SECTION 705 -- PRECAST/PRESTRESSED CONCRETE STRUCTURAL UNITS

705.01 -- Description

1. This work consists of all labor, materials, and equipment required in the production of precast/prestressed structural units.

2. Contract plans shall be supplemented by Contractor-provided working drawings submitted in accordance with Subsection 105.02.

705.02 -- Material Requirements

1. The materials used shall meet the requirements prescribed in Table 705.01.

Table 705.01

Material Requirements	
Applicable Materials	**Section**
Concrete	1002
Admixtures	1007
Water	1005
Fine Aggregate	1033
Course Aggregate	1033
Fly Ash	1008
Spiral Reinforcing Wire	1023
Prestressed Steel Strand	1026
Post-Tensioning Assembly Steel	1025

2. Precast/prestressed concrete structural units whose compressive strength does not achieve design strength shall be rejected.

3. The concrete class used in the manufacture of precast/prestressed structural units shall be shown in the plans.

4. The Contractor is responsible for the concrete mix design and may use other concrete mixes which are proportioned in accordance with ACI Standard 318 and the following additional requirements:

a. The mix designs shall be submitted to the Engineer 4 weeks before beginning any concrete work.

b. Concrete shall consist of Type I, Type II, or Type III portland cement, aggregate, air-entraining admixture, and water. Concrete may also contain Class C or Class F fly ash and ASTM C 494 approved Type A, Type B, Type D, and Type F admixtures.

c. The minimum cement content shall be 335 kg/m^3.

d. Coarse aggregate shall have a minimum limestone content of 30 percent of the total aggregate by mass.

e. Fly ash cannot exceed 15 percent of cement by mass.

f. Data from at least 15 individual batches shall be collected and given to the Engineer. The data collected shall include the following:

(1) The 28-day compressive and flexural strength test results.

(2) The water/cement ratio.

(3) The air content (between 2.0 percent and 6.0 percent inclusive).

(4) The cement and fly ash content.

(5) The amount of fine aggregate, coarse aggregate, and sand and gravel.

5. Gradation requirements for fine and course aggregate may be waived by the NDR Materials and Tests Engineer.

6. No change shall be made in the concrete mix design during the progress of the work without the prior written permission of the Engineer.

7. Reinforcement shall be furnished, handled, stored, and placed in accordance with the requirements of Section 707.

8. Welding of reinforcing steel is prohibited unless specifically authorized by the Engineer.

9. Prestressed steel other than that specified in the plans or special provisions may be furnished with the approval of the Engineer. The yield and ultimate strength and other pertinent characteristics of this steel shall be submitted to the Engineer.

10. The area of broken wires shall not exceed 2 percent of the cross sectional area of the stressing strands when the number of strands is 14 or less.

11. The area of broken wire shall not exceed 1 percent of the cross sectional area of the stressing strands when the number of strands exceeds 14.

12. No more than 1 broken wire will be allowed in a single strand.

13. Bars for post-tensioning shall be of high tensile strength steel. They shall be equipped with wedge type end anchorages which will develop the minimum specified ultimate bar stress on the nominal bar area. The physical properties of the bar steel determined by static tensile tests shall conform to the requirements in Table 705.02.

Table 705.02

High Strength Steel Post-Tensioning Requirements	
Ultimate Stress	1000 MPa minimum
Stress at 0.7% Elongation	896 MPa minimum
Stress at 0.3% Elongation	517 MPa minimum
Elongation in 20 Diameters	4% minimum
Modulus of Elasticity	172 GPa minimum
Diameter Tolerance	Plus or Minus 2.54 mm

14. Materials specified for testing shall be furnished 30 days before the anticipated time of use. All materials required for testing shall be furnished by the Contractor to the Engineer without additional costs to the Department. The Engineer shall select a representative sample length for the various prestressed steel as follows:

a. Two meters for wires requiring heading.

b. For wires not requiring heading, sufficient length to make up one parallel-lay cable 2.0 m long consisting of the same number of wires as the cable to be furnished.

c. Two meters between near ends of fittings for a strand furnished with fittings.

d. Two meters between threads at the ends of bars furnished with threaded ends.

15. If the anchorage assemblies are not attached to prestress steel samples, 2 anchorage assemblies shall be furnished for testing, complete with distribution plates of each size or type of prestress steel to be used.

