1/4 inch in depth and face the centerline of the roadway.

Longitudinal joints are permitted, but only to the extent necessary to accommodate the width of the finishing machine or to facilitate changes in roadway crown, except as accepted by the IQF. Longitudinal joints shall not be used in close proximity to faces of barriers or at edges of decks. All joints in the overlay shall be formed.

Any ponding problem which is noted prior to final acceptance of the overlay shall be corrected by the DBT.

A 10 foot straightedge shall be used to check the overlay directly behind the finishing machine. It shall also be used to check transversely along the edges of the overlay where hand finishing is done. Any irregularities exceeding 1/8 inch in 10 feet shall be corrected immediately.

.12 Curing

A cure day shall be defined as a 24-consecutive hour period of time. The temperature of the overlay surface shall be maintained above 35 °F until the curing period is completed. Any day during which the air temperature at the overlay surface falls below 45 °F shall not be counted as a cure day.

When curing is completed, all joints and abutting surfaces in the overlay shall be sealed with an approved high molecular weight methacrylate sealer meeting 705.15. The sealer shall be prepared and applied in accordance with the manufacturer's recommendations. Joints to be sealed shall include transverse joints in the overlay concrete, joints between overlay concrete and steel enddams, longitudinal joints between overlay concrete placements, and longitudinal joints between overlay concrete and barriers. Any cracking which occurs prior to opening to traffic shall be sealed as above or repaired or corrected in another manner as directed by the IQF and the Engineer at no cost to the State. The deck shall be sounded by the IQF prior to opening to traffic and any delaminated area shall be removed and replaced .

Any improperly cured overlay may be ordered to be removed and replaced at no cost to the State. Regardless of what type of overlay, curing shall start after the concrete has been tined and the surface will not be damaged by the cure.

.13 Curing Application

As soon as the tining operation is completed, the finished overlay surface shall be covered with a single layer of clean wet burlap. The fresh overlay surface shall receive a wet burlap cure for 3 days. For the entire curing period of 72 hours the burlap shall be kept wet by the continuous application of water through soaker hoses. Either a 4-mil white opaque polyethylene film or a wet burlap-white opaque polyethylene sheet shall be used to cover the wet burlap for the entire 72 hour period.

Traffic shall not be permitted on the finished overlay surface until after completion of the 3 day wet cure.

.14 Limitation on Placing Operations

Prior to overlay placement, the IQF shall establish the DBT's ability to place the overlay on a continuous basis and to consolidate, finish, texture, prior to the formation of plastic surface film, and commence curing.

When directed by the Engineer or IQF, a representative of the micro-silica supplier shall be present during the proportioning, mixing, placing and finishing of the overlay. Operations and procedures which are considered by this representative to be detrimental to the integrity and durability of the overlaid bridge deck shall not be permitted.

Once the finishing machine has made the first pass, workers shall not be allowed to walk in the freshly placed overlay.

No overlay concrete shall be placed when it is raining, when the ambient air temperature is below 45 °F or when it is predicted to fall below 45 °F for the duration of the curing period.

Overlays shall be placed only when the overlay surface evaporation rate, as affected by ambient air temperature, concrete temperature, deck temperature, relative humidity and wind velocity, is 0.1 pound per square foot per hour or less. The DBT shall determine and document the atmospheric conditions, subject to verification by the IQF. No overlay concrete shall be placed if the ambient air temperature is 85 °F or greater or predicted to go above 85 °F during the overlay placement regardless of the surface evaporation rate.

Figure 1 in ACI 308 (see 511.10) shall be used to determine graphically the loss of surface moisture for the overlay. In no case shall the temperature of the overlay concrete exceed 85 °F during placement. The measurement of weather parameters shall be made within 10 feet of the placement area. No overlays shall be placed after October 15 except by specific permission of the Director and the IQF.

If placement of the overlay is to be made at night, the DBT shall submit a plan which provides adequate lighting for the work area. The plan shall be submitted at least 15 calendar days in advance and be accepted by the IQF before concrete is placed. The lights shall be so directed that they do not affect or distract any traffic.

During delays in the overlay concrete's placement operations of more than 10 minutes, the work face of the overlay shall be temporarily covered with wet burlap. If an excessive delay is anticipated, a bulkhead shall be installed at the work face and the overlay placement operation terminated.

Unless otherwise authorized by the Engineer, an overlay shall not be placed adjacent to a previous overlay which has cured for less than 36 hours.

Adequate precautions shall be taken to protect the freshly placed overlay from rain.

Contamination by construction equipment or from any other source shall not be permitted.

.15 Sampling and Testing
After each charging of the transit mixer (MSC or SDC), the following testing shall be performed:

Testing shall be performed at the point of discharge onto the deck.
a. Slump: 6 +/-2 inches (MSC or SDC)
b. Unit weight
c. Air: 8% +/-2% (MSC or SDC)
d. Compressive strength cylinders shall be made for every 50 cubic yards.

Specifications for Cast-In-Place Segmental Concrete Bridge Structures

SPECIFICATIONS FOR
CAST-IN-PLACE SEGMENTAL CONCRETE BRIDGE STRUCTURES

.01 Description

This specification shall apply to construction of cast-in-place segmental box girder superstructures in accordance to contract documents.

.**02 Related Specifications**

Materials and construction for cast-in-place segmental concrete superstructures shall be in accordance with the contract documents.

.**03 Terminology**

Segment: A modular section of the superstructure consisting of a certain cross-section shape and length as detailed on the plans.

Balanced Cantilever Erection: A method whereby the segments are sequentially constructed alternately on either side of the pier in cantilever to a point where a closure segment is cast in place.

Bar: Post-tensioning bars are high strength steel bars, normally available from 5/8 to 1-3/4 inch diameter and usually threaded with very coarse thread.

Casting Curve: The curve of casting geometry that has to be followed in segment casting for achieving the theoretical bridge profile and alignment after all the final structural and time dependent (creep and shrinkage) deformations have taken place. The casting curve is a combination of the theoretical bridge geometrical profile grade, alignment and the camber.

Camber: The amount by which the concrete profile at casting time must differ from the theoretical geometric profile grade to compensate for all structural dead load, post-tensioning, all long term and time dependent deformations (creep and shrinkage) including all the intermediate erection stages and effects. (The opposite of deflections).

Falsework: Any temporary construction used to support vertical loads for a portion of the structure until that portion becomes self-supporting, including form travelers.

Form Travelers: Refers to a self-launching structural system that is supported off the tip of a cantilever and used for shoring the formwork to cast the adjacent cantilever superstructure segment in its final structural position.

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 is transferred to the concrete by means of anchorages.

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 strand, although some proprietary post-tensioning systems are made up of individual or groups of single wires.

.**04 Submittals and Reviews**

The DBT shall submit detailed drawings, shop drawings, calculations and other information as outlined below to the Independent Design Quality Manager (IDQM) for concurrence and acceptance. Certification shall be provided by the IDQM that the following information has been reviewed and accepted prior to construction.

(1) A schedule of the timing and sequence of segment casting and stressing including the sequence of making cast-in-place closures and continuity between spans.

(2) Details of the disposition and use of special erection equipment, falsework, temporary supports and the like, including all loads or reactions from such equipment applied to the structure during erection and the sequences and timings of these effects in accordance with the erection schedule.

(3) Formwork – complete details of the proposed superstructure fabrication system, including the forms, form travelers, and any temporary supports or attachments associated with the formwork.

(4) Construction Manual – see section .06 of this specification.

(5) Details and complete description of post-tensioning hardware components and any other embedments to be cast into the segments.

(6) The size, type, and components of the post –tensioning system to be used, including duct type, size and support spacing.

.05 Casting Requirements

General

Casting of segments shall not begin until IQF accepts the relevant shop drawings, calculations, concrete forms, concreting operations and post-tensioning system.

Segment Identification

Each segment shall be given an erection mark indicating its location, orientation and order in the erection sequence. Marks shall be affixed on the inside of each cast-in-place segment.

Forms

Design, engineering and construction of the formwork is the responsibility of the DBT. The forming system shall be capable of but not limited to the following:

1. Producing segments within tolerances listed below
2. Accommodating block-outs, openings and required embedded items
3. Adjusting to changes in segment geometry and correcting previous minor casting errors to prevent accumulation of geometric error.
4. Stripping without damage to the concrete
5. Providing a tight, leak-proof joint to the previous segment
6. Positioning and connecting ducts in a manner to hold their position and prevent intrusion of grout.

All exposed surfaces of the each segment of the structure shall be formed to produce similar concrete surface textures, color, and appearance. Exterior concrete surfaces shall have a smooth finish with no visible wood grain.

The same material shall be used to form concrete cast on traditional falsework and concrete cast on form travelers.

The DBT shall repair worn, damaged or otherwise unacceptable forms and obtain acceptance of the IQF before casting any segment. Where sections of forms are joined, DBT shall ensure that offsets in flat surfaces do not exceed 1/16 inch and that offsets with corners and bends do not exceed 1/8 inch. The forms shall be accurately surveyed on a monthly basis for the purpose of monitoring distortion in shape. If any distortions are found to violate the above tolerances, casting shall be discontinued until the problem is corrected.

The DBT shall ensure that all forms are mortar-tight and sufficiently rigid to prevent distortion due to the pressure of the concrete and other loads incidental to the concreting operation, including vibration. The DBT shall inspect forms on a weekly basis to ensure proper alignment and geometric accuracy.

Forms which fail to meet specified casting tolerances shall not be used until such corrections are made to produce segments within the specified tolerances.

The DBT shall clean the inside surfaces of all forms of dirt, mortar and foreign material prior to casting of each segment. Prior to each use, the forms shall be coated with commercial quality form oil or other approved equivalent coating that will permit the ready release of the forms and will not discolor the concrete. The form oil shall be applied such that the finished surface of each segment is uniform in color as compared to the previously and subsequently cast segments. The form oil shall be applied such that none is deposited on the reinforcement in the forms. On all surfaces to which the concrete coating is to be applied, the concrete forms shall be treated with a water based concrete form release agent prior to placing reinforcement.

Preparation for Casting

All items to be encased within the concrete of the segment shall be properly positioned and supported, to the satisfaction of the IQF, prior to beginning of casting of each segment. Extreme care shall be exercised in positioning the next segment to be cast in relation to the previously cast segment. Laitance and form release agents shall be thoroughly cleaned and removed from the abutting surface of the previously cast segment before casting the next segment. The DBT shall include details in the Construction Manual for roughening or providing shear keys between segments.

Geometry Control

Before commencing casting operations, the DBT shall submit, for review and acceptance by the IDQM, a Construction Manual which will include the proposed method of geometry control for all segment casting operations. The geometry control section of the Construction Manual shall include but not be limited to the following:

1. Description of measuring equipment, procedures and location of control points to be established on each segment
2. Location and values of all permanent benchmarks and reference points.
3. A geometry control procedure for the vertical and horizontal alignment control for the casting of segments, including survey controls and procedures, observations, checks, computational and/or graphical methods and correction techniques.
4. The casting curves which include the theoretical geometric horizontal alignment, profile grade and superelevation appropriately combined with the camber.

Embedded Items

The DBT shall utilize positive methods to ensure that ducts will not be displaced or damaged during concrete placement and consolidation. All post-tensioning ducts shall be adequately secured to the reinforcement cage at intervals not to exceed 30 inches for steel pipe and 24 inches for plastic ducts. Concrete cover requirements shall not be violated by ties or support bars.

Immediately prior to installation of the prestressing steel, the DBT shall demonstrate that all ducts are unobstructed and free of water and debris.

Prior to placing concrete in the forms, all tendon anchor plates and anchor castings shall be placed in their respective positions in the forms, connected to their duct and sealed to prevent mortar intrusion. DBT shall ensure that anchor plates and casting are rigidly fixed in the forms to maintain correct alignment and position during concrete placement and consolidation.

DBT shall not cut out or remove reinforcing steel to permit proper alignment of post-tensioning ducts.

Concrete Placement and Consolidation

Concrete shall not be deposited into the forms until the entire set-up of the forms, reinforcement, ducts, anchorages and embedded items has been thoroughly inspected.

A concrete placement sequence shall be developed and submitted as part of the Construction Manual. Concrete in the webs shall be placed in lifts not to exceed 24 inches at a time. Placement and consolidation of concrete shall be done with care so that post-tensioning ducts, anchorages and any other embedded items are maintained in their proper position and are not damaged.

The DBT shall use vibrators having a minimum frequency of sufficient amplitude to consolidate the concrete effectively. The DBT shall provide at least 2 stand-by vibrators in working condition for emergency use in case of malfunction. If external vibrators are used, the forms shall be sufficiently rigid to resist displacement or damage. Vibration shall be conducted in such a manner to avoid displacement or damage to reinforcement, post-tensioning ducts, anchorages or other embedded items.

Curing, Finishing and Repair

The top surface of the top slab of the segments shall be cured for a minimum of four (4) days. Locate curing mats or blankets as necessary to avoid interference for placement and launching operations of the form traveler. Maintain curing in these areas of interference as much as possible.

Do not use membrane curing for the segmental concrete bridge unit. All cracks, spalling, breakage, and honeycombing in the concrete shall be reviewed by the IQF. The DBT shall propose a corrective plan of action and submit to the IQF and the Engineer for acceptance. The IQF and the Engineer shall verify the corrective action addressed the deficiency. Removal of Forms

Weight-supporting forms shall remain in-place until the concrete has attained the minimum compressive strength listed in the Construction Manual, but no sooner than 48 hours after placement of concrete. Transverse and longitudinal post-tensioning shall not be stressed until after the concrete reaches the approved release strength specified in the Construction Manual. Do not remove remaining load-supporting forms until stressing operations are complete and at least 48 hours have elapsed since placement of concrete. Exercise care in removing the forms to prevent spalling and chipping of the concrete. Test cylinders shall be made and cured in the same manner as the segment to confirm the form release strength prior to removing forms.

Tolerances

The following tolerances shall apply to the casting of all superstructure box segments:

Component	Tolerance
Width of Web	±1/4 inch
Depth of bottom slab	±3/16 inch
Depth of top slab	±3/16 inch
Overall depth of segment	±3/16 inch
Overall width of segment	±1/4 inch
Length of segment	±3/8 inch
Diaphragm dimensions	±3/8 inch
Wingtip to Centerline	±1/4 inch
Tendon hole location	±1/4 inch

Dimensions shall be controlled from segment to segment and deviations shall be compensated for such that the overall dimensions of the completed structure are in conformance with the dimensions and overall erection tolerances outlined in this section.

06. Construction Manual

Before commencing construction operations, the DBT shall submit a plan for all segment casting operations to the IQF for acceptance.

This submittal must be in the form of a "Construction Manual" and include but not necessarily be limited to the items listed below. Any deviations from the sequence, schedule and provisions included in the Construction Manual will require the DBT to submit a revised Construction Manual to the IQF for acceptance.

Construction Plan – The Construction Plan shall include but not be limited to the following:

1. All intermediate procedures related to setting up and moving form travelers, construction equipment, falsework, temporary supports, and counterweights.
2. All sequences for support jacking, stressing of temporary and permanent tendons, closure operations including any partial stressing across the closure during concrete curing, stressing loads, and elongations.
3. Sequencing of grouting operations.
4. Procedures and sequence of operations including a detailed schedule that complies with any working hour limitations.
5. Temporary falsework supports, bracing, guys, deadmen, connection details and any attachments to other structural components.
6. Material properties and specifications for temporary works
7. Drawings, notes, and catalog data showing manufacturer's recommendations, performance tests, and calculations which verify the above-listed information.

Casting Curves – For all cast-in-place segments, include in the Construction Manual casting curves in accordance with the proposed casting methods and construction schedule. The casting curves shall give due consideration to the casting schedule, all loads (temporary and permanent), and properties of the proposed materials, including time-dependent properties. In developing casting curves, the deformations due to creep, shrinkage, and the concrete modulus of elasticity shall be computed in accordance with the time-dependent concrete model, which will be reviewed and accepted by the IDQM.

The casting curves shall be developed with sufficient accuracy to allow the determination of control point settings for the accurate casting of segments in accordance with the tolerances set forth in the contract documents. Any changes to the previously approved Construction Plan will necessitate the submittal of a new casting curve which shall be developed in the same manner as required for the original casting curve. The IDQM may waive submittal of a revised casting curve if the change to the Construction Plan is deemed insignificant. With the submittal of a revised casting curve, the DBT is required to submit a proposed method and location for transitioning between the current curve in use and the submitted proposed curve.

Geometry Control Procedures – The Construction Manual shall describe a detailed step-by-step procedure for the geometric control of all cast-in-place segments in agreement with the proposed methods for casting and construction of the superstructure segments. The geometry control procedures shall include but not be limited to:

1. Detailed narrative of the geometry control theory and step-by-step geometry control
2. Methods for elevation and alignment control, including initial survey
3. The sequence in which segments and individual components of each segment will be cast
4. A description of all measuring equipment and procedures to be used
5. Locations of control points to be established on each segment.
6. A summary of elevations for each joint which gives the elevation history of that joint during all steps of construction
7. A table of theoretical elevations and alignment of geometry control points for each stage of superstructure construction, including unloaded formwork in position to receive concrete, after concrete is placed (which may involve multiple positions if concrete is placed in stages), and after each stage of stressing the post-tensioning. The theoretical positions shall take into consideration all of the following:
    a. Effects of construction dead load and live load, as applicable, including the weight of the form travelers and other equipment. Form travelers shall be weighed prior to initial use.
    b. Effects of post-tensioning
    c. Effects of creep and shrinkage
    d. Final roadway profile
    e. For changes to a construction procedure already in effect, the as-cast geometry established from surveys during the casting of previous segments.

Other Construction Equipment – For systems not previously covered in this section, the DBT shall include in the construction manual a complete description of the equipment proposed to be used for casting concrete, as well as details related to access for post-tensioning stressing equipment, construction methods utilizing the proposed equipment, and the location and magnitude of all loads imposed on any portion of the permanent structure by this equipment.

.07 Other Erection Requirements

Erection Tolerances
The following geometric tolerances during cast-in-place segment construction shall apply:

1. Transversely, the angular deviation from the theoretical slope difference between two successive segment joints shall not exceed 0.001 rad.
2. Longitudinally, the angular deviation from the theoretical slope change between two successive segments shall not exceed 0.003 rad.
3. Dimensions from segment to segment shall compensate for any deviations within a single segment so that the overall dimensions of the completed structure meet the dimensions shown on the plans such that the accumulated maximum error does not exceed 1/1000 of the span length for either vertical profile and/or horizontal alignment.

