Section 2407. Precast and Prestressed Concrete Bridge Units

2407.01 DESCRIPTION.

A. Provide prestressed and precast concrete bridge units produced in a plant for which equipment, procedures, and quality of concrete have been approved by the Contracting Authority.

B. Provide, or have the fabricator provide, technical personnel experienced and skilled in the application of the prestressing system being used. Ensure technical personnel cooperate fully with the Engineer in all technical aspects of the work.

C. Apply the provisions of this section to production and construction of precast concrete and prestressed concrete as defined in Section 1101.

D. Unless modified elsewhere in the contract documents, all fabrication is required to be done only in precast fabrication plants that are approved prior to the letting as per Materials I.M. 445.

2407.02 MATERIALS.

Use materials in prestressed and precast concrete meeting the requirements of Division 41 for the respective material, and the following:

A. Aggregates.

1. Apply Sections 4110 and 4115, except the gradation requirements of Articles 4110.02 and 4115.03. If high performance concrete (HPC) is being used for prestressed concrete beams, use a coarse aggregate consisting of crushed limestone meeting class 3 durability or better.

2. Submit aggregate gradations and proportions with the mix design to the District Materials Engineer for approval.

3. Use aggregates similar to Class V only when 30% or more of the total weight (mass) of aggregate is limestone.

B. Admixtures.
When authorized by the Engineer, approved admixtures complying with Section 4103 may be used.

C. Steel for Prestressing.
Apply Article 4151.05.

D. Reinforcement.
Apply Article 4151.03.

E. Steel Sole and Masonry Plates.
Apply Section 2508 and Articles 2408.03, B; 2408.03, E; and 4152.02.

F. Neoprene Bearing Pads.
Apply Article 4195.02.

G. Bolts and Other Metal Fastenings.

1. Unless indicated otherwise in the contract documents, use non-high-strength fasteners meeting requirements of Article 4153.06.

2. For other fastenings use structural steel meeting the requirements of Article 4152.02, except for anchors and ties for diaphragm connections and hold down devices for deflected tendons. These items will generally be proprietary products and will require the Engineer's approval. The Engineer will approve only those samples that show an ultimate strength of 50% in excess of the manufacturer's advertised safe loads. Use fastenings that are of a type to be cast in the concrete.

3. Use bolts, nuts, washers, and other metal fastenings that have been galvanized as specified for steel structures in Article 4100.07.

H. Cement.
Apply Section 4101. If the use of Type III Portland cement has been authorized, use it in the same proportions as specified for Type I Portland cement.

I. Supplementary Cementitious Materials.

1. Apply Section 4108.

2. Fly ash may be substituted for Portland cement. Use a substitution rate of no more than 15% by weight (mass).

3. GGBFS may substituted for Portland cement. Use a substitution rate of no more than 35% by weight (mass) for GGBFS as a mineral admixture.

2407.03 CONSTRUCTION.

A. Equipment.
Use equipment meeting the requirements of Section 2001 and the following:

1. **Casting Beds.**
   a. For precast concrete and prestressed concrete, use casting beds rigidly constructed and supported so that under the weight (mass) of the concrete and the vertical reactions of holdups and hold downs there will be no vertical deformation of the bed.
   b. For pretensioned work use end anchorages, whether self anchored or supported horizontally by the bed, capable of resisting the maximum prestress force to which they will be subjected without permanent displacement.

2. **Forms.**
   a. Use forms for precast and prestressed concrete true to the dimensions as shown in the contract documents, true to line, mortar tight, and of sufficient rigidity to not sag or bulge out of shape under placement and vibration of concrete. Ensure inside surfaces are smooth and free of any projections, indentations, or offsets that might restrict differential movements of forms and concrete.
   b. On long beds for multiple pretensioned beam production where continuous forms and pallets are used, take necessary precautions to prevent damage to the beams from differential movements of forms and concrete due to temperature changes.

3. **Stressing Equipment.**
   a. To tension tendons, use equipment of a type so the prestressing force may be accurately known. Use load cells, dynamometers, and hydraulic gages of hydraulic pump and jacking systems capable of measuring the force applied to the tendons within 2% of the actual force. Calibrate this equipment at least once every 12 months or anytime the tensioning system indicates erratic results. Calibrate hydraulic gages, pumps, hoses and connections as a system.
   b. Perform all tensioning equipment calibrations using load cells calibrated by a testing laboratory or calibration service. For calibration purposes use equipment that has current calibration references. Allow the Engineer the opportunity to witness calibration of equipment during the Engineer's normal working hours or at a mutual agreeable time.

4. **Weighing and Proportioning Equipment.**
   Apply Article 2001.20, except that a vibrator will not be required on the cement batch hopper.

5. **Mixing Equipment.**
   Apply Article 2001.21.

6. **Bins.**
   Apply Article 2001.06.

B. Concrete.

1. For precast and prestressed construction, use at least than 610 pounds (360 kg) of total cementitious material per cubic yard (cubic meter) of concrete. Do not exceed the maximum

water-cementitious ratio, including free moisture in the aggregate, of 0.450 pound per pound (0.450 kg/kg).