16. Any defective material shall be rejected.

17. Concrete quality control shall be the responsibility of the Contractor. Concrete shall be sampled and tested as shown in Table 705.03.

Table 705.03

Required Concrete Sampling and Testing		
Test	**Contractor Test Samples***	**Department Correlation Test Samples**
Yield ASTM C 138 Air meter measuring bowl.	One per day.	One per 10 Contractor tests.
Air content ASTM C 231 (.8% variation allowed)	One per load.	One every 5 production days.
Concrete temperature ASTM C 1064	One per load.	One every 5 production days.
Concrete Compressive Strength		
28-day strength ASTM C 31 Section 9.3 Cure	Two cylinders - each from a different load; and one from the last load.	One set of two cylinders every 5 production days.
56-day strength (Used only if 28-day strength is less than specified.) ASTM C 31 Section 9.3 Cure	Two cylinders - each from a different load and from same load as 28-day break.	NA
* At least 6 cylinders shall be made each production day and at least 2 cylinders are required from each load.		
* Cylinders shall be 150 mm by 300 mm.		

18. Plant Approval Requirements:

a. (1) All precast/prestressed concrete structural units shall be produced in a Precast/Prestressed Concrete Institute (PCI) certified plant.

(2) The method of manufacture and quality of concrete are also subject to Department approval/inspection.

b. A Contractor proposing to furnish precast/prestressed structural units shall submit the following additional details to the Department concerning the method of manufacture:

(1) Type, number, size, and location of the prestressing elements, and the name of the manufacturer of the post-tensioning or pretensioning elements.

(2) Complete information as to type, size, and method of installation of devices for anchoring post-tensioning elements.

(3) The proposed manufacturing methods and the plans and design details of proposed casting beds and forms.

c. The use of portable pretensioning beds for the manufacture of concrete structural units or piles will not be allowed.

705.03 -- Construction Methods

1. The Contractor shall construct precast structures and piles as shown in the plans.

2. The Contractor shall erect precast concrete structures and drive precast concrete piles as prescribed in the plans.

3. a. When the precast superstructure units have been erected, the Contractor shall pack the shear key openings with grout.

b. A pneumatic tool shall be used.

c. (1) Grout to be used for constructing shear keys in the precast concrete superstructure shall be composed of either Type I or Type II portland cement, aggregate, and water.

(2) The aggregate shall be fine aggregate as specified for the class of concrete being furnished.

(3) The portland cement and aggregate shall be proportioned on the basis of 350 kg of dry aggregate per 100 kg of cement.

(4) The water content of the grout shall be limited to that necessary for proper mixing and placement. In no case shall the total water content exceed 45 kg per 100 kg of cement.

4. No live load shall be allowed on the superstructure units until the shear keys and tie bolts have been placed and the shear key grout has cured.

5. The Contractor shall provide the Engineer a 4-week production schedule that is updated as necessary. If the Engineer is given less than 1 NDR work day's notice of a schedule change, then the fabricator may not proceed until the Engineer has reviewed the change. The Engineer may observe any or all of the procedures and shall have access to all reported data at any time during fabrication. The Engineer shall report any inconsistencies to the job superintendent and note them in the plant diary.

6. The concrete producer shall report the following information for each load of concrete used to fabricate girders:

a. Brand, mill, type, certified test number, and mass of cement.

b. Brand, mill, class, certified test number, and mass of fly ash.

c. Type, source, location, mass, and free moisture content for each aggregate. Aggregate moisture shall be determined according to NDR T 506 for each half day.

d. Source, type, name, and amount of each admixture.

e. Water added during batching and at placement site.

f. Time water and cement are initially mixed into the batch.

g. Time placement is completed.

7. a. (1) (i) In all methods of tensioning, the stress induced in the prestressing elements shall be measured by the Contractor both with jacking gauges and by elongation of the elements; and these results shall be the same within a 5 percent tolerance.

(ii) Means shall be provided for measuring the elongation of reinforcement to at least the nearest 3 mm.

(iii) All steel stressing devices, whether hydraulic jacks or screw jacks, shall be equipped with accurate reading calibrated pressure gauges, rings, or other devices as applicable to the jack being used.