Closure Joints
The closure joint concrete shall reach the same minimum required strengths as the segments for stressing of tendons and removal of forms. Closure joint forms shall provide the same tolerances as specified above for segments. Formwork at closure joints shall be supported by the ends of the cantilevers to be joined. The cantilevers shall be secured together vertically, longitudinally and transversely such that the applied loads will yield equal deflections to both cantilevers.

Balanced Cantilever Construction
TheDBT's Construction Manual and plans shall clearly indicate the erection time assumptions used for computing deformations due to time dependent stress variations. During balanced cantilever erection, the cantilever shall be unbalanced by no more than one segment at any time. Pier segments shall not be cast more than one-half segment out of balance. In addition, the superstructure shall be designed for any other unbalanced loads applied by erection equipment.

.**08 Bird and Vermin Protection**

The DBT is required to provide a means for preventing the intrusion into the box girder of birds and vermin. Sufficient covering shall be provided on all openings in the box girder including but not limited to expansion joint openings, utility blockouts, drainage holes, and access openings. Coverings shall consist of galvanized wire mesh or approved equivalent with openings no larger than ¼". At expansion joint openings, attachment of the mesh to the box girder shall be done in such a fashion as to accommodate all movements due to thermal expansion and contraction or any other anticipated deformations.

Specifications for Precast Segmental Concrete Bridge Structures

.01 Description

This specification shall apply to construction of precast segmental box girder superstructures in accordance to the contract documents.

.**02 Related Specifications**

Materials and construction for precast segmental concrete superstructures shall be in accordance with the contract documents.

.**03 Terminology**

Segment: A modular section of the superstructure consisting of a certain cross-section shape and length as detailed on the plans.

Match Cast: A precast concrete fabrication process whereby a segment is cast against the preceding segment producing a matching interface which permits the re-establishment of the cast geometry at erection time. Match casting is accomplished by either the short line or long line casting method.

Short Line Casting: Casting segments one at a time in a casting cell between a bulkhead at one end and a previously cast segment at the other. The first segment is cast between the bulkhead and another, temporary bulkhead.

Long Line Casting: Casting segments on a casting bed of sufficient length to permit the cumulative casting of segments for the entire length of a span or cantilever between field closure pours without repositioning the segments on the casting bed. With this method, the first segment is cast between bulkheads and successive segments are cast between a movable bulkhead on one end and the previously cast segment on the other.

Casting Cell: A special formwork arrangement usually consisting of a fixed vertical bulkhead of the cross section shape at one end and adjustable soffit, side and core forms all designed and assembled into a machine for making a single superstructure segment. A casting cell for a substructure pier shaft segment consists of exterior and interior side forms and a soffit form of the cross section shape.

Wet Joint System: Where segments are made in a casting cell between two bulkheads and are not match cast. The segments are then erected in the superstructure with a narrow cast-in-place joint between each segment. (During erection, all the segments of a span or multiple spans are supported by falsework, truss or other technique until the joints have gained strength and the longitudinal post-tensioning installed to make them self supporting.)

Span By Span Erection: Placing a specified number of segments on a temporary support system, aligned and post-tensioned longitudinally forming a completed span of the superstructure.

Balanced Cantilever Erection: The segments are sequentially erected alternately on either side of the pier in cantilever to a point where a closure is cast-in-place.

Progressive Cantilever Erection: The segments are erected progressively in cantilever, in one direction, from one pier to the next, using temporary intermediate piers, or other systems as required to support the advancing cantilever between piers.

Casting Curve: The curve of casting geometry that has to be followed in the casting cell or bed for achieving the theoretical bridge profile and alignment after all the final structural and time dependent (creep and shrinkage) deformations have taken place. The casting curve is a combination of the theoretical bridge geometrical profile grade, alignment and the camber.

Camber: The amount by which the concrete profile at casting time must differ from the theoretical geometric profile grade to compensate for all structural dead load, post-tensioning, all long term and time dependent deformations (creep and shrinkage) including all the intermediate erection stages and effects. (The opposite of deflections).

Erection Elevation: The elevation at which a segment is set in the structure at the time it is erected. (This is profile grade corrected by the amount of deflection calculated to occur from that stage onwards.)

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 is transferred to theconcrete by means of anchorages.

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-tensioningcomponents.

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 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 5/8 to 1-3/4 inch diameter and usually threaded with very coarse thread.

.**04 Submittals and Reviews**

The DBT shall submit detailed drawings, shop drawings, calculations and other information as outlined below to the Independent Design Quality Manager (IDQM) for concurrence and acceptance. Certification shall be provided by the IDQM that the following information has been reviewed and accepted prior to construction.

(1) A schedule of the timing and sequence of segment casting and erection including the sequence of making cast-in-place closures and continuity between spans.

(2) Details of the disposition and use of special erection equipment, falsework, temporary supports and the like, including all loads or reactions from such equipment applied to the structure during erection and the sequences and timings of these effects in accordance with the erection schedule.

(3) Details of the forms and casting cells for the manufacture of the segments.

(4) Layout of the casting yard showing operational features, casting cells, rebar fabrication and material storage areas, movable rain and sun sheds, geometry control stations, segment handling and storage facilities.

(5) Calculations and details for lifting, storage or stacking of the segments.

(6) Details of inserts or lifting holes including any necessary localized strengthening and the materials and methods to fill and finish such holes.

(7) Details and complete description of post-tensioning hardware components and any other embedments to be cast into the segments.

(8) The size, type, and components of the post-tensioning system to be used, including duct type, size and support spacing.

(9) Casting curves and erection elevations, prepared in accordance with chosen construction methods, sequence and schedule. In this respect, the construction methods, sequence and schedule include, but are not limited to, general construction techniques, the erection equipment, its deployment and effect upon the structure, the introduction or removal of temporary supports, falsework, closure devices and the like, their deployment and effect upon the structure, the order (sequence) in which all casting, construction methods and step-by-step erection operations are executed, including post-tensioning, and the timing (schedule) of all such operations, with respect to the maturity of the concrete and affect thereon.

(10) A manual for the casting and geometry control of the segments.

(11) A manual for the detailed step by step erection of the segments including all intermediate procedures relating to any erection equipment, falsework, movement of equipment,

support jacking, stressing of temporary post-tensioning bars, closure operations including any partial stressing across the closure during concrete curing, main post-tensioning tendon sequences, stressing loads and elongations, erection elevations, a method for the field survey and alignment control for setting initial and subsequent segments and any other relevant operations. (This is referred to as the “Erection Manual”.)

.**05 Precasting Requirements**

General

Casting of segments shall not begin until IQF accepts the relevant shop drawings, calculations, concrete forms, concreting operations and post-tensioning system. Segment Identification

Each segment shall be given an erection mark indicating its location, orientation and order in the erection sequence.

Forms

Design, engineering and construction of the formwork is the responsibility of the DBT. All exposed surfaces of the each segment of the structure shall be formed to produce similar concrete surface textures, color, and appearance. Exterior concrete surfaces shall have a smooth finish with no visible wood grain.

DBT shall repair worn, damaged or otherwise unacceptable forms and obtain acceptance of the IQF before casting any segment. Where sections of forms are joined, DBT shall ensure that offsets in flat surfaces do not exceed 1/16 inch and that offsets with corners and bends do not exceed 1/8 inch.

DBT shall ensure that all joints in the forms and contact joints with bulkheads and existing segments have sufficient sealing to prevent loss of fine material and cement grout. DBT shall inspect forms on a weekly basis to ensure proper alignment and geometric accuracy. Forms which fail to meet specified casting tolerances shall not be used until such corrections are made to produce segments within the specified tolerances.

The DBT shall clean the inside surfaces of all forms of dirt, mortar and foreign material prior to casting of each segment. Prior to each use, the forms shall be coated with commercial quality form oil or other approved equivalent coating that will permit the ready release of the forms and will not discolor the concrete. The form oil shall be applied such that the finished surface of each segment is uniform in color as compared to the previously and subsequently cast segments. The form oil shall be applied such that none is deposited on the reinforcement in the forms. On all surfaces to which the concrete coating is to be applied, the concrete forms shall be treated with a water based concrete form release agent prior to placing reinforcement.

Geometry Control

Before commencing casting operations, the DBT shall submit, for review and acceptance by the IDQM, a Casting Manual which will describe the proposed method of geometry control for all segment casting operations. The Casting Manual shall include but not be limited to the following:

1. Description of measuring equipment, procedures and location of control points to be established on each segment
2. Location and values of all permanent benchmarks and reference points in the precasting yard.
3. A geometry control procedure for the vertical and horizontal alignment control for the precasting of segments, including survey controls and procedures, observations, checks, computational and/or graphical methods and correction techniques.
4. The casting curves which include the theoretical geometric horizontal alignment, profile grade and superelevation appropriately combined with the camber.

If the segments are match cast, after casting and before bond breaking to separate the segments, check the position of the new cast and match cast segments again. If positions are not as desired, make corrections in the next segments. Observations shall be made on the geometry control reference hardware cast into the segments to a precision of +/- 0.001 ft.

During casting operations, the DBTshall produce and maintain on a daily basis a graphical plot of the vertical and horizontal “as cast” alignments along each vertical and horizontal control line to an exaggerated scale in order to clearly highlight variations. Depict these against both the theoretical geometric vertical and horizontal alignment casting curves on a continuous layout of an entire unit of the bridge between expansion joints. Maintain this plot in good condition so that it may be used and referenced during erection.

Embedded Items

The DBT shall utilize positive methods to ensure that ducts will not be displaced or damaged during concrete placement and consolidation. All post-tensioning ducts shall be adequately secured to the reinforcement cage at intervals not to exceed 30 inches for steel pipe and 24 inches for plastic ducts. Concrete cover requirements shall not be violated by ties or support bars.

After installation in the forms, the ends of the ducts shall be sealed at all times to prevent entry of water, debris and fine material. Immediately prior to installation of the prestressing steel, the DBT shall demonstrate that all ducts are unobstructed and free of water and debris.

Prior to placing concrete in the forms, all tendon anchor plates and anchor castings shall be placed in their respective positions in the forms, connected to their duct and sealed to prevent mortar intrusion. DBT shall ensure that anchor plates and casting are rigidly fixed in the forms to maintain correct alignment and position during concrete placement and consolidation.

DBT shall not cut out or remove reinforcing steel to permit proper alignment of post-tensioning ducts.

Concrete Placement and Consolidation

Concrete shall not be deposited into the forms until the entire set-up of the forms, reinforcement, ducts, anchorages and embedded items has been thoroughly inspected.

A concrete placement sequence shall be developed and submitted as part of the Casting Manual. Concrete in the webs shall be placed in lifts not to exceed 24 inches at a time. Placement and consolidation of concrete shall be done with care so that post-tensioning ducts, anchorages and any other embedded items are maintained in their proper position and are not damaged.

The DBT shall use vibrators having a minimum frequency of sufficient amplitude to consolidate the concrete effectively. The DBT shall provide at least 2 stand-by vibrators in working condition for emergency use in case of malfunction. If external vibrators are used, the forms shall be sufficiently rigid to resist displacement or damage. Vibration shall be conducted in such a manner to avoid displacement or damage to reinforcement, post-tensioning ducts, anchorages or other embedded items.

Curing

Where casting cells are intended to operate on a short (daily) cycle and it can be demonstrated that the required initial concrete strengths for the removal of the forms, application of prestress, moving and handling of the segments and that the final concrete strength can be achieved in a timely and consistent manner, then steam curing will not be required. However, precautions shall be taken to promote proper curing and must meet or exceed the following:

(a) To prevent moisture loss, cover all exposed surfaces (those not in contact with a form or match cast segment) as soon as possible after casting with a moisture tight covering (wet curing blankets or other approved equal systems). Avoid spoiling the deck surface finish. Keep the cover on or within 12 inches of the deck surface.

(b) Keep the moisture-tight covering substantially in place throughout succeeding operations such as geometry control survey, stripping of internal forms, wing forms and shifting of and working with a segment in a match cast position. Keep the concrete surface wet throughout these operations.

(c) After stripping of the side and core forms, continue curing of the precast concrete by the application of an approved membrane curing compound to all exposed surfaces (including segment exterior once exposed by removal from the form). Apply an approved debonding compound to match cast surfaces to serve both as a bond breaker and seal for curing.

(d) Maintain the moisture tight covering for at least 72 hours. As an alternative, steam curing may be used.

(e) While the new cast segment is in contact with the match cast segment, cover the match cast segment with curing blankets, or other approved equal system, to minimize the effects of differential temperature between the segments.

Removal of Forms

The DBT shall adequately protect the concrete segment from adverse weather conditions prior to removal of forms. The supporting forms shall be left in place until the concrete has reached the required strength for form removal as specified in the released-for-construction plans. Test cylinders shall be made and cured in the same manner as the segment to confirm the form release strength prior to removing forms.

Age at Erection

Concrete segments shall be a minimum of 14 days old prior to incorporating into the structure.

Tolerances

The following tolerances shall apply to the casting of all superstructure box segments:

Component	Tolerance
Width of Web	±1/4 inch
Depth of bottom slab	±3/16 inch
Depth of top slab	±3/16 inch
Overall depth of segment	±3/16 inch
Overall width of segment	±1/4 inch
Length of segment	±3/8 inch
Diaphragm dimensions	±3/8 inch
Wingtip to Centerline	±1/4 inch
Tendon hole location	±1/4 inch

Dimensions shall be controlled from segment to segment and deviations shall be compensated for such that the overall dimensions of the completed structure are in conformance with the dimensions and overall erection tolerances outlined in this section.

Repairs

All cracks, spalling, breakage, and honeycombing in the concrete shall be reviewed by the IQF. The DBT shall propose a corrective plan of action and submit to the IQF and the Engineer for acceptance. The IQF and the Engineer shall verify that the corrective action addressed the deficiency.

06 Handling, Storage and Shipment of Segments

All precast segments shall be stored level in the upright position and firmly supported for storage and shipment on an approved three point bearing system which does not introduce a twist under self weight. Segments shall not be stacked one upon another unless approved by IQF.

Prior to shipment the DBT and the IQF will thoroughly inspect each segment for damage. Prior to shipment the DBT shall clean the faces of all joints of laitance, bond breaking compound and any other foreign material by light sand blasting. Upon arrival at the bridge site the DBT and IQF will inspect each segment again. If any damage has occurred during shipment the DBT shall propose a corrective plan of action and submit to the IQF and the Engineer for acceptance. The IQF and the Engineer shall verify that the corrective action addressed the deficiency.. The DBT shall provide a storage area of suitable stability for the segments to prevent differential settlement of the segment supports during the entire period of storage.

07. Erection

Erection Manual

Before commencing erection operations, the DBT shall submit a plan for all segment erection operations to the IDQM for acceptance. This submittal must be in the form of an "Erection Manual" and include but not necessarily be limited to:

1. A detailed step-by-step sequence for the erection of each segment including all intermediate procedures relating to erection equipment, temporary and permanent post-tensioning and making of closures between spans and/or cantilevers etc.
2. Positioning, use and sequencing of falsework, jacking and/or releasing of falsework, temporary towers, closure devices and the like.
3. Positioning, use and sequencing of erection equipment such as cranes, beam and winch devices, gantries, trusses and the like, including the movement, introduction and/or removal of any supports onto or connections with the structure.
4. Detailed scheduling of all temporary and permanent post-tensioning operations and sequences in accordance with the segment erection and closure operations etc.
5. Stressing forces and elongations for post-tensioning.
6. Sequencing of grouting operations.
7. A method for the field survey control for establishing and checking the erected geometry (elevations and alignments) with particular attention to the setting of critical segments such as, for example, pier segments for balanced cantilever erection.

Erection may not commence without IDQM acceptance of the erection manual.

Erection Geometry Control

The DBT's Erection Manual shall define provisions for maintaining geometric control consistent with the DBT's method of erection. The manual shall include a table of elevations and alignments required at each stage of the erection in accordance with the plans, as-cast geometry, camber and erection elevations. Corrective measures for geometric control during construction must be submitted to the IDQM and accepted before implementation. Shims used for geometry control shall be made of ASTM A 240 Type wire cloth or approved equivalent with a minimum of 1/8 inch thickness.

Erection Tolerances

The following geometric tolerances during precast segment erection shall apply:

1. The maximum differential between outside faces of adjacent segments in the erected position shall not exceed 3/16 inch.
2. Transversely, the angular deviation from the theoretical slope difference between two successive segment joints shall not exceed 0.001 rad.

3. Longitudinally, the angular deviation from the theoretical slope change between two successive segments shall not exceed 0.003 rad.
4. Dimensions from segment to segment shall compensate for any deviations within a single segment so that the overall dimensions of the completed structure meet the dimensions shown on the plans such that the accumulated maximum error does not exceed 1/1000 of the span length for either vertical profile and/or horizontal alignment.

Other Miscellaneous Erection Requirements

Closure Joints: For construction of closure joints, concrete meeting the same specifications and criteria as the concrete in the segments shall be used. The closure joint concrete shall reach the same minimum required strengths as the segments for stressing of tendons and removal of forms. Closure joint forms shall provide the same tolerances as specified above for segments. Formwork at closure joints shall be supported by the ends of the cantilevers to be joined. The cantilevers shall be secured together vertically, longitudinally and transversely such that the applied loads will yield equal deflections to both cantilevers.

Balanced Cantilever Erection: The DBT's Erection Manual and released for construction plans shall clearly indicate the erection time assumptions used for computing deformations due to time dependent stress variations. During balanced cantilever erection, the cantilever shall be unbalanced by no more than one segment at any time. In addition, the superstructure shall be designed for any other unbalanced loads applied by erection equipment.

.**08 Epoxy Jointing of Precast Segments**

See Specifications for Epoxy Joining of Precast Concrete Segments.

.09 Bird and Vermin Protection

The DBT is required to provide a means for preventing the intrusion into the box girder of birds and vermin. Sufficient covering shall be provided on all openings in the box girder including but not limited to expansion joint openings, utility blockouts, drainage holes, and access openings. Coverings shall consist of galvanized wire mesh or approved equivalent with openings no larger than ¼". At expansion joint openings, attachment of the mesh to the box girder shall be done in such a fashion as to accommodate all movements due to thermal expansion and contraction or any other anticipated deformations.

Specifications for Epoxy Joining of Precast Concrete Segments

.01 Description

This work shall consist of furnishing, mixing and applying a two component epoxy bonding system to the match cast faces of all joints between precast concrete superstructure segments in accordance with details shown in the released-for-construction plans and the requirements of this specification. The work covered by this section shall also include temporary post-tensioning across a joint, if required, by provisions contained elsewhere in this specification.

This specification covers use of normal setting epoxy bonding agents and slow-setting epoxy bonding agents.

In its workable state, epoxy bonding agent must provide lubrication along the keys as the precast concrete segments are brought together. In its hardened state, epoxy bonding agent must provide a watertight seal between precast concrete segments. For superstructure precast concrete segments, hardened epoxy bonding agent must provide shear stress transfer across the joint without reliance on shear keys to transfer forces.

.02 Epoxy Material

A. General

Epoxy bonding agents for match-cast joints between precast segments shall be thermosetting 100 percent solid compositions that do not contain solvent or any non-reactive organic ingredient except for required coloring pigments. Epoxy bonding agents shall be of two components, a resin and a hardener. Both components shall be distinctly pigmented, so that mixing produces a third color similar to the concrete in the segments. Samples shall be provided to the Independent Quality Firm (IQF) and the Engineer.

Epoxy bonding agents shall be insensitive to damp conditions during application, and after curing, the epoxy shall exhibit high bonding strength to cured concrete, good water resistance, low creep characteristics and tensile strength greater than the concrete.

The components shall be packaged in two parts in sealed containers, pre-proportioned in the proper reacting ratio, ready for combining and mixing in accordance with the manufacturer's instructions. Each container shall bear a label designating the manufacturer's name, the type of component (resin or hardener), the range of substrate (surface of concrete) temperature over which application is suitable, the date of formulation, the shelf life of the material and the manufacturer's Lot number. Material from containers, which are damaged or have been previously opened, shall not be used. Combining of epoxy bonding agent components from bulk supplies will not be permitted. Only full buckets of components will be mixed immediately after opening.

Instructions shall be furnished by the manufacturer for the safe storage, handling, mixing and application of the material. The DBT shall furnish to the IQF and the Engineer samples of the material for testing, upon request, and certified reports of tests performed by an independent laboratory approved by the IQF and the Engineer.

B. Classification of Epoxy Material

This specification provides for epoxy bonding agents which remain workable for a short time referred to herein as normal-set epoxy bonding agents and epoxy bonding agents which remain workable over an extended period of time referred to herein as slow-set epoxy bonding agents.

C. Formulation for Temperature Range

An epoxy bonding agent shall be formulated to provide application temperature ranges which are suitable for erection of segments with substrate temperatures between 40°F and 115°F or as recommended by the manufacturer. There shall be a minimum of two, and preferably three, formulations dividing the overall range into equal subsets which overlap by 5°F. Additionally, each of these formulations shall be identified as either normal-set or slow-set epoxies as defined in the following section (D.3) on Contact Time.

D. Physical Requirements

Epoxy bonding agents proportioned as designated by the manufacturer and mixed in accordance with the manufacturer's recommendations shall meet the physical requirements of ASTM C 881/C 881M–02 except as modified below. The components of the epoxy bonding agent shall be conditioned to the temperature at which testing is to be done prior to mixing the test specimen.

1. Consistency

This property determines application workability of the epoxy bonding agent. Mixed epoxy bonding shall be tested and conform to the prescribed consistency in accordance with ASTM C 881/C 881M–02 at the maximum temperature of the temperature range for the formulation being tested.

2. Gel Time

This property is the period of time during which the epoxy bonding agent will remain workable in the mixing container and must be applied to the match cast joint surfaces.

The mixed epoxy bonding agent shall be tested and conform to the prescribed gel time in accordance with ASTM C 881/C 881M–02 at the maximum temperature of the temperature range for the formulation being tested.

3. Contact Time & Strength

This property is the workable period of time allowable between mixing of the epoxy bonding agent components and the application of a minimum 40 PSI compression over the cross section of the joining segments.

The contact time of the epoxy bonding agent, determined in accordance with the test procedure set out below, shall be as follows:

Normal-Set Epoxy	60 Minutes, Minimum
Slow-Set Epoxy	8 Hours, Minimum

The test procedure for determining contact time shall be determined in accordance to ASTM C 881/C 881M–02 with the following modifications.

a. Soaking of the concrete specimens prior to application of the epoxy bonding agent shall be for 24 hours in water which is at the maximum temperature of the application temperature range for the formulation being tested.

b. Joining of the sloped surfaces shall be delayed for the period of time, measured from the time the epoxy was mixed, set out below:

Normal-Set Epoxy	60 Minutes
Slow-Set Epoxy	8 Hours

c. During the delay period between mixing of the epoxy and joining of the sloped surfaces, the specimens shall be uncovered and maintained at the maximum temperature of the application range for the formulation being tested.

d. The joined specimen shall be cured at the maximum temperature of the application range for the formulation being tested.

e. The formulation of epoxy bonding agent being tested will be acceptable if the specimen when tested sustains the following compressive stress:

Normal-Set Epoxy	1,000 PSI at 48 Hours
Slow-Set Epoxy	1,000 PSI at 14 Days

NOTE: For slow-set epoxy, an additional test specimen shall be made and tested to failure at 24 hours. The formulation being tested is acceptable only if the epoxy bonding agent exhibits a brittle break.

f. If the manufacturer proposes an epoxy formulation for use when the temperatures are below 40°F, tests shall be performed at the minimum temperature and at temperatures of 50°F intervals to determine that the material doesn't soften and lose shear capabilities when transitioning from Class A to Class B sets. All test samples shall be made with all materials being at the minimum temperature and then warmed to provide the intermediate tests.

4. Compressive Yield Strength

This property is the compressive yield strength of the epoxy bonding agent at various ages. Comparison of this property between batches is an indication of the level of quality control achieved in manufacturing the material.

The required compressive yield strength of the epoxy bonding agent shall be determined according to ASTM C 881/C 881M–02 with the following modifications.

a. Epoxy bonding agent shall be poured into the mold for forming specimens within ten minutes after starting mixing of the components.

b. The physical requirements are:

Normal-Set Epoxy	2,000 PSI at 24 Hours and 7,000 PSI at 48 Hours
Slow-Set Epoxy	1,000 PSI at 36 Hours and 2,000 PSI at 72 Hours

5. Bond Strength

This property is the strength of epoxy bonding agent as it bonds with concrete. This bond strength property shall be determined in accordance with and conform to ASTM C 881/C 881M–02 which references ASTM C 882 with the following modifications:

a. The test cylinder of mortar shall have a compressive strength of at least 6,000 PSI at seven days age.

b. The specimens shall be conditioned by soaking in water which is at the minimum temperature of the application temperature range for the formulation being tested.

The required strength of ASTM C 881/C 881M–02 shall be modified as follows:

Normal-Set Epoxy	1,000 PSI at 48 Hours
Slow-Set Epoxy	1,000 PSI at 14 Days

6. Heat Deflection of Epoxy Bonding Agent

This property is the temperature at which an arbitrary deflection occurs under arbitrary testing conditions in the cured epoxy bonding agent. It is a screening test to establish performance of the epoxy bonding agent throughout the temperature range at which a particular formulation may be applied. It shall be tested and satisfy the requirements in accordance with ASTM C 881/C 881M–02.

7. Testing

The DBT shall furnish to the IQF and the Engineer, for each manufactured lot, certified test reports from an independent testing laboratory. These test reports shall document that the epoxy material has passed all tests required in this specification.

<u>.03 Construction Requirements</u>

A. General

An epoxy bonding agent meeting the requirements of this specification shall be applied to joining surfaces of all precast concrete segments. The epoxy bonding agent shall be applied only when the substrate temperature of both surfaces to be joined is between 40°F and 115°F or as recommended by the manufacturer and accept by the IQF.

The formulation of epoxy bonding agent used shall have an application temperature range as previously defined in the Epoxy Material section of this specification which conforms to the substrate temperature of the surfaces to be joined. If the surfaces have different substrate temperatures, the formulation for the higher temperature shall be used for joining the segments.

The DBT's construction scheme shall provide for a minimum contact pressure of 40 PSI compression over the entire joint of precast concrete segments while the epoxy is curing in the joint. The DBT shall plan his erection and post-tensioning operations such that for the particular formulation of epoxy bonding agent being used, the time elapsing between initial mixing of the components for the first batch of epoxy bonding agent and application of the minimum contact pressure of 40 PSI compression shall not exceed 70 percent of the contact time.

Prior to beginning erection, the DBT shall submit to the IQF for review, details covering how compliance with this 40 PSI contact pressure and the time limit will be achieved during erection of segments.

For superstructure segments, the compressive force across a joint (contact pressure) may be accomplished through temporary post-tensioning or permanent post-tensioning. For superstructure segments, the specified contact pressure shall be continuously maintained across a joint.

B. Qualifications of DBT's Personnel

The work of mixing, handling and applying the epoxy bonding agent shall be under the direct supervision of a person who has extensive knowledge of and experience in the use of this material. The IQF and the Engineer may require the DBT to arrange for a technical representative of the manufacturer to be at the site as an advisor at the beginning of this operation.

The DBT shall ensure that all personnel who will be working with the epoxy bonding agent are thoroughly familiar with the safety precautions necessary when handling this material.

C. Cleaning of Surfaces to be Joined

The surfaces to which the epoxy bonding agent are to be applied shall be free from oil, form release agent, laitance or any other material that would prevent the epoxy bonding agent from bonding to the concrete surface. These detrimental materials shall be removed by high pressure water blasting with a minimum pressure of 5,000 PSI.

The surfaces shall have no free moisture on them at the time the epoxy bonding agent is applied. Free moisture will be considered to be present if a rag, after being wiped over the surface, becomes damp.

D. Mixing Epoxy Bonding Agent

Only epoxy bonding agent components from full containers opened immediately prior to being combined and for which the shelf life indicated on the containers has not expired shall be used during erection. Each container of a component shall be thoroughly mixed for a minimum of 3 minutes prior to combining of the components.

The two components of the epoxy bonding agent shall be combined and thoroughly mixed in a mechanical mixer in strict accordance with the manufacturer's recommendations.

Mixing of the epoxy bonding agent shall be scheduled so that the material in a batch is applied to the face of the joint within 20 minutes after the components are combined.

E. Applying Epoxy Bonding Agent

The epoxy bonding agent shall be uniformly applied to a nominal thickness of 1/16 inch per face or 1/8 inch if applied to only one face of the joint in accordance with the manufacturer's recommendations with a spatula or by gloved hand. The material shall be applied to only one of the faces to be joined except that material shall be applied to both faces in the vicinity of post-tensioning ducts. No material shall be placed within ½ inch of a post-tensioning duct except, regardless of spacing, a bead of epoxy bonding agent shall be applied between all adjacent post-tensioning ducts.

No epoxy bonding agent from a batch shall be used for which the time since combining of components has exceeded 20 minutes.

After concrete segments have been joined and the specified contact pressure applied, a discernable bead line of epoxy bonding agent must appear along the entire exposed edges of a joint. All excess epoxy bonding agent shall be cleaned from exterior surfaces of the concrete segment in such a way as to not damage or stain the concrete surface. Excess epoxy squeezed from a joint shall be captured and not allowed to free fall from the structure onto the ground, river, traffic lanes or railroad right-of-way below.

F. Artificial Heating

If the DBT elects to erect segments in cold weather when the substrate temperature of the joint surfaces of concrete segments is below 40°F (or other minimum temperature as recommended by the manufacturer), they shall provide an artificial environment to increase the substrate temperature subject to the following restrictions.

1. The artificial environment shall be created by an enclosure surrounding the joint through which warm air is circulated.

2. The temperature of the concrete shall be raised to at least 40°F (or other minimum temperature as recommended by the manufacturer) to a depth of approximately three inches beneath the surface to be joined.

3. Localized heating shall be prevented and the temperature of the substrate shall not exceed 105°F at any point on the surface of a joint.

4. The temperature of substrate surfaces shall be maintained between 40°F and 105°F for at least 24 hours after joining of the surfaces for normal-set epoxy and 72 hours for slow-set epoxy.

The DBT may propose, for review and acceptance by the IQF and the Engineer, an optional method of raising and maintaining the substrate temperature of the joint surfaces. Any optional method shall meet the restrictions set out above. The IQF and the Engineer will base their acceptance of an optional method on it accomplishing an environment suitable for the epoxy bonding agent to perform satisfactorily.

G. Failure to Comply with Time Limits

If the time limit between mixing of the epoxy bonding agent and application of contact pressure to a joint is exceeded, the concrete segments shall be moved apart and all epoxy bonding agent shall be removed from both faces of the joint. If solvent is used to remove the epoxy bonding agent, reapplication of the epoxy bonding agent to the joint surfaces shall not be done for at least 24 hours.

H. Cantilever Segment Support

A maximum of three segments can be supported in cantilever beyond an epoxy joint, which has not developed a state of substantial cure. For this requirement, substantial cure is defined as that state in which the epoxy will transfer an average shear stress of 250 PSI across a joint of two plan surfaces.

If the DBT elects to support more than three segments beyond a joint that has not developed a state of substantial cure, the IQF and the Engineer may require the DBT to submit calculations substantiating the joints ability to safely transfer all applied forces.

I. Failure to Provide Watertight Seal

In the event that water seepage through the deck slab at an epoxy precast segment joint becomes evident, the DBT shall take measures to seal the joint such as applying a gravity feed low viscosity concrete crack sealer or epoxy pressure injection. Proposed methods for sealing leaking segment joints shall be submitted to the IQF and the Engineer for acceptance.

.04 Record of Segment Joining

The DBT shall record and make available to the IQF and Engineer the following information:

A. General - For the period when precast segments are being erected

1. Weather condition.

2. Air temperature at the site on an hourly basis.

B. For Each Joint - Identified as to Location in the Structure

1. Lot number for the epoxy bonding agent components.

2. Temperature of the concrete on the surface of each concrete segment when application of epoxy bonding agent was started.

3. Time of mixing the first batch of epoxy bonding agent applied to the joint.

4. Time of applying the specified contact pressure to the joint.

5. Date of joining segments with epoxy.

Inspection Access Requirements for Main-Span Structure

.01 GENERAL REQUIREMENTS

In general, bridge superstructures, joints, and bearings shall be made accessible for inspection and maintenance. All elements shall be designed and detailed by the DBT to allow for replacement of joints and bearings.

Design shall consider longitudinal inspection platforms combined with other inspection facilities such as ladders, manholes and safety cables. Consider all critical areas that require close inspection such as splices, expansion joints, bearings, utility lines, navigation lights, and areas that require frequent maintenance.

Longitudinal inspection platforms, including attachment hardware, shall not extend below the bottom of the superstructure in any configuration.

.02 STEEL BOX GIRDER SUPERSTRUCTURE

Access shall be provided to the interior of the superstructure for inspection and maintenance. Access to the interior of the box girders shall be located at the ends of the box girders.

Each side of all interior box girders shall allow for access to the pier seat from the interior of the box girder.

Interior to exterior access holes at the ends of the box girders and interior diaphragms shall have a minimum opening of 3 feet wide by 5 feet high. All others access holes shall have a minimum opening of 3 feet in diameter. Corners of all non-circular shaped interior to exterior access holes shall be filleted with a minimum radius of 12 inches. The location of the lowest point of the access opening shall not be greater than 2 feet from the bottom flange. Access openings shall be placed at locations that do not impact traffic on and under the bridge.

Access covers with a minimum opening of 3 feet wide by 5 feet high shall be stainless steel and louvered to allow for air circulation, keep out rain and direct sunshine. Metal screening shall be added to the interior side of the louvered opening. The access covers at the ends of the box beam girders shall be hinged, accessible, and lockable from both sides. Access covering and hardware shall be made for high security usage.

The access covers shall be hinged and accessible from both sides. Two tie-off attachment points shall be placed adjacent to exterior access holes on both the interior and exterior side.A permanent longitudinal inspection platform shall be erected between each box girder for the length of the bridge. Provide inspection walks with a minimum width of 2 feet. Minimum headroom clearance shall be 6.5 feet 6.5 feet when not limited by structure depth. Inspection walks shall not extend below the bottom of lower flange of the superstructure. Grating shall be stainless steel.

Interior and exterior diaphragms, or cross frames, over 6 feet in height shall have means of vertical access to the top flange (i.e. grab bars or foot holes)

Interior bracing shall consider the use of K-frames allowing better construction and inspection access.

Interior box girder maintenance lighting shall be provided:

1. Ensure Installation meets all requirements of the latest edition of the National Electric Code (NEC) and local ordinances. Install grounding in accordance with NEC Article 250. Maintain separation between 480V and 120V Conductors / Conduits throughout.

2. Use only new, Underwriters Laboratories (UL) listed equipment and materials for outdoor use.

3. Furnish and install polyvinyl chloride (PVC) conduit in accordance with UL Section 651, NEC section 347, NEMA TC-2, UV resistant and schedule 80. Bend conduits as necessary to connect to loads.

4. Install a UL labeled expansion fitting for specified PVC conduit at all structure expansion joints. Provide certification that the expansion fitting meets the following requirements: Compatibility with the connected conduits, waterproof, UV protected, and allows longitudinal movement equal to that of the Expansion Joint.

5. Use only Alloy 316 stainless steel supporting hardware. Provide minimum 3/16" diameter fasteners. For concrete or SIP form mounting, provide anchor bolts (expansion, drop-in or adhesive) suitable for dynamic loading (due to vibrations caused by traffic). Install fasteners to avoid conflicts with reinforcing steel and PT ducts. For structural steel mounting, do not attach fasteners to the webs or flanges of the main members.

6. Furnish power distribution of 480V AC, 1 phase, with step down transformers at regular intervals. Furnish7.5 KVA mini power center with eight 20A breakers as the step down transformer, feeding a maximum of 20 amps and 20 receptacles. Each mini power center will provide power to no more than 1000' of bridge, preferably 500' on each side of the mini power center. 480V top feed, 120V bottom feed to maintain separation.

7. Furnish and install lighting contactors to switch the 480V AC feeding the mini power centers.

8. Furnish and install copper conductors, Type XHHW. Do not use conductor larger than #4 AWG.

9. Provide enough slack in all interior cable terminations to allow for minor shifting of the structure.

10. Furnish and install National Electric Manufacturer's Association (NEMA) Type 4X (non-metallic) surface mounted boxes sized in conformance with the NEC.

11. Furnish and install 120V duplex receptacles (GFI, NEMA Type 5-20R), in non-metallic outlet boxes at 50' maximum on centers. Provide each receptacle with a gasketed weather-protective outdoor plate. Maximum wire size to connect to receptacle is #12 AWG.