(iv) All devices shall be calibrated and, if necessary, recalibrated so as to allow the stress in the prestressing steel to be computed at all times.

(v) A certified calibration curve shall accompany each device.

(vi) Safety measures must be taken by the Contractor to prevent accidents due to possible breaking of the prestressing steel or the slipping of the grips during the prestressing process.

(2) (i) Pressure gauges, load cells, dynamometers, and any other devices used in determination of loads and/or pressures shall be accurate in their effective range within a 2 percent tolerance.

(ii) Such equipment shall be calibrated by an approved testing laboratory.

(iii) The Contractor's laboratory shall furnish calibration curves for each device and shall certify the curves as being accurate and verifiable.

(iv) The calibration of tensioning devices shall be accomplished in place.

(v) The configuration of jacks, gauges, and other components during calibration shall be exactly the same as during the actual stressing operation.

(vi) The method of calibration shall be as approved by the Engineer.

(vii) Tensioning devices shall be calibrated at least once a year and at any time a system appears to be operating in an erratic or inaccurate manner or gauge pressure and elongation measurements fail to correlate.

(3) If the strand tension indicated by the gauge pressure and by elongation methods fail to agree within 5 percent, the operation shall be carefully checked and the source of error determined before proceeding further.

b. (1) The Contractor's elongation and jacking pressure measurements shall make appropriate allowance for friction and all possible slippage or relaxation of the anchorage.

(2) For pretensioned members, independent references shall be established adjacent to each anchorage by the Contractor to indicate any yielding or slippage that may occur between the time of initial stressing and final release of the cables.

(3) The Contractor may tension straight post-tensioned tendons from one end. Curved tendons shall generally be stressed by simultaneous jacking from both ends.

c. In all stressing operations, the Contractor shall keep stressing force symmetrical about the member's vertical axis.

8. Stressing Procedure:

a. Prestressing methods are shown in the plans. When the Contractor elects to use a method other than that shown in the plans, the Contractor shall submit complete shop plans for the proposed method.

b. Pretensioning Method:

(1) The amount of stress to be given each strand by the Contractor shall be as shown in the plans.

(2) All strands to be prestressed in a group shall be brought to a uniform initial tension before being given their full pretensioning. This uniform initial tension of approximately 4.5 to 9.0 kN shall be measured by a dynamometer or other approved means so that it can be used as a check against the computed and measured elongation.

(3) After initial tensioning, either single strand or multiple strand groups shall be stressed until the required elongation and jacking pressure are attained and reconciled within the 5 percent tolerance.

(4) With the strand stressed in accordance with the plan requirements and these *Specifications*, and with all other reinforcing in place, the Contractor shall cast the concrete to the lengths desired. Strand stress shall be maintained between anchorages until the concrete has reached the compressive strength specified in the plans.

c. Post-tensioning Method - For all post-tensioned elements, the Contractor shall set the anchor plates exactly normal in all directions to the axis of the bar or tensioning strand. Parallel wire anchorage cones shall be recessed within the beams. Tensioning shall not be done until the concrete has reached the compressive strength specified in the plans.

d. Combined Method - In the event that the girders are manufactured with part of the reinforcement pretensioned and part post-tensioned, the applicable portions of the requirements listed above shall apply to each type.

9. Forms:

a. Forms for precast/prestressed concrete structural units shall conform to the requirements for concrete formwork as provided in Subsection 704.03.

b. Forms shall be accessible for the vibration and consolidation of concrete.

10. Placing Concrete:

a. The Contractor shall provide the Department a 4-week production schedule that is updated as necessary. Unscheduled production changes may delay fabrication when the Department elects not to reschedule inspectors.

b. The Engineer may observe any or all of the procedures and shall have access to all reported data at any time during fabrication. The Engineer shall report any inconsistencies to the job superintendent and note them in the plant diary.

c. Concrete shall not be placed before completing the forming and placing of reinforcement.

d. (1) Concrete shall be placed continuously in each unit, taking care to avoid horizontal or diagonal planes of weakness.

(2) However, if there is a delay in delivery of concrete or for some other reason placement is interrupted for more than 30 minutes, then the concrete shall be rejected.

e. (1) Special care shall be exercised to work and consolidate the concrete around the reinforcement and to avoid the formation of stone pockets, honeycombs and other defects.