12. Furnish and install surface mounted, fully enclosed, incandescent light fixtures with gasketed clear globes and wire guards at 50' maximum on centers. Provide 100 watt, 130 volt, vibration resistant and brass base incandescent lamps.

13. Locate switches at each end of each span and at every access opening.

14. Provide state-of-the-art programmable timers for each circuit to turn off the lighting system automatically.

.03 CONCRETE SEGMENTAL SUPERSTRUCTURE

Access shall be provided to the interior of the superstructure for inspection and maintenance. Access to the interior of the box girders shall be located at the ends of the box girders.

Access shall be provided to all pier seats from the inside of each box girder. Interior box girders shall allow for access to the pier seat from the interior of the box girder.

Interior to exterior access holes at the ends of the box girders, interior diaphragms, and integral pier caps shall have a minimum opening of 3 feet wide by 5 feet high. All others access holes shall have a minimum opening of 3 feet in diameter. Corners of all non-circular shaped interior to exterior access holes shall be filleted with a minimum chamfer of 3 inches. The location of the lowest point of the access opening shall not be greater than 2 feet from the bottom flange when not located in the bottom flange. Access openings shall be placed at locations that do not impact traffic on and under the bridge.

Access covers with a minimum opening of 3 feet wide by 5 feet high shall be stainless steel and louvered to allow for air circulation, keep out rain and direct sunshine. Metal screening shall be added to the interior side of the louvered opening. The access covers at the ends of the box beam girders shall be hinged, accessible, and lockable from both sides. Access covering and hardware shall be made for high security usage.

The access covers shall be hinged and accessible from both sides. Two tie-off attachment points shall be placed adjacent to exterior access holes on both the interior and exterior side.

Interior concrete box girder maintenance lighting shall be the same as **STEEL BOX GIRDER SUPERSTRUCTURE** section.

.04 STEEL OR CONCRETE I-GIRDER SUPERSTRUCTURE

Longitudinal inspection platforms shall be erected between girders for the length of the bridge. Inspection platforms shall be located in each outside bay and in every other bay so that each girder can be inspected. Provide inspection walks with a minimum width of ~~of~~ 2 feet. Minimum headroom clearance shall be 6.5 feet when not limited by structure depth. Inspection walks shall not extend below the bottom of lower flange of the superstructure. ~~Grating shall be stainless steel.~~

Comment [apg1]: Addendum No. 2

Comment [apg2]: Addendum No. 2

Each concrete I-girder side shall have a foot-rail for inspection personnel. The outside face of the fascia beam and concrete I-girder side adjacent to an inspection platform are not required to have a foot rail. The foot-rail shall have a non-slip, skid resistant, flat surface width of 3 inches with the centerline of the rail located 6 inches away from the vertical surface of the I-girder bottom flange. The bottom of foot-rail elevation shall match the bottom of the I-girder elevation. The foot-rail and anchorages shall be designed to hold two 500 pound point loads, 2 feet apart, at any location.

Each steel or concrete I-girder face, except the outside face of the fascia beam and concrete I-girder side adjacent to an inspection platform , shall receive a hand rail and safety cable. The handrail shall be a minimum of 1 inch diameter to a maximum of 1 3/8 inch diameter. For steel I-girders, the handrail and safety cable shall be placed 4 feet above the top of the bottom flange. For concrete I-girders, the handrail and safety cable shall be placed 4 feet above the top of the foot-rail. The safety cable shall not use the same anchorage as the handrail. The safety cable and anchorage system shall have a minimum capacity of 5,000 pounds.

Access shall be provided between bays at all pier locations. If provided, access holes shall have a minimum diameter of 3 feet.

Diaphragms, or cross frames, over 8 feet in height shall have means of vertical access to the top flange (i.e. grab bars or foot holes)

For steel and concrete I-girders, the inspection platforms, hand rails, and all associated supports and attachments shall be galvanized steel according to C&MS 711.02. The safety cable shall be steel cable manufactured in accordance with ASTM A741, AASHTO M30, Type I, Class A coating.

Comment [apg3]: Addendum No. 2

.05 ABUTMENTS AND PIERS

Abutment and pier seats shall allow for inspection access of all bearings. Access may utilize a number of permanent inspection facilities. Examples of acceptable inspection facilities are inspection platforms, bearings on pedestals with wide caps, and handrails and foot-rails around the cap with ample tie-off attachment points. Handrails, foot-rails, tie-off attachment points and all associated supports and attachments shall be galvanized steel according to C&MS 711.02.

Comment [apg4]: Addendum No. 2

Access to superstructure inspection platforms shall be provided from ground level at the start and finish substructure units of the main spans for hollow piers. All inspection access openings shall have a minimum opening of 3 feet wide by 5 feet high. Access covering and hardware shall be made for high security usage.

Access to superstructure inspection platforms shall be provided from 15 feet above ground level at the start and finish substructure units of the main spans for solid piers. Access covering and hardware shall be made for high security usage. Hollow substructure units shall have access doors placed 15 feet above final grade. Access hatches shall have a minimum opening of 3 feet wide by 5 feet high. The access hatch shall be hinged, accessible, and lockable from both sides. Tie-off attachment points shall be located adjacent to the hatch r near the locking mechanism. A Ladder shall be added on the interior of the substructure unit from the lowest access hatch to the bottom of the void. The ladder shall be made of either stainless steel or a non-metallic non-corrosive material.

Hollow substructure units with the height of the void exceeding 50 feet shall add a second access hatch located 5 feet from the top of the void or an access hatch located on the substructure seat . The access hatch shall be a minimum of 3 feet in diameter. The access hatch shall be hinged, accessible, and lockable from both sides. Tie-off attachment points shall be located adjacent to the hatch near the locking mechanism.

The access hatch shall be stainless steel and louvered to allow for air circulation, keep out rain and direct sunshine. Anti-bird and vermin screening shall be added to the interior side of the louvered opening. Access covering and hardware shall be made for high security usage.

.06 STRUCTURE TYPES REQUIRING AN ALTERNATIVE TECHNICAL CONCEPT (ATC)

In the event that one of the four listed structure types is not proposed, the contractor will be required to submit an Inspection Access Plan with the ATC. The Inspection Access Plan shall meet the intent of the requirements described herein.

Specification for Post-Tensioning Systems

1.0 General.

1.1 Description: Furnish and install all post-tensioning systems and any other pertinent items necessary for the particular prestressing system used, including but not limited to ducts, anchorage assemblies, local zone reinforcement, vents, inlets, outlets and grout. Both temporary and permanent post-tensioning shall comply with the requirements of this Specification. Furnish all components of a post-tensioning system, including prestressing steel and steel pipes, from a single supplier. Perform required testing.

Install prestressing steel, which may be strands or bars as shown on the released-for-construction Drawings, through ducts in the concrete. Stress to a predetermined load and anchor directly against the hardened concrete so that stresses are imparted from the tendon to the concrete through end bearing. Grout ducts to fill all voids and install protection at end anchorages.

Submit shop and working drawings and manuals in accordance with this Specification. The Design Build Team (DBT) shall produce, sign and seal all shop drawings related to post-tensioning and submitted per Section 2 of the Project Scope.

1.2 Qualifications and Inspection: Provide a crew foreman and crew members as follows:
Perform all post-tensioning field operations under the direct on-site supervision (crew foreman) of a qualified post-tensioning technician who holds a current Level 2 Certification under the Post-Tensioning Institute's (PTI) Training and Certification of Field Personnel for Bonded Post-Tensioning program, has three years verifiable job-site experience in bridge related post-tensioning operations and has experience on at least four (4) previous and satisfactorily completed projects of a similar size and scope in the same capacity. When tensioning, provide at least one other crew member who holds a current Level 1 Certification under the Post-Tensioning Institute's (PTI) Training and Certification of Field Personnel for Bonded Post-Tensioning program. Operators of stressing jacks will have a current Level 2 PTI certification.

Perform all grouting field operations under the direct on-site supervision (crew foreman) of a qualified grouting technician who is a qualified post-tensioning technician as defined above, has three years verifiable job-site experience in bridge related post-tensioning grouting operations, holds current certification as a "ASBI Certified Grouting Technician" under the American Segmental Bridge Institute (ASBI) Grouting Certification Course program and has experience on at least four (4) previous and satisfactorily completed projects of a similar size and scope in the same capacity. When grouting, provide at least two other crew members who hold a current ASBI certification. Grout pump operators will have a current ASBI certification.

Provide sufficient project personnel to complete all activities within the specified time frames of this Specification.

1.3 Shop Drawings: Prepare and submit per Section 2 of the Project Scope, shop drawings to address all requirements stated in the released-for-construction drawings, this Specification, CMS 501 and the following:

1. A complete description of all details covering each of the post-tensioning systems to be used

for permanent tendons including the properties of each component.

2. Designation and details of the specific post-tensioning steel, anchorage devices, duct material, bar couplers and accessory items to be used.
3. Details covering the assembly of each type of post-tensioning tendon and bars.
4. Equipment, including jacks, to be used in the post-tensioning sequence including certifications and calibration charts.
5. Size and type of ducts for all post-tensioning tendons and their horizontal and vertical profiles will be clearly detailed. Include the method of support for the duct and location of the duct so that the center of gravity of the enclosed tendon will be at the proper position. Show the offsets from the bottom of the duct relative to the position of the tendon within the duct and the distance from the bottom form to the bottom of the duct. Show duct supports and grout tubes and vents, including size, type and location.
6. Release procedures.
7. A table giving jacking sequence, jacking forces and initial elongation, and estimates of anchor sets of the tendons at each stage of erection for all post-tensioning.
8. Parameters to be used to calculate the typical tendon force such as expected friction coefficients and anchor set.
9. Details for any reinforcing steel needed due to stresses imposed in the concrete by the anchorages and as required by this Specification.
10. Substantiate the post-tensioning system and procedures to be used including stress-strain curves typical of the tendon steel to be furnished, required jacking forces, elongation of tendons during tensioning at each stage/step, seating losses, short-term prestress losses, long-term prestress losses, temporary overstress, stresses in anchorages including distribution plates and reinforcing steel needed in the concrete to resist stresses imposed by anchorages. Substantiate the tendon force after applying the expected friction coefficient, anticipated thermal affects and anticipated losses for the stressing system to be used including anchor set losses. Additionally, substantiate the elongations associated with the preliminary jacking force. Elongation calculations will be revised when necessary to properly reflect the modulus of elasticity, or other properties, of the wire or strand as determined from testing required by this Specification and/or the actual material properties of the wire, strand and bar that are to be incorporated into the work.
11. Certified copies of test reports covering tests performed on post-tensioning steel and anchorages devices as required by this Specification.
12. Certified test reports on ducts as required by this Specification.
13. If friction reduction lubricants are to be used, the details will state that use and the calculations will be based on appropriate friction factors.
14. Details of all air tests for all phases and sequences of construction including specifics regarding placement of temporary plugs and the connections to be tested during each air test.
15. Inspection procedure for outlets, anchorages and grout caps.
16. Protection system materials and application rates.
17. Complete details of apparatus and methods to be used for all required testing of this specification.
18. Names, experience and proof of training and certification for the stressing crew and the crew foreman in conformance with this Specification.
19. All other details as required by this Specification.

Certified test data will be according to CMS 101.03 and itemize and identify each specific test, its corresponding code (AASHTO, FIB, etc.) with article/section number and the test result.

Certified test data is acceptable from either new or previous tests performed in accordance with this Specification.

1.4 Material Storage: Store all materials in a weatherproof building, shed or container until time of use and then protect as specified elsewhere in this Specification.

2.0 Certification of Post-Tensioning Systems.
Certify to the Independent Quality Firm (IQF) that the post-tensioning system being furnished is in compliance with all requirements stated herein. Provide the IQF 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. Test plastic components 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. with comparable accreditation Perform certification test for the plastic on a sample formed or cut from the finished product. Provide the IQF 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.

Ensure that all components of a system are stamped with the suppliers name, trademark model number and size corresponding to catalog designation.

3.0 Definitions.

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

Anticipated Set: The wedge set assumed to occur in the design calculation of the post-tensioning forces at the time of load transfer.

Bar: Post-tensioning bars are high strength steel bars, normally available from 5/8 to 1 3/4 inch diameter and usually threaded with very coarse thread.

Bearing Plate: Any hardware that transfers the tendon force directly into a structure or the ground.

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.

CMS: The current edition of the Department’s Construction and Material Specifications.

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 prestressing steel 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 shall be furnished by a single supplier and shall have a common design with varying sizes.

Final Set of Grout: The degree of stiffening of the grout mixture greater than the initial set, indicating the time in hours and minutes required for the grout to stiffen sufficiently to resist to an established degree, the penetration of a weighted needle test.

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 pumpable consistency without segregation of the constituents, when injected into the duct to fill the space around the prestressing steel.

Grout Cap: A device that contains the grout and forms a protective cover sealing the post-tensioning steel at the anchorage.

GUTS (acronym for Guaranteed Ultimate Tensile Strength): This is the tensile strength of the material that can be assured by the Manufacturer.

Initial Set of Grout: A degree of stiffening of the grout mixture less than the final set, indicating the time in hours and minutes required for the grout to stiffen sufficiently to resist to an established degree, the penetration of a weighted needle test.

Inlet (also inlet pipe or grout injection port): Tubing or duct used for injection of the grout into the duct.

Outlet (also ejection pipe or grout outlet vent or vent): Tubing or duct to allow the escape of air, water, grout and bleed water from the duct.

Post-tensioning: A method of prestressing where tensioning of the tendons occurs after the concrete has reached a specified strength. The force in the stressed tendons is transferred to the concrete by means of anchorages.

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

Post-Tensioning Scheme or Layout: The pattern, size and locations of post-tensioning tendons provided on the released-for-construction drawings.

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.

Pour-Back: The filling of the void or block-out between an anchorage terminus and formwork that is constructed to complete the final geometric shape of a concrete member and protect the anchorage terminus. Can also be referred to as a “secondary pour”.

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).

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.

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 or slightly larger diameter.

Suppl. Spec.: The Department’s Supplemental Specifications.

Tendon: A single or group of prestressing steel elements and their anchorage assemblies imparting prestress forces to a structural member or the ground. Also, included are ducts, grouting attachments, grout and corrosion protection filler materials or coatings.

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.

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.

Wedge Plate: The hardware that contains tapered holes through which the strands pass and holds the wedges of a multi-strand tendon and transfers the tendon force to the anchorage assembly. (Commonly referred to as anchor head)

Wedge: A conically shaped device that grips and anchors the strand by wedge action in a tapered hole in the wedge plate.

4.0 Materials.

Meet the requirements of following:

Wire Strand .... Section 4.1
Bar .... Section 4.1
Water .... Section 4.4
Post-Tensioning Grout .... Section 4.3
Epoxy Grout (Pour-backs, Block-outs)... Section 4.6
Elastomeric Coating System .... Section 4.5
Epoxy Trowelable Mortar.. Suppl. Spec. 843.03
Epoxy-Urethane Sealer.. CMS 705.23.A
High Molecular Weight Methacrylate..CMS 705.15

4.1 Prestressing Steel:

(a) Strand: Use uncoated Grade 270, low relaxation 7-wire strand meeting the requirements of ASTM A 416.

(b) Bar: Use uncoated Grade 150, high strength, coarse thread bar meeting the requirements of ASTM A 722, Type II.

4.2 Post-Tensioning System: Use only post-tensioning systems that utilize tendons fully encapsulated in anchorages and ducts and use wedges to secure prestressing strand. Systems using “button heading” are not allowed. Systems which transfer prestress force by bonding the prestress steel strand directly to concrete are not permitted (“dead-end”, “bond head”, etc.). Embedded anchors for bars are permitted.

Systems utilizing formed, ungrouted voids or “Diablos” will meet all requirements of this Specification. Provide the necessary details in the released-for-construction drawings.

Strand or tendon couplers are not permitted.

Plastic components will not react with concrete or enhance corrosion of the post-tensioning steel, and will be free of water-soluble chlorides.

4.2.1 Post-Tensioning Anchorages: Provide anchorages that are either “Normal Anchorage Devices” or “Special Anchorage Devices” as defined in AASHTO LRFD Bridge Design Specifications.

Ensure that the anchorages develop at least 95% of the actual ultimate tensile strength of the prestressing steel, when tested in an unbonded state, without exceeding the anticipated set (anchor efficiency test).

Manufacturing of anchorages or any part of the anchorage system from composite materials (i.e. anchors with thin metal confining a precast cementatious fill or similar) is not allowed.

Wedges for anchoring the tendon will be either two-part or three-part. Discontinue use of two-part wedges if these show any sign of slippage or fail to grip the strand without exceeding the anticipated set.

The anchoring devices must effectively distribute tendon forces to the concrete and must be so arranged that the tendon force may be verified prior to the removal of the stressing equipment.

Design anchorages so that the average concrete bearing stress and the individual anchorage components are in compliance with AASHTO LRFD Bridge Design Specifications and interims. Test and provide written certification to the IQF that anchorages meet or exceed the testing requirements in AASHTO LRFD Bridge Construction Specifications and interims.

Reinforce the concrete in the vicinity of the anchorage device.

Galvanize the embedded body of the anchorage in accordance with CMS 711.02. Other components of the anchorage, including wedges and wedge plate are not required to be galvanized with the exception of local zone reinforcement. Local zone reinforcement will be either galvanized in accordance with CMS 711.02 if the design/testing assumed the reinforcement to be uncoated or will be epoxy coated in accordance with CMS 509 if the design/testing assumed the reinforcement to be epoxy coated. Construct the bearing surface and wedge plate from ferrous metal. Equip all anchorages with a permanent grout cap that is vented and bolted to the anchorage.

Provide wedge plates with centering lugs or shoulders to facilitate alignment with the bearing plate.

Cast anchorages with grout outlets suitable for inspection from either the top or front of the anchorage. The grout outlet will serve a dual function of grout outlet and post-grouting inspection access. The geometry of the grout outlets must facilitate being drilled using a 3/8” diameter straight bit to facilitate endoscope inspection directly behind the anchor plate. Anchorages may be fabricated to facilitate both inspection locations or may be two separate anchorages of the same type each providing singular inspection entry locations.

Trumpets associated with anchorages will be made of either ferrous metal or polypropylene plastic material conforming with the requirements stated in 4.2.5.5. The thickness of the trumpet at the transition location (choke point) will not be less than the thickness of the duct as established in 4.2.5.5. Alternately, the trumpet material may be polyolefin containing antioxidant(s) with a minimum Oxidation Induction Time (OIT) according to ASTM D 3895 of not less than 20 minutes. Perform OIT test on samples taken from the finished product. 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.