(2) The concrete shall be consolidated by vibrating or other means approved by the Engineer.

f. The forms shall be overfilled, the excess concrete screeded off, and the top surfaces finished to a uniform, even texture.

g. Each precast/prestressed concrete structural unit shall be stamped or marked with an identification number and its manufacture date.

h. (1) The optimum range of concrete temperatures from the time the concrete is completely mixed until the beginning of the presteam segment of the steam curing cycle shall be 10° to 35°C. Failure to operate within the optimum range shall be cause for curtailment of operations. During the presteam segment of the curing cycle, the temperature of the concrete shall not exceed 38°C nor fall below 10°C.

(2) When placing concrete under cold weather conditions (ambient air temperature less than 2°C), the cold weather specifications in Sections 1002 and 704 shall be followed.

(3) Forms and reinforcing materials shall be preheated to a minimum temperature of 5°C and a maximum temperature not to exceed that of the concrete at the time of placement.

(4) The Contractor may preheat the drums of the mixer-trucks to the limits set for forms and reinforcing, but under no condition shall heat be applied to the drums while they contain any of the batch materials or concrete.

11. Curing:

a. General:

(1) The Contractor shall cure the concrete with wet burlap, waterproof covers, polyethylene sheets, or liquid membrane-forming compounds. Curing with liquid membrane-forming compounds shall be accomplished in accordance with the requirements of Section 1012 and Subsection 704.03, except that liquid membrane-forming compounds shall not be used on that portion of precast/prestressed concrete girders, twin tees, or bridge beams upon which concrete will be cast later.

(2) Water spray curing or other moist curing methods may be used subject to the approval of the Engineer.

(3) The period of curing shall be determined by the results of the compressive strength test on cylinders made during the progress of the work and cured to closely approximate the concrete strength of the product it represents.

(4) Side forms may be removed 12 hours after placing the concrete, provided curing is continued with one of the approved NDR curing procedures.

b. Steam or radiant heat will be allowed for accelerated curing provided the following procedure is adhered to:

(1) Curing chambers shall be reasonably free of leakage and shall have a minimum clearance of 75 mm between the enclosure and restricting portions of the forms in order to insure adequate circulation of heat. The relative humidity within the curing enclosure shall be maintained between 70 and 100 percent.

(2) (i) One approved continuous recording thermometer for each 35 m of casting bed, with a minimum of 2 continuous recording thermometers, shall be located in each enclosure or curing chamber.

(ii) Continuous temperature record charts for each casting shall be available to the Engineer for examination and approval at any time.

(iii) If the temperature records or other temperature readings taken by the Engineer indicate that manual control of heat is producing temperature changes in excess of those specified, the Engineer may direct that automatic controls which can be activated by the recording thermometers or by separate temperature switches be installed. These automatic controls are to control the rate of temperature change and maximum curing temperature according to a preset plan.

(3) (i) Temperature of the curing concrete shall be 10°C to 30°C and shall be maintained near placement temperature until the concrete has reached initial set as determined by ASTM C 403 "Time of Setting of Concrete Mixture by Penetration Resistance".

(ii) The temperature rate of rise shall not exceed 30°C per hour.

(iii) The concrete shall be completely enclosed with a waterproof curing chamber during accelerated curing periods.

(4) Steam jets shall not be directed at the concrete or the steel forms.

(5) When the heat has been applied for a minimum of 3 hours and the desired concrete temperature has been reached (not to exceed 80°C) the heat source may be turned off. Should the temperature within the concrete rise above 80°C, the concrete shall be rejected.

(6) The temperature in the concrete shall be maintained so that at any given time the difference between the highest and lowest temperature station readings will not be more than 15°C. If the temperature varies more than 15°C, the product shall be rejected.

(7) Eight hours after placing the concrete, individual sections may be uncovered to remove their forms. The curing may be discontinued during this operation. The section shall not be left uncovered longer than necessary and never longer than 30 minutes. Waterproofed covers shall be used to recover the product.

(8) After the heat source has been turned off, the curing cover shall be maintained in place during the soaking period until the release strength has been reached.

(9) Detensioning shall be accomplished before the temperatures of the units drop below 40°C and while they are still moist.