4.2.2 Bar Couplers: Use couplers meeting the requirements of AASHTO LRFD Bridge Design Specifications and Bridge Construction Specifications. Test and provide written certification to the IQF that the couplers meet or exceed the testing requirements in the AASHTO LRFD Bridge Construction Specifications. Perform testing using samples of the post-tensioning bar to be used on the project. Assemble test specimens in an unbonded state and in testing, the anticipated set is not to be exceeded.

The couplers will only be of the thread type. Thread the post-tensioning bar into one-half (1/2) of the coupler length, +/- ¼ inch, so that when two bars are mated in a coupler, the length of each bar positively engaged in the coupler will be one-half the coupler's length within the accepted tolerances.

4.2.3 Inlets, Outlets, Valves and Plugs: Provide permanent grout inlets, outlets, and threaded plugs 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 D5989 will be S-PA0141 (weather resistant), S-PA0231 or S-PA0401 (ultimate strength not less than 10,000 psi with UV stabilizer added). Products made from polyolefin will contain antioxidant(s) with a minimum Oxidation Induction Time (OIT) according to ASTM D 3895 of not less than 20 minutes. Perform OIT test on samples taken from the finished product. 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. All inlets and outlets will be equipped with pressure rated mechanical shut-off valves or plugs. Inlets, outlets, valves and plugs will be rated for a minimum pressure rating of 150 psi. Inlets will allow for the injection of grout into the duct and outlets will allow the escape of air, water, grout and bleed water. Use inlets and outlets with a minimum inside diameter of 3/4 inch for strand and 3/8 inch for single bar tendons and four and less strand duct.

Provide dual mechanical shutoff valves when performing vertical grouting. Specifically designate temporary items, not part of the permanent structure, on the Post-Tensioning System shop drawings. Temporary items may be made of any suitable material and are the responsibility of the Post-Tensioning System supplier. All temporary items will be removed when no longer needed.

4.2.4 Permanent Grout Caps: Use permanent grout caps made from polymer or ASTM A 240 Type 316L stainless steel. The resins used in the polymer will be either nylon, Acrylonitrite Butadiene Styrene (ABS) or polyester. For products made from nylon, the cell class of the nylon according to ASTM D5989 will be S-PA0141 (weather resistant), S-PA0231 or S-PA0401 (ultimate strength not less than 10,000 psi with UV stabilizer added). Seal the cap with "O" ring seals or precision fitted flat gaskets placed against the bearing plate. Place a grout vent on the top of the cap. Grout caps must be rated for a minimum pressure rating of 150 psi. Use ASTM A 240 Type 316L stainless steel bolts to attach the cap to the anchorage. When stainless steel grout caps are supplied, provide certified test reports to the IQF documenting the chemical analysis of the steel.

4.2.5 Duct and Pipe:

4.2.5.1 General: Use only plastic duct, steel pipe or a combination of plastic duct and steel pipe as specified below. Ensure that all connectors, connections and components of post-tensioning system hardware are air and water tight and pass the pressure test requirements herein. Ensure all connections and fittings produce a smooth interior alignment with no lips or kinks. Use smooth plastic duct in all post-tensioning systems used for external tendons. Use corrugated plastic duct in all post-tensioning systems used for all internal tendons except where steel pipe is required.

All duct material will be sufficiently rigid to withstand the stresses imposed by placement of concrete, grouting, and construction loads without damage or excessive deformation and will remain air and water tight.

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

4.2.5.2 Duct or Pipe Minimum Diameter: For prestressing bars, provide duct with a minimum internal diameter of at least 1/2 inch larger than the outside diameter, measured across the deformations. For prestressing bars with couplers, size the duct to be 1/2 inch larger than the diameter of the bar and/or coupler.

For multi-strand tendons, provide ducts (when empty) with a minimum interior cross-sectional area 2 1/2 times the cross-sectional area of the prestressing steel.

For single strand tendons, provide ducts (when empty) with a minimum inside diameter 1/2 inch greater than the nominal diameter of the tendon.

4.2.5.3 Connection Tolerance between Pipe and Duct: 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 diameters of the steel pipe and the plastic duct are outside of this tolerance.

4.2.5.4 Steel Pipes: Unless "Diablos" are utilized, use galvanized steel pipes (ASTM A53, Grade B, Type E, Schedule 40 galvanized in accordance with CMS 711.02) in all deviation blocks and diaphragms. The pipes will have smooth inner walls and be capable of being curved to the proper configuration without crimping or flattening. Prefabricate the pipe to the correct radius. Bend pipe to a uniform radius along a curve extending between tangent points located three (3) inches inward from the face of the deviation block or diaphragm and so as to accurately conform to the alignment of the tendon taking into consideration the minimum bending radius shown in the released-for-construction drawings.

4.2.5.5 Corrugated Plastic Duct: Do not use ducts manufactured from recycled material. Use seamless fabrication methods to manufacture ducts.

Use corrugated duct manufactured from non-colored, unfilled polypropylene meeting the requirements of ASTM D4101 "Standard Specification for Polypropylene Plastic Injection and Extrusion Materials" with a cell classification range of PP0340B14541 to PP0340B67884. The duct will be white in color containing antioxidant(s) with a minimum Oxidation Induction Time (OIT) according to ASTM D 3895 of 20 minutes and containing a non-yellowing light stabilizer. Perform OIT test on samples from the finished product. Furnish duct with a minimum thickness as defined in the following table:

Duct Shape	Duct Diameter	Duct Thickness
Flat	any size	0.08 inch
Round	0.9 inch	0.08 inch
Round	2.375 inches	0.08 inch
Round	3.0 inches	0.10 inch
Round	3.35 inches	0.10 inch
Round	4.0 inches	0.12 inch

Duct Shape	Duct Diameter	Duct Thickness
Round	4.5 inches	0.14 inch
Round	5.125 inches	0.16 inch
Round	5.71 inches	0.16 inch

4.2.5.5.1 Testing Requirements for Corrugated Plastic Duct: Ensure that the duct system components and accessories meet the requirements of Chapter 4, Articles 4.1 through 4.1.8 of International Federation of Structural Concrete (FIB) Technical Report, Bulletin 7, titled "Corrugated Plastic Duct for Internal Bonded Post-Tensioning" as modified herein.

The requirements in FIB Technical Report, Bulletin 7, are modified as follows: Conduct the lateral load resistance test (FIB 4.1.4), without the use of a duct stiffener plate, using a load of 150 lbs. 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 length test (FIB 4.1.8) must achieve 40 % GUTS in a maximum length of 16 duct diameters when tested on twelve (12) samples with ten (10) of the tests being successful.

4.2.5.5.2 Minimum Bending Radius for Corrugated Plastic Duct: In addition to the component testing stated herein, the manufacturer must establish, through testing, the minimum bending radius for the duct. The test 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 will 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 diameter and not less than 0.08 inch for duct greater than 3.35 inches in diameter.

4.2.5.5.3 Corrugated Duct Connections and Fittings: Make all splices, joints, joints between segments (segmental construction), couplings and connections to anchorages with devices or methods (i.e. mechanical couplers, plastic sleeves in conjunction with shrink sleeve) producing a smooth interior alignment with no lips or kinks. Design all connections and fittings to be airtight. The use of any tape, including duct, is not permitted to join or repair duct connections.

Construct connections and fittings from polyolefin materials containing antioxidant stabilizer(s) meeting the requirements established in 4.2.3 or 4.2.5.5.

For post-tensioned systems intended for use with segmental constructed box girder bridges, the post-tensioning system must include duct couplers at the segment joints. The tendon duct coupler located at the segment joint will be mounted perpendicular to the bulkhead and designed to receive a duct at an angle of 6 degrees deviation from perpendicular. The coupler must be able to accommodate angular deviation of the duct without the tendon strands touching the duct or coupler on either side of the segment joint.

4.2.5.6 Smooth Duct: Use smooth duct manufactured from 100% virgin polyethylene resin meeting the requirements of ASTM D 3350 with a minimum cell class of 344464C. Use resin containing antioxidant(s). Perform OIT test on samples taken from the finished product resulting in a minimum Oxidative Induction Time (OIT) according to ASTM D 3895 of 40 minutes. Manufacture duct with a dimension ratio (DR) of 17.0 or less as established by either ASTM D 3035 or ASTM F 714 as appropriate for the manufacturing process used.

Use smooth duct meeting the minimum pressure rating (working pressure) of 100 psi and manufactured to either of the following Specifications: ASTM D 3035 "Standard Specifications for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter" or ASTM F 714 "Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter".

4.2.5.6.1 External Smooth Duct Connections: Use heat welding techniques to make splices between sections of plastic duct, in accordance with the duct manufacturer's instructions or make connections with electrofusion coupler or other mechanical couplers meeting the material requirements of this Specification. Ensure all connections have a minimum pressure rating (working pressure) of 100 psi, produce a smooth interior alignment and a connection with no lips or kinks.

Ensure all connections between steel pipe embedded in concrete and plastic duct are made by using a mechanical coupler or a circular sleeve made of Ethylene Propylene Deine Monomer (EPDM), having a minimum pressure rating (working pressure) of 100 psi. Use EPDM materials having 100 % quality retention as defined by ASTM D 1171 Ozone Chamber Exposure Method B.

Use EPDM sleeves having a minimum wall thickness of 3/8 inch and be reinforced with a minimum of four ply polyester reinforcement. Use a 3/8 inch wide power seated band and clamps constructed from 316 stainless steel on each end of the boot to seal against leakage of grout. Install the band with an 80 to 120 lb seating force.

4.2.5.7 Corrugated Ferrous Metal Ducts: Do not use corrugated ferrous metal ducts in any location.

4.2.5.8 Shipping and Storage of Ducts: Furnish duct with end caps to seal the duct interior from contamination. Ship in bundles which are capped and covered during shipping and storage. Protect ducts against ultraviolet degradation, crushing, excessive bending, dirt contamination and corrosive elements during transportation, storage and handling. Do not remove end caps supplied with the duct until the duct is incorporated into the bridge component. Store duct 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, wash duct before use to remove any contamination.

4.2.6 Internal Duct Mechanical Couplers, O-Rings, Segment Seal Assemblies and Heat Shrink Sleeve Requirements: Ducts for prestressing bars used exclusively for temporary post-tensioning are not required to be coupled across segment joints.

4.2.6.1 Mechanical Couplers: Construct mechanical internal duct couplers with stainless steel, plastic or a combination of these materials. Use plastic resins meeting the requirements for of sections 4.2.3 or 4.2.5.5 to construct plastic couplers. Use ASTM A 240 Type 316 stainless steel to make metallic components.

4.2.6.2 O-rings: Provide O-ring duct coupling assemblies and **s**egment seal mounting assemblies made from plastic resins meeting the requirements of sections 4.2.3 or 4.2.5.5.

Furnish standard O-ring material (diameter $\leq$ 0.25 inch) conforming to the following requirements:

1. **Mechanical Properties**
   Shore hardness, A ASTM D2240 50-75
   Ultimate elongation %, ASTM D412 ....250 % Min.
   Tensile strength, ASTM D412.. 1400 psi Min.
2. **Accelerated Testing**
   Thermal Deterioration 70 hours @ 257^{o} F, ASTM D573
   Change in tensile strength .... ± 30 %
   Change of elongation.. -50 %
   Change of hardness .... ± 15 points
   Compression Set Method B 22 hours @257^{o} F, ASTM
   D395... 50 %
   Volume change due to absorption of H_2O, Method D,
   for 70 hours @ 212^{o} F, ASTM D471 .... + 10 %
3. **Environmental Resistance**
   Ozone Resistance Exposure Method B, ASTM
   D1171..Pass
   Low Temp. Non-brittle after 3 Min. @ -40^{o}F, ASTM
   D2137..Pass

Furnish segment seal assemblies for large diameter compression seals, used to couple ducts at segment joints, which conform to the requirements stated above and with the following additions and changes:

1. **Mechanical Properties**
   Shore hardness, A ASTM D2240 30-40
   Tensile strength, ASTM D412... 600 psi Min.
   Compression Set Method B 22 hours @257^{o} F,
   ASTM D395 .... 60 %
2. **Compression Force -** The maximum force to compress the O-ring to its final compressed position will not be greater than 25 psi times the area encircled by the O-ring.
3. **Voided Area -** The seal will be designed to accommodate the material flow within its own cross sectional area by using a hollow or voided design.
4. **Mounting Assemblies -** Assemblies holding the O-ring must mount to the form bulkhead and provide for duct alignment.

4.2.6.3 Heat Shrink Sleeves: Furnish heat shrink sleeves having unidirectional circumferential recovery manufactured specifically for the size of the duct being coupled consisting of an irradiated and cross linked high density polyethylene backing for external applications and linear-density polyethylene for internal applications. Furnish adhesive having the same bond value to steel and polyolefin plastic materials. Ensure the heat shrink sleeves have an adhesive layer that will withstand 150° F operating temperature and meet the requirements of the following table:

Property	Test Method	Minimum Requirements

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	216ºF
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%

Install heat shrink sleeves using procedures, methods and equipment in accordance with the manufacturer's written recommendations.

4.2.7 System Test Requirements: For each family of post-tensioning systems, assemble systems and perform the pressure test defined herein. For each family of post-tensioning systems test two assemblies (largest and smallest) from the family. The post-tensioning assembly includes at least one of each component required to make a tendon from grout cap to grout cap. If applicable, include plastic duct to steel pipe connections and segment duct couplers.

4.2.7.1 Grouting Component Assembly Pressure Test: Assemble anchorage and grout cap with all required grouting attachments (grout tube, valves, plugs, etc.). Seal the opening in the anchorage where the duct connects. 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 five 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 on a Department project with written certification that the same components are being utilized in both anchorages.

4.2.7.2 External Duct Systems: System testing for external duct requires two additional tests. (1) The anchorage and its connection to the duct/pipe assembly must be tested in accordance with and meet the requirements for internal duct systems (duct/pipe assembly consists of all components internal to the diaphragm concrete). Test the assembly at 1.5 psi. (2) The duct and pipe assembly consisting of all external duct connections (welded duct splices, duct-pipe, etc.) and a grout vent must comply with the following test. 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 five minutes with no more than 15 psi reduction in pressure. The length of the test pipe assembly for the second test is 15 feet.

4.2.7.3 Internal Duct Systems: Perform a system test of the assembly 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. For systems being tested for use in precast segmental construction, modify this test to include one duct coupler (or O-ring assembly) which is to be used at the segment joint.

Test the coupler for proper function by casting the coupler into a two part concrete test block using match cast techniques. Use blocks that are at least 12 inch x 12 inch x 12 inch. After the concrete has hardened, pull the blocks apart and clean the surface of any bond breaker materials. Using an external apparatus clamp the blocks together and maintain 40 psi pressure on the block cross-section during the pressure test. Do not apply epoxy between the blocks for this portion of the test. Pressurize the duct within the test block to 5 psi and lock-off the outside air source. The assembly must sustain a 5 psi internal pressure for five minutes with no more than a 0.5 psi reduction in pressure. Separate the duct coupler blocks from the duct system remove the clamping device and place a 1/16 inch layer of epoxy on the face of both blocks, clamp the blocks together and maintain a pressure of 40 psi on the block cross-section for 24 hours. Upon removal of the clamping force, demolish the blocks. The coupler and the attached ducts shall be intact and free of epoxy, and properly attached without crushing, tearing or other signs of failure.

4.3 Grout

4.3.1 General Requirements
Provide grout that is thixotropic.

Grout applications are differentiated into three applications: horizontal, vertical and repair. Select the grout for use by the proper application.

Grouts will be prepackaged in moisture proof containers. Grout bags will indicate application, date of manufacture, LOT number and mixing instructions. Any change of materials or material sources requires new testing and certification of the conformance of the grout with this Specification. A copy of the Quality Control Data Sheet for each lot number and shipment sent to the job site will be provided by the DBT and furnished to the IQF. Materials with a total time from manufacture to usage in excess of six months will be tested and certified by the supplier that the product meets this Specification before use or the material will be removed and replaced. Use grout from one plant only for any given project location.

Maintain grout fluidity in strict compliance with the grout manufacturer’s recommendations and test with a flow cone.

4.3.2 Acceptance of Products.
Only post-tensioning grouts that meet these specifications and are accepted by the IQF shall be used. Supply certified test data from an independent laboratory, audited by the Cement Concrete Reference Laboratory (CCRL) which shows the material meets all the requirements specified herein. Grout products will be accepted by the IQF by application (horizontal, vertical or repair).

4.3.3 Mixing.
Mix the material in strict accordance with the manufacturer's recommendations. Grout will be mixed with potable water meeting the requirements of Section 4.4.

4.3.4 Grout Physical Properties.

4.3.4.1 Gas Generation: The grout must not contain aluminum or other components which produce hydrogen, carbon dioxide or oxygen gas.

4.3.4.2 Laboratory Test: The grout will meet or exceed the specified physical properties stated herein as determined by the following standard and modified ASTM test methods conducted at normal laboratory temperature (65-78°F) and conditions. Conduct all grout tests with grout mixed to produce the minimum time of efflux. Establish the water content to produce the minimum and maximum time of efflux.

Property	Test Value	Test Method
Total Chloride Ions	Max. 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	0.0% to + 0.1% expansion at 24 hours and 0.0 % to +0.2% expansion at 28 days	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	Min. 3 hours Max. 12 hours	ASTM C 953
Time of Efflux***		
(a) Immediately after mixing		
	Min. 9 Sec. Max. 20 Sec.	ASTM C 939****
(b) 30 minutes after mixing with remixing for 30 sec		
	Max. 30 Sec.	ASTM C 939****
Bleeding @ 3 hours	Max. 0.0 percent	ASTM C 940*****
Permeability @ 28 days	Max. 2,500 coulombs At 30 V for 6 hours	ASTM C 1202

Property	Test Value	Test Method
API Mud Balance Test	Value ≥ 1.9 Report maximum and minimum obtained test value	******

*Use ASTM C117 procedure modified to use a #50 sieve. Determine the percent passing the #50 sieve after washing the sieve.

**Modify ASTM C1090 to include verification at only 24 hours and 28 days.

***Adjustments to flow rates will 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.

****Modify the ASTM C939 test by filling the cone to the top instead of to the standard level and measure time to fill one liter container.

*****Modify ASTM C940 to conform with the wick induced bleed test as follows:

(a) Use a wick made of a 20 inch length of ASTM A416 seven wire 0.5 inch diameter strand. Wrap the strand with 2 inch wide duct or electrical tape at each end prior to cutting to avoid splaying of the wires when it is cut. Degrease (with acetone or hexane solvent) and wire brush to remove any surface rust on the strand before temperature conditioning.

(b) Condition the dry ingredients, mixing water, prestressing strand and test apparatus overnight at 65 to 75°F.

(c) Mix the conditioned dry ingredients with the conditioned mixing water and place 800 ml of the resulting grout into the 1,000 ml graduate cylinder. Measure and record the level of the top of the grout.

(d) Completely insert the strand into the graduated cylinder. Center and fasten the strand so it remains essentially parallel to the vertical axis of the cylinder. Measure and record the level of the top of the grout.

(e) Store the mixed grout at the temperature range listed above in (b).

(f) Measure the level of the bleed water every 15 minutes for the first hour and hourly for two successive readings thereafter.

(g) Calculate the bleed water, if any, at the end of the three hour test period and the resulting expansion per the procedures outlined in ASTM C940, 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.

******API (American Petroleum Institute) Recommended Practice 13B-1, Standard Procedures for Field Testing Water-based Drilling Fluids. The mud balance apparatus is to be non-reactive with the grout. Report maximum and minimum values, when compared to water, obtained when using maximum and minimum w/c ratios as specified by grout manufacturer.

4.3.5 Accelerated Corrosion Test Method (ACTM).

Perform the ACTM as outlined in Appendix B of the "Specification for Grouting of Post-Tensioning Structures" published by the Post-Tensioning Institute. Report the time to corrosion for both the grout being tested and the control sample using a 0.45 water-cement ratio neat grout.

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.

4.3.6 Variation in Testing for Specific Applications.

4.3.6.1 Horizontal Applications: Horizontal grout applications are defined as grouting of all superstructure tendons and transverse substructure tendons in caps, struts, etc. All physical requirements defined in sections 4.3.4 and 4.3.5 are applicable for grouts used in horizontal applications.

4.3.6.2 Vertical Applications: Vertical grout applications are defined as grouting of substructure column tendons. All physical requirements defined in sections 4.3.4 and 4.3.5 are applicable for grouts used in vertical applications. In addition, perform the Schupack Pressure Bleed Test Procedure for Cement Grouts for Post-Tensioned Structures as outlined in Appendix C of the "Specification for Grouting of Post-Tensioned Structures" published by the Post-Tensioning Institute. Report the percent bleed for the grout tested. Test grout at the specified pressure of 100 psi. An acceptable test will result in no bleed water (0.0 percent).

4.3.6.3 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 accepted for use in the tendon as long as the volume of the void is less than 0.5 gal. If more than 0.5 gal. is needed, use a non-sanded grout meeting the requirements of sections 4.3.4 and 4.3.5 with a modified maximum permeability of 2,800 coulombs (ASTM C 1202 at 30 volts). Non-sanded grouts will have 95% passing on the #100 sieve and 90% passing the #170 sieve as determined by ASTM C33. Each sieve may be washed and dried before weighing in accordance with the procedure in ASTM C117 modified for sieve size.

4.3.7 Grout Storage: Store grout, only when ready for its direct and immediate use, in a location that is both dry and convenient to the work otherwise store as required by this Specification. 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 from the time of receipt.

4.4 Water: Provide water that is potable, clean and free of injurious quantities or substances, including chlorides, sulfides, sulfates and nitrate, known to be harmful to Portland cement or prestressing steel for use in the post-tensioning grout. Water from public water supplies that are approved by a public health department may be accepted without testing. Otherwise, test water at the location where the water is placed into containers for the project, in accordance with AASHTO T 26 or Standard Methods for Examination of Water and Wastewater (American Public Health Association, Inc.) and provide test results to the IQF for acceptance before use. If water is stored in containers which might cause contamination, test water coming from the storage tanks before its used, if directed by the IQF. When tested, the water will not have chloride, sulfide, sulfate and nitrate contents in excess of 500, 100, 650 and 13 ppm respectively, nor exceed the following allowable limits:

Chemical Test	Maximum (%)
Acidity or alkalinity calculated in terms of calcium carbonate	0.05
Total organic solids	0.05
Total inorganic solids	0.08
Total chlorides as sodium chloride	0.05

4.5 Elastomeric Coating

4.5.1 General: Provide an elastomeric coating system to provide a waterproof barrier over post-tensioning anchorages or other areas designated in this Specification or in the released-for-construction drawings. The components of the coating system must be supplied by a single manufacturer and sold as a waterproof coating system. The surface preparation and application of the coating system must be applied in strict accordance with the manufacturer's specifications.

Upon curing, all coatings and/or coating systems must produce an adherent coating that is visually uniform and capable of performing according to its designated purpose for an extended service life of greater than 20 years. The composition of the coating is left to the discretion of the manufacturer, but the finished product must meet all requirements of this section. All coatings must be designed for a marine, coastal environment and must be self-curing. Coatings that are multi-component must be prepackaged in required ratios for ease of mixing. Any coating not meeting this Specification will be rejected.

4.5.2 Safety Requirements: Provide Material Safety Data Sheets (MSDS) to the IQF a minimum of 5 days prior to performing any work. Do not begin work until submitting the MSDS.

4.5.3 Packaging and Labeling: Ship materials in strong containers plainly marked with user information and lot or batch number. Each lot or batch manufactured must have a unique number. Show the name and address of the manufacturer.

4.5.4 Product Testing and Certification.

4.5.4.1 General: Provide to the IQF for acceptance, certified test data conforming to the requirements of CMS 101.03 from the manufacturer of the coatings materials confirming that the requirements of this Section are met. Each certification will cover only one batch of coating. Additionally, supply the IQF with manufacturer's technical product data, including surface preparation, mixing and placement instructions.

4.5.5 Physical Properties: The use of an epoxy prime coat is dependent upon the requirements of the manufacturer's waterproofing system. The polyurethane chemistry may be either waterborne aromatic (moisture-curing) or aromatic (moisture-sensitive). The minimum thickness of the system must not be less than 30 mils. The cured coating system must meet the following requirements:

Property	Test Value	Test Method
Hardness, Shore A	Between 60 and 90	ASTM D 2240
Tensile Strength	≥750 psi	ASTM D 412
Elongation	≥400%	ASTM D 412
Tear Strength	>70 pli	ASTM C 957
Abrasion Resistance H-18 wheels 1,000 gm/wheel	≤350 mg loss / 1,000 revs.	ASTM C 957
Crack Bridging 1,000 Cycles	System Passes	ASTM C 957
Elongation Recovery	≥94%	ASTM C 957

4.6 Epoxy Grout for Anchorage Protection and Hole Repair

4.6.1 General Requirements: Provide a three component (part) epoxy grout consisting of Component A (resin), Component B (hardener) and Component C (aggregate) with all components supplied by the grout manufacturer. No additional fillers are to be added.

All material shall contain no volatile solvent and shall be basically pure reactive material with a maximum ash content of 2%.

All material shall have simple mix ratios of one to one or two to one or shall be supplied in pre-measured containers in which all of the contents of both packages are to be mixed.

The material shall produce a low exothermic reaction and have flow and fill characteristics suitable for machine base plate applications. The material shall be extended with the aggregate supplied by the manufacturer. Mix with the full aggregate loading.

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 must be within the manufacturer's recommended shelf life. Store and condition the product in full compliance with manufacturer's recommendations.

4.6.2 Certification: Provide to the IQF for acceptance, certified test results conforming to the requirements of CMS 101.03 from the manufacturer of the epoxy, confirming that the requirements of this Section are met. Each certification will cover only one batch of epoxy materials. Additionally, supply the IQF with manufacturer's technical product data, including surface preparation, mixing and placement instructions.

4.6.3 Mixing and Application: Mix, apply, and cure grout in accordance with the manufacturer's directions.

4.6.4 Grout Physical Properties: The epoxy grout plus aggregate mix will meet or exceed the following requirements:

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 at 7day Cure at 77ºF	> 3,600 psi	ASTM C 580
Modulus of Elasticity 7 day Cure at 77ºF	< 2,100,000 psi	ASTM C 580
Coefficient of Thermal Expansion at 74 to 210°F	< 20 x 10 $^{-6}$ in/in/ºF	ASTM C 531
Peak Exotherm, Specimen 12 x 12 x 3 in.	< 150ºF	ASTM D 2471

Property	Test Value	Test Method
Slant Shear at 7 days (Bond Strength to Concrete)	> 3000 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

4.6.5 Packaging, Labeling, and Safety: All containers will be identified as Component A - contains epoxy resin or Component B - contains hardener, and will show the type, mixing directions, batch numbers, manufacturer's name, date of packaging, shelf life expiration date and quantity in pounds or gallons or Component C – contains aggregate. Mix ratios will be prominently shown on labels. Potential hazards are to be stated on each package.

Provide Material Safety Data Sheets (MSDS) to the IQF a minimum of 5 days prior to performing any work. Do not begin work until submitting the MSDS.

4.6.6 Storage: Epoxy materials, which have been in storage for more than 12 months, will not be accepted for use. Store acceptable materials as required by this Specification.

4.7 Acceptance of Materials: The acceptance of any material by the IQF or Engineer will not preclude subsequent rejection if the material is damaged in transit or later damaged or found to be defective.

5.0 Testing by the DBT

5.1 Tendon Modulus of Elasticity Test: If ordered by the IQF, perform a tendon modulus of elasticity test in accordance with the following procedure.

For the purpose of accurately determining the tendon elongations while stressing, bench test two samples of each size of tendon 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. Tension the test specimen to 80% of ultimate in ten increments and then detention from 80% of ultimate to zero in ten decrements. For each increment and decrement, record the gauge pressure, elongations and load cell force. Note elongations of the tendon for both ends and the central 30 feet, measured to an accuracy of ± 1/32 inch. Correct the elongations for the actual anchorage set of the dead end.

Calculate the modulus as follows:

E = PL/Adl

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 on nominal area.
dl= strand elongation for load P.

If the bench test varies from the modulus of elasticity used for the shop or released-for-construction drawings by more than 1%, submit revisions to the theoretical elongations.

When the observed elongations of the tendons in the erected structure fall outside the acceptable tolerances, additional Tendon Modulus of Elasticity Tests may be required to the satisfaction of the IQF and the Engineer.

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

The apparatus and methods used to perform the test must be submitted to the IQF for acceptance.

5.2 In Place Friction Test: Test in place a minimum of one tendon in each tendon group type. Tendon group types include cantilever tendons, continuity tendons, draped external tendons or continuous profiled tendons passing through one or more spans. The selected tendon will represent the size and length of the group of tendons being tested. The in-place friction test is not required for straight tendons used in flat slabs.

The test procedure consists of stressing the tendon at an anchor assembly with a load cell or a second certified jack at the dead end. Stress the test specimen to 80% of ultimate tendon strength in eight equal increments. For each increment, record the gauge pressure, elongations and load cell force. Take into account any wedge seating in both the live end (i.e., back of jack) and the dead end (i.e., back of load cell) and 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, keep an accurate account of the elongation at the jacking end allowing for intermediate wedge seating and slip of the jack's wedges.

If the elongation's fall outside the ± 5% range compared to the anticipated elongations based on expected friction coefficients, investigate the reason and make detailed calculations confirming the final tendon forces are in agreement with the requirements of the released-for-construction drawings.

In reconciling theoretical and actual elongations, do not vary the value of the expected friction and wobble coefficients by more than ± 10%. Significant shortfall in elongations is indicative of poor duct alignments and/or obstructions. Correct or compensate for such elongations acceptable to the IQF.

One successful friction test for each tendon group for the project is required.

If there are irreconcilable differences between forces and elongations, or other difficulties during the course of routine stressing operations, the IQF may require additional in place friction tests.

The apparatus and methods used to perform the test must be submitted to the IQF for acceptance.

5.3 Tests Reports Required: Submit two test reports of the "Tendon Modulus of Elasticity Test" to the IQF before installing the tendon.

Submit two test reports of the “In Place Friction Test” to the IQF after successful installation of the tested tendon and prior to performing any further stressing operations.

5.4 Application of Test Results: Reevaluate the theoretical elongations shown on the post-tensioning shop drawings or released-for-construction drawings using the results of the tests for Tendon Modulus of Elasticity and In Place Friction as appropriate and correct as necessary. Submit revisions to the IQF of the theoretical elongations.

6.0 Protection of Prestressing Steel.

6.1 Shipping, Handling and Storage: Protect all prestressing steel against physical damage and corrosion at all times, from manufacturer to final grouting or encasing in the concrete. The IQF or the Engineer will reject prestressing steel that has sustained physical damage. Carefully inspect any reel that is found to contain broken wires during use and remove and discard lengths of strand containing broken wires. The wire must be bright and uniformly colored, having no foreign matter or pitting on its surface.

Prestressing steel must be packaged in containers for protection of the steel against physical damage and corrosion during shipping and storage. A corrosion inhibitor, which prevents rust, must be placed in the package, or be incorporated in a corrosion inhibitor carrier type packaging material. The corrosion inhibitor must have no deleterious effect on the steel or the concrete or bond strength of steel to concrete. Inhibitor carrier type packaging material must conform to the provisions of Federal Specification MIL-P-3420. Immediately replace or restore packaging damaged from any cause, to the original condition. Do not apply a corrosion inhibitor directly to the steel itself.

The shipping package must be clearly marked with the heat number and a statement that the package contains high-strength prestressing steel, the care 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. Specifically designate low relaxation (stabilized) strands per requirements of ASTM A 416. Strands not so designated will be rejected.

6.2 During Installation in the Structure:
At the time of installation, prestressing steel must be free from loose rust, loose mill scale, dirt, paint, oil, grease or other deleterious material. The time between the first installation of the unstressed prestressing steel in the duct and the completion of the stressing operations shall not exceed seven (7) calendar days. If the stressing operation is not completed within seven (7) calendar days from first installation, remove the entire length of the strand and inspect the strand in the presence of the IQF. Any strand that has experienced rusting to the extent it exhibits pits visible to the naked eye will be replaced with new strand.

The time between the first installation of the unstressed prestressing steel in the duct and the completion of the grouting operation shall not exceed twenty (20) calendar days. Failure to grout tendons within the twenty (20) calendar days specified will result in the strand being rejected, removed from the duct and discarded.

Within 24 hours of grouting, blow dry, oil free air into the duct system to remove any water or debris. The use of corrosion inhibitors such as vapor phase inhibitors or water-soluble oils for any corrosion protection, including temporary, is not permitted.

6.3 Tendon Protection During Staged or Segmental Construction: When the released-for-construction drawings provide for the tendons to be installed in one unit or segment, either longitudinally, transversely or vertically, with a length of bare strand left projecting for purposes of threading into another unit or segment during later erection operations, the provisions described in this Specification will apply. All of the prestressing steel will be protected immediately after it is first installed in the first unit or segment until the tendon is grouted in the second unit or segment.

6.4 Cleaning and Flushing Tendons and Duct: Flushing of tendons and ducts is not permitted except in situations in which a lubricant is applied to the prestressing steel as defined in Section 10.5.

If flushing is to be performed, the inside of the duct system will be flushed with water, under pressure, meeting the requirements of this Specification to remove all traces of the lubricant. Use flush water containing slack lime (calcium hydroxide) or quicklime (calcium oxide) in the amount of 0.17 lb/gal. Flushing pressures will not exceed allowable grout pumping pressures for the ducts. Following the flushing operation, water will be totally drained from within the duct system and it will be blown out with oil-free compressed air to the extent necessary to dry the prestressing steel and/or the inside surfaces of the ducts.

Flushing of grout is not permitted and vacuum grouting is required to repair all voids and blockages as defined in Section 11.5.8.

7.0 Fabrication.

7.1 General: Accurately and securely fasten all post-tensioning anchorages, ducts, inlet and outlet pipes, miscellaneous hardware, reinforcing bars, and other embedments at the locations shown on the released-for-construction drawings or on the Shop Drawings.

7.2 Ducts: Accurately align ducts and position at the locations shown on the released-for-construction drawings or according to the Shop Drawings. Securely fasten all internal ducts in position at regular intervals not exceeding 30 inches for steel pipes, 24 inches for round plastic duct and 12 inches for flat ducts or manufacturer specified spacing if less regardless of duct type, to prevent movement, displacement or damage from concrete placement and consolidation operations. Provide any additional epoxy coated reinforcing steel in accordance with CMS 509 required to support the post-tensioning ducts.

Any duct confinement reinforcement will be epoxy coated in accordance with CMS 509.

Ensure that ducts for external tendons are straight between connections to internal ducts at anchorages, diaphragms and deviation saddles and are supported at intermediate locations according to the released-for-construction drawings or shop drawings.

Ensure that all alignments, including curves and straight portions, are smooth and continuous with no lips, kinks or dents. This requirement also applies to curves in pre-bent steel pipe.

Carefully check and repair all ducts, using IQF accepted methods, as necessary before placing any concrete.

After installing the ducts and until grouting is complete, ensure that all ends of ducts and anchorages, connections to anchorages, splices, inlets and outlets are sealed at all times. Ensure all ducts, anchorages, block-outs, openings and vents are kept clean and free of debris, fuel, oil, other contaminants and site trash at all times prior to and after installing the tendons. Provide an absolute seal of anchorage and duct termination locations by using plumber's plugs or equal, located such that ALL connections can be air pressure tested. Grout inlets and outlets will be installed with plugs or valves in the closed position. Leave low point outlets open. The use of any tape, including duct tape, is not permitted.

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

During concrete placement for precast segments, mandrels must be used as stiffeners in each duct and will extend throughout the length of the segment being cast and at least 2.0 feet into the corresponding duct of the previously cast segment. The mandrels must be of sufficient rigidity to maintain the duct geometry within the tolerances specified in Section 7.5

7.3 Splices and Joints: All splices, joints, couplings, connections (inlet and outlet) and valves will be part of the post-tensioning system.

Shrink-sleeve material may be used to repair duct. The use of any tape, including duct tape, to repair or seal duct is not permitted.