(10) An automatic master slave heat curing system may be used for curing quality control cylinders.

c. Prior to detensioning prestressed concrete girders, they shall be inspected by the Engineer for cracking. If any cracks are discovered, the Contractor shall wet burlap cure the entire girder for 7 days immediately after detensioning. If cracks are discovered in the bottom flange, the girder shall be rejected.

12. Defects and Repair Procedures:

a. After the forms are removed, stone pockets, honeycombs, or other defects may be exposed. The Engineer shall determine if these defects affect the item's structural integrity and whether the item will be rejected.

b. Precast or prestressed concrete structural units which have chipped, spalled, honeycombed, or otherwise defective areas which are not considered detrimental to the structural integrity may be used after being repaired in the following manner:

(1) All unsound concrete shall be removed.

(2) The affected area shall be coated with epoxy resin binder meeting the requirements of Section 1018 for epoxy resin binder. Care shall be taken to prevent getting epoxy on the exposed surface.

(3) The formwork shall be placed and secured.

(4) The prepared areas shall be filled with Class 47B-35 concrete mix (Aggregate with a diameter larger than 10 mm is not allowed) using the type of cement in the unit. Where the unit is exposed to view, white cement shall be added to give a uniform appearance with the concrete surrounding the patch.

(5) The work shall be cured 24 hours with wet burlap. Steam curing at 25°C will be allowed.

(6) The patch shall be ground smooth to remove all joint seams.

(7) The units shall be finished as required in Subsection 704.03.

13. Surface Finish:

a. On structures serving as highway grade separations, the following shall apply:

(1) The exterior face of all exterior girders or beams plus the bottoms and chamfers on all lower flanges shall be given the following finish:

(i) All uneven form joints in excess of 3 mm shall be ground smooth.

(ii) The surface shall be steel brushed to remove scale, laitance, and to open partially obstructed holes.

(iii) The surface shall be dampened.

(iv) Grout shall be applied to the surface.

(v) The grout shall consist of 1.5 parts of fine sand, 1 part of portland cement, and sufficient water to produce a consistency of thick paint. The cement used in the grout shall be a blend of regular Type I and white portland cement to duplicate the lighter appearance of the steam cured units.

(vi) If necessary, an admixture which will not discolor the concrete may be used in the grout to reduce shrinkage if approved by the Engineer. Admixtures containing iron particles shall not be used.

(vii) The surface shall be float finished with a cork or other suitable float. This operation shall completely fill all holes and depressions on the surface.

(viii) When the grout is of such plasticity that it will not be pulled from holes or depressions, sponge rubber or burlap shall be used to remove all excess grout.

(ix) Surface finishing during cold weather shall not be performed unless the temperature is 5°C and rising. The surface shall be protected against temperature drops below 5°C for a period of 12 hours after finishing.

(x) A uniform appearance will be required. In the event the appearance produced by the above procedure is not uniform, both in texture and coloration, other methods approved by the Engineer shall be employed.

(2) The interior face of an exterior girder or beam and all interior girders or beams shall be finished from the lower flange to the fillet of the web in accordance with Paragraphs 13.a.(1)(iii), (iv), (v), (vi), and (vii) of this Subsection.

b. All other structures shall receive an Ordinary Finish as described in Subsection 704.03, Paragraph 17.b.

c. On bearing and sheet piles, the Ordinary Finish described in Subsection 704.03 will not be required except that all honeycombed areas shall be repaired after removal of all unsound concrete.

14. Grouting for Post-Tensioned Units:

a. The Contractor shall install steel in flexible or other approved tubes which shall be cast in the concrete and shall be pressure-grouted after the post-tensioning process has been completed.

b. Bonding grout shall be made to the consistency of thick paint and shall be mixed in the proportions as follows: portland cement (Type I), 45 kg; fly ash (ASTM C 618), 15 kg; water, 20 to 27 kg (adjust at site); and admixture (Interplast B), 0.5 kg.

c. The final grouting pressure shall be at least 550 kPa.

d. The Contractor shall make provisions to demonstrate to the Engineer that grouting material has completely filled all areas within the conduit.

15. The Contractor shall paint all exposed metal, except weathering grade steel, as prescribed in Section 709.

16. Handling, Transporting, and Storing:

a. (1) After precast structural units have attained a compressive strength of 20 MPa, the Engineer shall approve the method used to remove the units from the casting beds.