7.4 Location of Grout Inlets and Outlets: Place grout inlets and outlets at locations as shown on the released-for-construction drawings and shop drawings. Equip all grout inlets and outlets with positive shut-off devices. At a minimum, grout inlets and outlets will be placed in the following positions:

(a) Top of the tendon anchorage;
(b) Top of the grout cap;
(c) At the high points of the duct when the vertical distance between the highest and lowest point is more than 20 inches;
(d) At a location 3 feet past high points of the duct on the downstream side in the direction of grout flow, opposite the direction of grouting;
(e) At all low points (free-draining);
(f) At major changes in the cross section of the duct, such as couplers and anchorages;
(g) At each side of couplers (as necessary);
(h) For external tendons, provide vents as close to the inside face of the diaphragm as practical, located on top of the duct;
(i) An inlet at the lowest point of the tendon. Note judgment should be used in locating the lowest point. For example, if the absolute low point is in a deviation block for an external tendon, then place the inlet close to the block in an accessible portion of the duct;

Extend grout tubes (inlet and outlet) a sufficient distance out of the concrete member to allow for proper operation (closing) of the valves. Connect the outlet at all high points at the uppermost part of the duct profile

7.5 Tolerances: Ensure that post-tensioning ducts in their final position are 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, ensure that tendons are not out of position by more than ± 1/4 inch in any direction.

Ensure entrance and exit angles of tendon paths at anchorages and/or at faces of concrete are within ± 3 degrees of desired angle measured in any direction and any deviations in the alignment are accomplished with smooth transitions without any kinks.

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

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

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

7.6 Internal Duct Pressure Test: Pressure test each duct assembly at the sight of casting. Test the assemblies in their final position just prior (within 24 hours) to concrete placement by sealing them at their anchorage or construction joint termini and then by applying compressed air to determine if the assembly connections are pressure tight. In the presence of the IQF, slowly pressurize and condition the duct to 1.5 psi and lock-off the outside air source then record the pressure loss for a duration of one minute. If the pressure loss exceeds 0.15 psi, find and repair the leaks in the duct assembly using repair methods accepted by the IQF and retest. Continue this cycle until an acceptable test is achieved. Include in the test, the duct to trumpet and trumpet to anchorage connections and any duct to anchorage connections. Retest if duct assembly is disturbed in anyway.

8.0 Placing Concrete.

8.1 Precautions: Use methods to place and consolidate concrete which will not displace or damage any of the post-tensioning ducts, anchorage assemblies, splices and connections, reinforcement or other embedments. Fabricate all duct splices to prevent duct kinks during concrete placement. Use mandrels as needed to maintain duct alignment and shape.

8.2 Proving of Post-Tensioning Ducts: Upon completion of concrete placement, prove that the post-tensioning ducts are free and clear of any obstructions or damage and are able to accept the intended post-tensioning tendons by passing a torpedo through the ducts. Use a torpedo having the same cross-sectional shape as the duct and that is a 1/4 inch smaller all around than the clear, nominal inside dimensions of the duct. Make no deductions to the torpedo section dimensions for tolerances allowed in the manufacture or fixing of the ducts. For straight ducts, use a torpedo at least 2 feet long. For curved ducts, determine the length 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 IQF and the Engineer will reject the member, unless a workable repair can be made to clear the duct. The torpedo must pass through the duct easily, by hand, without resorting to excessive effort or mechanical assistance.

8.3 Problems and Remedies: The IQF and the Engineer will reject ducts or any part of the work found to be deficient. Perform no remedial or repair work without the IQF and Engineer's approval.

9.0 Installing Tendons.
Prior to installation of strands, blow dry oil-free compressed air through the duct to remove any moisture and debris in the duct.

Push or pull post-tensioning strands through the ducts to make up a tendon using methods which will not snag on any lips or joints in the ducts. Strands which are pushed shall be rounded off the end of the strand or fitted with a smooth protective cap. During the installation of the post-tensioning strand into the duct, the strand must not be intentionally rotated by any mechanical device.

Alternatively, strands may be assembled to form the tendon and pulled through the duct using a special steel wire sock ("Chinese finger") or other device attached to the end. The ends of the strands may not be electric arc welded together for this purpose. Strands may be brazed together for pulling as long as 3 feet of strand from the brazed end is removed after installation. Round the end of the pre-assembled tendon for smooth passage through the duct. Cut strands using an abrasive saw. Flame cutting or the use of a plasma cutter is not allowed.

Do not install permanent tendons before the completion of testing as required by this Specification. As a sole exception, the tendon to be tested in the "In Place Friction Test" may be installed for the test.

Within four hours after tendon installation, seal all tendon openings and temporarily weatherproof the open ends of the anchorage including any projecting prestressing steel. The use of any tape, including duct tape, will not be allowed. If tendon contamination occurs, remove and replace the tendon.

10.0 Post-Tensioning Operations.

10.1 General: Do not apply post-tensioning forces until the concrete has attained the specified compressive strength as determined by cylinder tests. Store cylinders under the same conditions as the concrete in order to accurately represent the curing condition of the concrete as poured in place. The design of the structure is based on the assumed friction and wobble coefficient shown in the released-for-construction drawings.

10.2 Stressing Tendons: Tension all post-tensioning steel with hydraulic jacks so that the post-tensioning force is not less than that required by the released-for-construction drawings or shop drawings. Do not utilize monostrand jacks to stress tendons with five or more strands.

10.2.1 Maximum Stress at Jacking: The maximum temporary stress (jacking stress) in the post-tensioning steel must not exceed 80% of its specified minimum ultimate tensile strength. Do not overstress tendons to achieve the expected elongation unless approved by the IQF and the Engineer.

10.2.2 Initial and Permanent Stresses: Tension tendons to a preliminary force as necessary to eliminate any take-up in the tensioning system before elongation readings are started. This preliminary force will be between 5% and 20% of the final jacking force and will be shown in the shop drawings. Measure the initial force by a method acceptable to the IQF, so that its magnitude can be used as a check against elongation as computed and as measured. Mark each strand prior to final stressing to permit measurements of elongations, to ensure that anchor wedges set properly and to serve as a quick visual check for individual strand slippage during stressing, seating and after release.

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 released-for-construction drawings or the shop drawings. Unless otherwise approved by the IQF and the Engineer, 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, thermal effect, losses in the post-tensioning steel from the sequence of stressing, friction and unintentional wobble of the ducts, anchor set, friction in the anchorages, take up of anchorages and all other losses peculiar to the post-tensioning method or system.

10.2.3 Stressing Sequence: Except as noted on the released-for-construction drawings or the shop drawings, permanent post-tensioning tendons must be stressed from both ends. The required force may 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 double end stressing.
(b) The calculated elongation of the post-tensioning steel at the second end is 1/2 inch or less and wedges are power seated.
(c) Single end stressing applied at alternate ends of paired adjacent post-tensioning tendons is required to produce a symmetrical force distribution in agreement with the released-for-construction drawings.

For construction in stages where some tendons are required to be stressed before others, install and stress in accordance with the released-for-construction drawings.

10.3 Stressing Equipment: Only use equipment furnished by the supplier of the post-tensioning system (tendons, hardware, anchorages, etc.).

10.3.1 Stressing Jacks and Gauges: Each jack must be equipped with a pressure gauge for determining the jacking pressure. The pressure gauge must have an accurate reading gauge with a dial at least 6 inches in diameter and use the English system.

10.3.2 Calibration of Jacks and Gauges: Calibrate each jack and its gauge(s) as a unit. The calibration must 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, average the forces from each test cycle to obtain an average force. Perform the calibration with the equipment (jack, pump, hoses, etc.) setup in the same configuration that is intended to be used at the job site including the same length of hydraulic lines. The post-tensioning supplier or an independent laboratory must perform initial calibration of jacks and gauge(s). Use load cells calibrated within the past 12 months to calibrate stressing equipment. For each jack and gauge unit used on the project, furnish certified calibration charts and curves to the IQF prior to stressing. Supply documentation denoting the load cell(s) calibration date and tractability to NIST (National Institute of Standards and Technology) along with the jack/gauge calibration.

Provide the IQF with certified calibration charts and curves prior to the start of the work and every six months thereafter, or as requested by the IQF. Calibrations subsequent to the initial calibration with a load cell may be accomplished by the use of a master gauge. Supply the master gauge to the IQF in a protective waterproof container capable of protecting the calibration of the master gauge during shipment to a laboratory. Provide a quick-attach hydraulic manifold next to the permanent gauge in the hydraulic lines to enable quick and easy installation of the master gauge to verify the permanent gauge readings. The master gauge must be calibrated and provided to the IQF. The master gauge will be calibrated at the same time as the initial calibration of the jacks and will be part of the unit for each jack. The data recorded during the initial calibrations will be furnished to the IQF for use in the field. The master gauge will remain in the possession of the IQF for the duration of the project.

Any jack repair or modification, such as replacing seals or changing the length of the hydraulic lines, requires recalibration using a load cell by the post-tensioning supplier or an independent laboratory.

10.4 Elongations and Agreement with Forces: Ensure that the forces being applied to the tendon and the elongation of the post-tensioning tendon can be measured at all times. Keep a permanent record of gauge pressures and elongations. Verify post-tensioning force as deemed necessary by the IQF.

Elongations will be measured to the nearest 1/16 inch using a rigid rule. Flexible tapes are not allowed.

For the required tendon force, except for post-tensioning bars with lengths less than 20 feet, the observed elongation must agree within 7% ($\pm$) of the theoretical elongation or the entire operation must be checked and the source of error determined and remedied to the satisfaction of the IQF before proceeding further. Do not overstress the tendon 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 IQF or the Engineer may require additional tests for "Tendon Modulus of Elasticity" and/or "In-Place Friction" in accordance with Sections 5.1 and 5.2.

For the required tendon force for post-tensioning bars with lengths less than 20 feet, verify the anchor force with a lift-off after initial stressing operations. The resulting lift-off shall be within ± 5% of the expected final anchor force as specified in the released-for-construction drawings.

10.5 Friction: 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. Show these coefficients and values on the shop drawings.

When friction must be reduced, as a last effort to reconcile elongations and agreement with forces, graphite, with no corrosive agents, may be used as a lubricant, subject to the approval of the IQF. Lubricants will be flushed from the duct as soon as possible after stressing is completed by use of water under pressure. These ducts will be flushed again just prior to the grouting operations. Each time ducts are flushed, they will be immediately blown dry with compressed oil-free air. Flushing will be performed as described in Section 6.4.

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 must 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 must be at least 98% of the post-tensioning required for that mating joint for that stage of erection.
(c) Any single tendon must have no more than a 5% reduction in cross-sectional area of post-tensioning steel due to wire failure.

10.7 Cutting of Post-Tensioning Steel: Cut post-tensioning steel/bar with an abrasive saw within 3/4 to 1 1/2 inches away from the anchoring device. Flame or plasma cutting of post-tensioning steel/bar is not allowed.

10.8 Record of Stressing Operations: Keep a record of the following post-tensioning operations for each tendon installed:

(a) Project name, State Project Number;
(b) DBT;
(c) Tendon location, size and type;
(d) Date tendon was first installed in ducts;
(e) Reel number for strands and heat number for bars;
(f) Tendon cross-sectional area (assumed and actual);
(g) Modulus of elasticity (assumed and actual);
(h) Date Stressed;
(i) Jack and Gauge numbers per end of tendon;
(j) Required jacking force;

(k) Gauge pressures;
(l) Elongations (theoretical and actual);
(m) Anchor sets (anticipated and actual);
(n) Stressing sequence;
(o) Stressing mode (one end only/ two ends in sequence/ two ends simultaneously);
(p) Witnesses to stressing operation;
(q) Date grouted

Record any other relevant information. Provide the IQF and Engineer with a complete copy of all stressing operations.

10.9 Duct Pressure Field Test: After stressing and before grouting internal or external tendons, install all grout caps, inlets and outlets with valves (no plugs and/or caps) in-place and test the tendon with compressed air to determine if duct connections require repair and to test operation and tightness of valves. In the presence of the IQF, pressurize and condition the tendon to 50 psi and lock-off the outside air source. Record pressure loss for one minute. A pressure loss of 25 psi is acceptable. If the pressure loss exceeds the allowable, repair leaking connections using methods accepted by the IQF and retest. Continue this cycle until an acceptable test is achieved.

Test operation of each vent by blowing dry, oil free air into the duct system and opening and closing each vent in turn.

10.10 Tendon Protection: Within four hours after stressing, install the permanent grout caps with o-rings already installed and seal all other tendon openings. If acceptance by the IQF of the tendon is delayed, seal all tendon openings and temporarily weatherproof the open ends of the anchorage including any projecting prestressing steel. The use of tape, including duct tape, is not allowed. If tendon contamination occurs, remove and replace the tendon.

10.11 Reuse of Tendons: Previously tensioned strands must not be reused. Previously tensioned post-tensioning bars must not be reused with the exception of bars that have been used to apply temporary post-tensioning force provided that they are undamaged and will only be used in a temporary condition. The post-tensioning system supplier will specify the maximum number of times that the temporary post-tensioning bars may be stressed.

11.0 Grouting Operations.

11.1 Grouting Operations Plan: A grouting operations plan shall be accepted by the IQF in advance of any scheduled grouting operations.

At a minimum, the plan will address and provide procedures for the following items for work performed at a precast yard and/or on the project site and reflect the chosen method and sequence of construction:

(a) Names, experience and proof of training and certification for the grouting crew and the crew foreman in conformance with this Specification;
(b) Type, quantity, and brand of materials used in grouting including all certifications required and identity of testing lab;

(c) Type of equipment furnished, including capacity in relation to demand and working condition, as well as back-up equipment, spare parts and duct flushing equipment;
(d) Source of water for grout mixing and flushing of duct and how stored;
(e) General grouting procedure;
(f) Details of temporary shimming when grouting external tendons;
(g) Proposed grouting time with respect to placement of post-tensioning steel in duct;
(h) Duct pressure test and repair procedures;
(i) Method to be used to control the rate of flow within ducts;
(j) Theoretical grout volume calculations;
(k) Mixing and pumping procedures including control of w/c ratio;
(l) Production grout testing;
(m) QC Forms;
(n) Tendons or groups of tendons to be grouted in each operation and order of grouting;
(o) Direction of grouting;
(p) Sequence of use of the inlets and outlet pipes;
(q) Procedures for inspection of external ducts and inlets, outlets, grout caps, etc. for both internal and external ducts, during grouting operation and repair procedures;
(r) Procedures for handling blockages;
(s) Procedures for inspection of tendons after grouting;
(t) Procedures for possible post grouting repair;
(u) Method of sealing and protecting tendons and ducts prior to and after grouting;
(v) Methods of providing any temporary weatherproofing required.

11.2 Grout Inlets and Outlets: Ensure the connections from the grout pump hose to inlets are free of dirt and are air- tight. Inspect valves to be sure that they can be opened and closed properly.

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

11.4 Equipment:

11.4.1 General: Provide grouting equipment consisting 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. Provide pumping equipment with 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.

The grouting equipment will contain a screen having clear openings of 1/8 inch maximum size to screen incompletely mixed lumps from the grout prior to its introduction into the storage hopper. The screen will be located between the mixer and storage hopper and be easily accessible for inspection and cleaning.

Provide an air compressor and hoses with sufficient output to perform the required functions.

Provide vacuum grouting equipment (volumetric measuring type) and experienced operators within a time frame that ensures all voids will be filled within 48 hours of the completion of inspections.

11.4.2 Mixer, Storage Hopper: Provide a high speed shear colloidal mixer capable of continuous mechanical mixing producing a homogeneous and stable grout free of lumps and indispersed cement and be able to deliver a continuous supply of grout to the pumping equipment. 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.

Add water 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.

11.4.3 Grout Pumping Equipment: Provide pumping equipment capable of continuous operation with little variation of pressure and which will include a system for circulating the grout when actual grouting is not in progress. The piping will have a minimum number of bends, valves, and changes in diameter and incorporate a sampling tee. Firmly connect all grout hoses to pump outlets, pipes and inlets of the duct.

The equipment will be capable of maintaining pressure on completely grouted ducts and will be fitted with a valve that can be closed off (locked-off) without loss of pressure in the duct. The use (injection) of compressed air for pumping grout is prohibited.

Grout pumps will be positive displacement type, will provide a continuous flow of grout, will be able to maintain a discharge pressure of at least 145 psi, have exact pressure control capabilities and be fed from the holding tank.

Pumps will be constructed to 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 ft) are used, place two gauges, 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.

11.4.4 Vacuum Grouting Equipment: When necessary, provide vacuum grouting equipment consisting of the following:

(a) Volumeter for the measurement of void volume.
(b) Vacuum pump with a minimum capacity of 10 cfm and equipped with 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 5 gal. in volume.
(d) Standard colloidal mixers, for voids 5 gal. and greater in volume.

11.4.5 Stand-by Equipment: During grouting operations, provide a stand-by colloidal grout mixer and pump. Additionally, provide adequate flushing equipment to facilitate complete removal of the grout in the event that the IQF requires the flushing of the grout from the duct. Keep all equipment in working order. Where potable water is not available, provide a tank of sufficient water. Flushing will be performed as described in Section 6.4.

11.5 Grouting:

11.5.1 General: Perform test to confirm the accuracy of the volume-measuring component of the vacuum grouting equipment each day when in use before performing any grouting operations. Use either water or grout for testing using standard testing devices with volumes of 0.5 gal and 6.5 gal and an accuracy of equal to or less than 4 oz. Perform one test 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 IQF must be present when any test is performed.

Grout tendons in accordance with the procedures set forth in the grouting operation plan. Grout all empty ducts.

Prior to grouting external tendons, provide temporary shimming of the duct so that the duct is raised off the strand and the strand is centered within the duct during all grouting operations. Remove shimming after grout has cured. Shimming must not damage or permanently deform the duct.

11.5.2 Temperature Considerations: Maximum grout temperature must not exceed 90°F at the grout inlet. Use chilled mix water (free of ice) and/or pre-cooling of the bagged material to maintain mixed grout temperature below the maximum allowed temperature. Grouting operations are prohibited when the ambient temperature is below 40°F or is 40°F and falling. Postpone grouting operations 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.

11.5.3 Mixing and Pumping: Mix the grout with a metered amount of water.
The materials will be mixed in accordance with the grout manufacturer's written directions/recommendations to produce a homogeneous grout. Continuously agitate the grout until grouting is complete. Verify calibration of water measuring device in the presence of the IQF prior to the start of mixing.

11.5.4 Grout Production Test: During grouting operations the fluidity of the grout must be strictly maintained within the limits established by the grout manufacturer. Determine grout fluidity by use of the test method found in Section 4.3. Perform fluidity test for each tendon to be grouted and maintain the correct water to cementitious ratio. Do not use grout which tests outside the allowable flow rates. After the correct grout fluidity is established, perform wet density testing as described in Section 11.5.5 if this testing method will be later used to check the quality of the grout at the outlets.

Prior to grouting empty ducts, condition the grout materials as required to limit the grout temperature at the inlet end of the grout hose to 90°F. Prior to performing repair grouting operations with vacuum grouting, condition the grout materials to limit the grout temperature at the inlet end of the grout hose to 85°F. Check the temperature of the grout at the inlet end of the grout hose hourly and as required by the IQF.

At the beginning of each day's grouting operation, if required by the IQF, perform a wick induced bleed test in accordance with Section 4.3. If zero bleed is not achieved at the end of the required time period, do not begin grouting of any new or additional tendons until the grouting operations have been adjusted and further testing shows the grout meets the specified requirements.

After achieving required grout properties, do not add any additional water to the grout.

11.5.5 Grout Operations: Open all grout outlets before starting the grouting operation. Grout tendons in accordance with the Grouting Operations Plan and maintain a continuous one-way flow of grout at all times.

Unless accepted otherwise by the IQF, pump grout at a rate of 16 feet to 50 feet of duct per minute. Conduct normal grouting operations at a pressure range of 10 psi to 50 psi measured at the grout inlet. The initial pumping pressure for thixotropic grouts at the inlet may need to be higher in order to get the grout moving. However, once the grout is moving/flowing, the pressure needed to maintain the flow shall be in the earlier specified range. Do not exceed the maximum pumping pressure of 145 psi at the grout inlet for round ducts and 75 psi for flat ducts in deck slabs.

Use grout pumping methods which will ensure complete filling of the ducts and complete encasement of the steel within 30 minutes of the first addition of water to the dry ingredients. Grout must flow from the first and subsequent outlets until no visible slugs or any residual water or entrapped air has been removed and the grout being ejected has the same consistency as the grout being injected prior to closing the outlet. At this time, at least one gallon of grout will be vented (ejected) from the first vent hole into a suitable receptacle and discarded properly prior to closing the outlet. Grout injection will continue until all vents have been closed one after another in the direction of flow following the same process. At intermediate crests where vents have been provided both at the crest and immediately downstream from the crest, the vent downstream of the crest will be closed before the associated crest vent.

Pump grout through the duct and continuously discharge it at the anchorage and grout cap outlets until any free water, air and debris are discharged and the consistency of the grout is equivalent to that of the grout being pumped into the inlet. Close the anchorage outlet and discharge a minimum of 2 gallons of waste grout from the grout cap into a clean receptacle and discard properly. Close the grout cap outlet.

For each tendon, immediately after uncontaminated uniform discharge begins, perform a fluidity test using the flow cone on the grout discharged from the anchorage outlet. The measured grout efflux time will not be less than the efflux time measured at the pump or minimum acceptable efflux time as established in Section 4.3. Alternately, check the grout fluidity using either of the Wet Density methods contained in Section 4.3 (ASTM C 138 or API 13B-1). The measured density must fall within the values established in Section 4.3. The density at the final outlet must not be less than the grout density at the inlet. “Pocket size” mud balances are acceptable for the field testing. If the grout fluidity is not acceptable, discharge additional grout from the anchorage outlet and test the grout fluidity. Continue this cycle until an acceptable grout fluidity is achieved. Discard grout used for testing fluidity. After all outlets have been bled and sealed, elevate the grout pressure to ±75 psi seal the inlet valve and wait two minutes to determine if any leaks exist. At the same time visually inspect inlet, outlets, grout caps, etc. for leaks. Additionally inspect external duct for leaks or signs of distress. If leaks are present, fix the leaks using methods accepted by the IQF before grouting is continued. Repeat the above stated process until no leaks are present. If no leaks are present, bleed the pressure to 5 psi and wait a minimum of ten minutes for any entrapped air to flow to the high points. After the minimum ten minutes period has expired, increase the pressure as needed and discharge grout at each high point outlet to eliminate any entrapped air or water. Complete the process by locking a pressure of 30 psi into the tendon.

Perform additional fluidity and/or density testing when there is a visual or apparent change in the characteristics of the grout or as directed by the IQF.

Additionally, periodically inspect the interiors of box girders during the grouting operation for grout leakage. Leaks will be repaired using IQF accepted methods before the grouting operation is continued.

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, stop the grouting operation. Do not flush the grout from the duct unless either approved or directed to by the IQF. After waiting 48 hours, fill the tendon with grout in accordance with the procedure outlined in Section 11.5.8.

Monitor all anchorages, grout inlets and outlets (vents) periodically until the grout sets. If bleed water is observed dripping from these locations, notify the IQF. Inspect these areas for voids as described in Section 11.5.8 after the grout sets (48 hours).

11.5.6 Vertical Grouting: Grouting of cable stays is not covered by this Specification. For all vertical tendons, provide a standpipe at the upper end of the tendon to store bleed water and grout, maintain the grout level above the level of the prestressing plate and anchorage. This device will be designed and sized to maintain the level of the grout at an elevation which will assure that bleeding will at no time cause the level of the grout to drop below the highest point of the upper anchorage device and that as bleed water migrates to the top, grout is able to migrate downward to replace it. Design the standpipe to allow all bleed water to rise into the standpipe, not into the uppermost part of the tendon and anchorage device.

Discharge grout and check grout fluidity as described in Section 11.5.5. As grouting is completed, the standpipe will be filled with grout to a level which assures that, as settlement of the grout occurs, the level of the grout will not drop below the highest point in the upper anchorage device. If the level of the grout drops below the highest point in the anchorage device, immediately add grout to the standpipe. After the grout has hardened, the standpipe will be removed. In the presence of the IQF, visually inspect for voids using an endoscope or probe. Fill all voids found in the duct using volumetric measuring vacuum grouting processes.

For vertical tendons in excess of 100 feet or if the grouting pressure exceeds the maximum recommended pumping pressure, then grout will be pumped at increasingly higher outlets (which become injection locations) which have been or are ready to be closed as long as a one-way flow of grout is maintained. Grout will be allowed to flow from each outlet until all air and water have been purged prior to using that outlet for pumping.

For external vertical tendons, lifts of grout will not exceed 30 feet until the lower lift has set without acceptance of the IQF. Two steel band clamps will be securely fastened around the external duct at the top of the lower lift. Injection will proceed from a point just above the top of the lower lift.

11.5.7 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.

11.5.8 Post-Grouting Operations and Inspection: Do not remove or open inlets and outlets until the grout has cured for 48 hours. Remove all outlets located at anchorages and high points along the tendon to facilitate inspection and perform inspections within one hour after the removal of the inlet/outlet. Drill and inspect all high points along the tendon as well as the inlets or outlets located at the anchorages unless otherwise accepted the IQF. Depending on the geometry of the grout inlets, drilling may be required to penetrate to the inner surface of the trumpet or duct. Use drilling equipment that will automatically shut-off when steel is encountered. Unless grout caps are determined to have voids by sounding, do not drill into the cap. Perform inspections in the presence of the IQF using endoscopes or probes. The presence of a void and an estimation of its extent or length will be recorded. Within one hour of completion of the inspections, temporarily weatherproof the voids created by the inspection using methods that will ensure the complete exclusion of any moisture or debris from the voids prior to repair and that can be fully removed when no longer needed. The use of any tape, including duct tape, cannot be used for the temporary weatherproofing. Fill all duct and anchorage voids using the volumetric measuring vacuum grouting process within 48 hours of the completion of inspections.

Seal and repair all anchorage and inlet/outlet voids that are produced by drilling for inspection purposes as specified in Section 12.2. Remove the inlet/outlet to a minimum depth of 1 inch, or as necessary, to provide a clear cover of at least 1 inch. Use an injection tube to extend to the bottom of the drilled holes for backfilling with epoxy.

If tendon grouting operations were prematurely terminated prior to completely filling the tendon, drill into the duct and explore the voided areas with an endoscope. Probing is not allowed. Determine the location and extent of all voided areas. Within one hour of completion of the inspections, temporarily weatherproof the voids created by the inspection using methods that will ensure the complete exclusion of any moisture or debris from the voids prior to repair and that can be fully removed when no longer needed. The use of any tape, including duct tape, cannot be used for the temporary weatherproofing. Install grout inlets as needed and fill the voids using volumetric measuring vacuum grouting equipment within 48 hours of the completion of inspections.

11.5.9 Grouting Report: Provide a grouting report signed by the DBT and IQF within 72 hours of each grouting operation for each tendon installed, stressed and grouted, and submit to the Engineer.

Report the theoretical quantity of grout anticipated as compared to the actual quantity of grout used to fill the duct. The actual quantity of grout will be reflective of the amount wasted at the vents and any remaining in the mixer, hopper and grout injection equipment. Notify the IQF and the Engineer immediately of shortages or overages.

Information to be noted in the records, in addition to the above, must include but not necessarily be limited to the following:

(a) identification of the tendon
(b) date grouted
(c) number of days from tendon installation to grouting
(d) type of grout
(e) fluidity of grout
(f) injection point, direction of grout flow and applied grouting pressure
(g) ratio of actual to theoretical grout quantity
(h) summary of any problems encountered and corrective action taken
(i) witnesses to grouting operation

12.0 Repair of Grout Inlets and Outlets.

Place threaded plastic caps in all inlet/outlet locations required in the released-for-construction drawings. Repair inlets/outlets using an epoxy trowelable mortar (grout) which is on the Department's Qualified Products List for Supplemental Specification 843. Provide the name of the grout and a copy of the manufacturer's technical data sheet and job specific surface preparation, mixing and application instructions to the IQF at least five (5) days before performing the work. Prepare the surface to receive the material in strict compliance with the manufacture's recommendations. Form, mix, place and cure the material in strict compliance with the manufacture's recommendations.

13.0 Protection of Post-Tensioning Anchorages.
Within seven days upon completion of the grouting, protect the anchorage of post-tensioning bars and tendons as indicated in the released-for-construction drawings or shop drawings. The application of the elastomeric coating may be delayed up to 90 days after grouting. Use plastic or stainless steel threaded caps to plug all grout inlets/outlets. Use an epoxy grout meeting the requirements of Section 4.6 to construct all pour-backs (recesses and blockouts) located at anchorages.

Remove all rust, misplaced grout, laitance, grease, curing compounds, surface treatments, coatings and oils by grit blasting or water blasting using a minimum 10,000 psi nozzle pressure. Flush surface with water and blow dry. Surfaces must be clean, sound and without any standing water. Use ACI 503 for substrate testing and develop a minimum of 175 psi. tension (pull-off value). Do not damage the grout caps.

Mix and apply epoxy as per manufacturer's current standard technical guidelines. Construct all pour-backs in leak proof forms creating neat lines. The epoxy grout may require pumping for proper installation. Construct forms to maintain a liquid head to insure intimate contact with the concrete surface. Use vents as needed to provide for the escape of air to ensure complete filling of the forms.

If concrete is indicated to be the pour-back material ("secondary pour"), apply a heavy, unbroken coat of an epoxy bonding compound conforming to ASTM C 881, Type V, in a manner and thickness as recommended by the manufacturer along the entire surface to be covered by the pour-back concrete. Place the pour-back concrete while the epoxy is still tacky.

Coat the exposed surfaces of all pour-backs and grout caps, except on tendons with pour-backs visible to the traveling public, and an area extending 12 inches outside the perimeter of the pour-backs and grout caps with an elastomeric coating system meeting the requirements of Section 4.5 and having a thickness of 30 to 45 mils. Assure concrete, grout caps or other substrates are structurally sound, clean and dry. Concrete must be a minimum of 28 days old. Remove all laitance, grease, curing compounds, surface treatments, coatings and oils by grit blasting or water blasting using a minimum 10,000 psi nozzle pressure to establish the anchor pattern. Terminate the coating in a 3/8" wide by 3/8" deep groove cut into the concrete. Blow the surface with compressed air to remove the dust and/or water.

Construct a 2 ft x 4 ft concrete test block with a similar surface texture to the surfaces to be coated and coat a vertical face with the elastomeric coating system chosen. Determine the number of coats required to achieve a coating thickness between 30 to 45 mils without runs and drips. Mix and apply elastomeric coating as per manufacturer's current standard technical specifications. Spray or roller application is permitted. If requested by the IQF or the Engineer, have the coating manufacturer representative on site to supervise and comment on the application of the elastomeric coating onto the test block. Apply coatings using experienced personnel with a minimum of three years experience applying similar polyurethane systems. For tendons with exposed pour-backs, coat the exposed surfaces of pour-backs and block-outs and an area extending 12 inches outside the perimeter of the pour-backs and block-outs with an epoxy-urethane sealer. Provide a sealer which is on the Department's Qualified Products List for CMS 705.23.A. Prepare surfaces in accordance with CMS 512.03(F). Apply the epoxy-urethane sealer in accordance with CMS 512.03 except use a coverage rate of 120 square feet per gallon. Provide the name of the sealer and a copy of the manufacturer's technical data sheet and job specific surface preparation, mixing and application instructions to the IQF at least five (5) days before performing the work.

Surface Smoothness Requirements for Bridges and Approaches

Measure the highway surface smoothness in both wheel paths for each proposed travel lane using an operator and equipment certified according to Supplement 1058. The wheelpaths are located parallel to the centerline of the highway and approximately 3.0-ft inside all lane edges, measured transversely. The measured lanes are according to the interim condition of five lanes westbound traffic and not the bi-directional configuration. Measurement shall start approximately 250-ft before the approach slab/approach pavement interface at the entry end and continue to approximately 250-ft after the approach slab/approach pavement interface at the exit end. Ensure there is sufficient distance to get the profiler up to operating speed prior to initiating measurement. The bridge encounter will include 25-ft of approach pavement, entry approach slab, bridge deck, exit approach slab and 25-ft of exit pavement.

Notify the engineer a minimum of 24 hours prior to road profile measurements. The engineer will verify the smoothness measuring equipment conforms to Supplement 1058. Do not perform any measurements until all concrete surfaces have reached specified curing and loading requirements. Remove all dirt and debris from the surface of the travel lanes prior to performing the surface smoothness measurements. Provide temporary pavement markings for all travel lanes that are of sufficient size to be visible during profiling measurements. Ensure the path of the profiler is parallel to the lane edges at all times during data collection.

Provide the Engineer the International Roughness Index (IRI) using a continuous 25-ft base length analysis for each wheel path and a Mean IRI (MRI) for each travel lane. Provide both IRI and MRI results for the entire length of the bridge encounter in accordance with ASTM E 1926 and Supplement 1110. The MRI is the average of the IRI values for the right and left wheel tracks in each travel lane.

Corrective work is required for all localized areas of roughness with an IRI in excess of 300 inches per mile in any 25-ft interval along each wheel path of the bridge encounter. Corrective work is required for all travel lanes with an MRI in excess of 130 inches per mile along the entire length of the bridge encounter. If corrective work is required, develop a corrective work plan. Submit, to the Engineer: two copies of the corrective work plan (if required); all IRI and MRI analyses; and all collected road profile in ProVAL compatible format. The engineer will submit one copy of the corrective work plan (if required), all IRI and MRI analyses and all collected road profile data to the Office of Innovation, Partnerships, & Energy; Attn.: Infrastructure Management Section, 1980 W. Broad St., Columbus, OH 43223. Do not begin corrective work until receiving the Department's approval of the corrective work plan.

Remove temporary pavement markings when no longer required for testing.

Specifications for Structural Survey and Monitoring of Vibrations

.01 Description

This work consists of conducting a survey of the condition of property and structures adjacent to the project and the monitoring of ground vibrations caused by the project. The survey work is to be conducted before and after all construction work is performed which could cause undesirable ground vibrations. Ground vibrations and acoustics shall be monitored at the appropriate times during the duration of this project.

.02 Personnel Qualifications

A Professional Engineer, registered in the State of Ohio, shall be engaged by the DBT to be in charge of conducting a structural survey and in charge of monitoring vibrations and acoustics. The engineer in charge of performing the required work is herein referred to as the Monitoring Foreman. The Monitoring Foreman and/or his team of experts shall have collectively worked on two similar projects or shall have collectively accrued not less than two years of successful experience in performing the type of work specified by this note. The monitoring foreman and/or his team of experts shall have expertise in (1) conducting structural surveys by video methods, (2) monitoring vibrations with a seismograph or with other appropriate instrumentation, and (3) assessing sites for potential damage that may occur as a result of the proposed construction. Documentation of this experience shall be furnished at the preconstruction meeting.

The requirement for the Monitoring Foreman to be an engineer can be waived provided that the Monitoring Foreman's experience or the collective experience of the monitoring team shows substantial expertise in performing the required work.

.03 Structural Survey

The structural survey shall include but not be limited to the following:

Based on the DBT's proposed means and methods of demolition and construction, the monitoring foreman shall establish the limits of property and structures to be surveyed and the locations and elevations of reference points for documentation of measurements.

The structures may include, but not be limited to, residences, commercial properties, and railroad bridges/facilities located within and adjacent to the project.

Documentation of the integrity of existing building materials and the general overall condition of the property and structures recorded by written text, photographs, and VHS video cassette or digital recording.

Documentation of all structural deficiencies with regard to location, size, type, etc.

A detailed on-site inspection conducted in the presence of the IQF, property owners, property tenants, and representatives of any involved utility companies. If owners or occupants fail to allow access to the property for the pre-construction survey, send a certified letter to the owner or occupant. Make the notification effort and the certified letter part of the structural survey records.

.04 Monitoring of Vibrations and Acoustics

The monitoring of vibrations and acoustics shall include but not be limited to the following:

1. Determination and documentation of existing levels of vibrations and noise.
2. Monitoring of all construction operations that significantly contribute to the production of vibrations and noise with a special effort made to document the vibration and sound levels associated with blasting, demolition, and/or pile installation procedures.
3. The development of criteria for controlling construction activities so that the Monitoring Foreman's allowable predetermined vibration levels are not exceeded during construction.

.05 Ground Vibration

Vibration monitoring guidelines can be found in FHWA's May 1985 manual entitled "Rock Blasting" and in various other reports. The peak particle velocity (PPV) of ground vibrations is generally used to monitor the effect of vibrations on structures. When monitoring vibrations consideration must be given to (1) the type of structure being evaluated and (2) the frequency of the vibrations (low frequency 40 Hz). Generally allowable ground vibration peak particle velocities range from 13mm/second (0.5 inches per second) to 50mm/second (2.0 inches per second) depending on the type of structure under consideration. When an allowable PPV is exceeded, the vibration producing operation shall be suspended and alternative construction procedures should be evaluated. The IQF and the Engineer shall be notified whenever the measured magnitude of the vibration level is considered potentially capable of producing structural damage.