(2) Prestressed concrete structural units shall attain the "release" strength specified in the plans before being delivered to the site. Prestressed concrete structural units will not be incorporated in the final product until the minimum age and strength specified in the plans is attained.

(3) All precast/prestressed concrete structural units shall be supported at or within 150 mm of all lifting or bearing devices. When supported at the proper positions, no part of the units shall be allowed to rest on the ground. Prestressed concrete bridge girders shall be set on a level area to prevent field bowing, and adequate supports shall be placed under their lifting or bearing devices to prevent settlement into the ground.

(4) (i) The girders shall be transported in an upright position, and the points of support and direction of the reactions with respect to the girder shall be approximately the same during the transportation and storage as when the girder is in its final position. If the Contractor finds it necessary to transport or store the precast girders in some other position, the Contractor shall be prepared to prove no internal damage results.

(ii) Adequate padding shall be provided between tie chains and cables to prevent chipping of the concrete.

(iii) Live loads shall not be allowed on the superstructure units until the floor slab is placed and attains the design strength shown in the plans.

17. Inspection Facilities:

The Contractor shall arrange with the producer of precast/prestressed concrete structural units to provide an office, laboratory, and bathroom for the Department's inspector. The areas shall meet the following requirements:

a. Thermostatically controlled heating and air conditioning shall be provided so that temperature can be maintained between 20° and 25°C.

b. The floors shall be tile or a similar floor covering.

c. Interior and exterior walls shall be well maintained and painted.

d. All exterior doors shall have cylinder locks, and all keys shall be turned over to the Engineer.

e. Ceiling lighting shall provide a minimum of 5000 lx of light on all working surfaces.

f. Electrical outlets shall be spaced no more than 2 m apart with no less than 1 outlet on any wall of the office or lab.

g. A single trunk telephone shall be installed in the office, and the installation charges shall be paid by the Contractor. The monthly service charges shall be paid by the Department.

h. A fire extinguisher and first aid kit shall be provided.

i. A ventilated bathroom with a toilet and sink shall be provided in the structure. A fresh water supply and drain will be required in the lab area.

j. The lab, office, and bathroom shall be separate rooms with interconnecting doors.

k. The minimum lab area is 21 m^2.

l. The minimum toilet area is 2 m^2.

m. The minimum office area is 15 m^2.

n. The Contractor shall clean and maintain the rooms and shall supply all heating fuel, electricity, and water.

o. The Contractor shall also supply for the sole use of the inspectors all desks, work tables, chairs, files, lockers, and sanitary supplies necessary and commensurate with the inspection of his/her plant. It is anticipated that the following minimum amount of office and lab equipment will be required: One desk with approximately 1.0 m x 2.0 m top; one upright locker or wardrobe, with shelves, approximately 1.5 m deep; two 4-drawer file cabinets; 1 chair per inspector; 1 m^2 of work surface per inspector in the office area; and a 1.0 m x 6.0 m lab counter with storage space beneath.

705.04 -- Method of Measurement

1. Precast/prestressed concrete piles shall be measured in accordance with the requirements of Section 703.

2. Precast/prestressed concrete superstructures will be measured for payment by the lump sum.

705.05 -- Basis of Payment

1. Prestressed and/or precast concrete piles shall be measured and paid for as prescribed in Section 703.

2.

Pay Item	Pay Unit
Precast/Prestressed Concrete _____ Superstructure at Station _____*	Lump Sum (LS)

* Reinforcing steel, prestressing tendons, and all other components of the precast/prestressed concrete superstructure are subsidiary to this pay item.

3. The cost of furnishing and maintaining the inspection facilities will not be paid for directly, but shall be subsidiary to "Precast/Prestressed Concrete _____ Superstructure at Station _____".

4. If a precast or prestressed structural item's 56-day compressive strength is less than the design strength, then the Engineer will determine if the item can be used. If the item is to be used, a payment deduction of 25 percent will be taken if the 56-day compressive strength is less than 95 percent of the design strength.

5. All equipment calibrations and tests are subsidiary to "Precast/Prestressed Concrete _____ Superstructure at Station _____".

6. Payment is considered full compensation for all work prescribed in this Section, including the cost of prestressing and precasting.