2. If the units will form curbs or floors of structures, add an approved air-entraining admixture. The intended air entrainment of the finished concrete is 6%. To allow for loss during placement, use a target value of 6.5% for the air content of fresh unvibrated concrete, with a maximum variation of ± 1.0%.

3. Properly proportion, mix, place, and cure concrete within these limits to produce concrete of a minimum compressive strength specified in Table 2407.03-1 at the designated age.

4.

Table 2407.03-1: Concrete Strength

Classification	Concrete Strength Before Moving or Prestressing, psi (MPa)	Concrete Strength at Age 28 calendar days, psi (MPa)
Precast Sheet or Bearing Piles	3500 (24)	4500 (31)
Precast Bridge Deck Units	3500 (24)	5000 (35)
Prestressed Piles	4000 (28)	5000 (35)
Prestressed Deck Panels	4000 (28)	5000 (35)
All Other Prestressed Concrete[(a)]	4500 (31)	5000 (35)

[(a)] Unless noted otherwise in the contract documents.

NOTE: Do not ship beams until the concrete has attained the 28 day strength.

4. If using HPC for prestressed concrete beams, apply the following additional specifications:

a. The Contractor may submit up to two trial batches of concrete per project at no cost. The Contractor will be charged $500 for each additional trial batch submittal or resubmittal. Submit trial batch concrete that is of a size and mix typically used in day-to-day operations and is made at least 60 calendar days prior to placement. Ensure the trial batch concrete design produces a slump within ± 4 inches (100 mm) of placement slump.

b. The District Materials Engineer may waive trial batch testing for a mix, provided the mix was previously tested and resulted in satisfactory mix properties. Adjustments to a previously approved mix, not requiring a new trial batch, will be at the discretion of the District Materials Engineer.

c. Notify the District Materials Engineer, Plant Inspector, and Materials Structural Engineer at least 7 calendar days prior to batching. Ensure the Plant Inspector casts all samples from the trial batch concrete.

d. The Contracting Authority will test trial batch concrete permeability. Two permeability samples will be cast in 4 inch by 8 inch (100 mm by 200 mm) plastic cylinder molds and capped. Within 5 calendar days of casting, the samples will be delivered to the Central Materials Testing Laboratory. The samples will remain in their plastic molds with lids until delivered. The samples will be stripped of their molds and wet cured to an age of 7 days in the moist room. After 7 days, the samples will be submerged in water heated to 100°F (37.7°C) until an age of 28 days or more. Two test specimens will be obtained from each cylinder. Permeability will be tested in accordance with AASHTO T277 at 28 days or more. A coulomb reading of 2500 or less, based on the average of four test results, is considered acceptable.

e. Trial batch materials, proportions, and test results will be reported to the District Materials Engineer for approval.

C. Proportioning, Mixing, and Placing Concrete.

1. Proportion and mix concrete according to the applicable requirements of Article 2403.02, D, 3.

2. Do not place concrete when the ambient temperature is below 35°F (2°C) unless the Engineer has approved the plant for cold weather concrete placement. When necessary, heat the aggregate or water, or both, so that the temperature of concrete when deposited in the forms is 40°F to 90°F (4°C to 32°C). Do not use frozen material in concrete.

3. When a series of units is cast in a line, cast the entire series in one continuous operation, or as directed by the Engineer. Place successive batches before the preceding batch has perceptibly hardened or dried. Do not allow more than 45 minutes to pass between the placement of successive batches of concrete in a unit. Do not retemper the concrete or add water to the interface of the concrete between batches.

4. Carefully work and consolidate concrete around reinforcement without displacing it. Ensure the formation of honeycomb, stone pockets, or similar defects has not occured. Consolidate the concrete using small diameter vibrators or by other means the Engineer approves. Overfill the forms during consolidation. Screed off excess concrete and finish the surface to the desired texture.

5. On specific request and approval, provisions may be made for inserts in beams as an aid to stripping floor forms. Complete this according to the conditions of such approval.

D. Curing.

1. Use a method of curing that prevents loss of moisture and maintains an internal concrete temperature at least 40°F (4°C) during the curing period. Obtain the Engineer's approval for this method.

2. When using accelerated heat curing, do so under a suitable enclosure. Use equipment and procedures that will ensure uniform control and distribution of heat and prevent local overheating. Ensure the curing process is under the direct supervision and control of competent operators.

3. When accelerated heat is used to obtain temperatures above 100°F (38°C):
   - **a.** Record the temperature of the interior of the concrete using a system capable of automatically producing a temperature record at intervals of no more than 15 minutes during the entire curing period.
   - **b.** Space the systems at a minimum of one location per 100 feet (30 m) of length per unit or fraction thereof, with a maximum of three locations along each line of units being cured.
   - **c.** Ensure all units, when calibrated individually, are accurate within ± 5°F (3°C).
   - **d.** Do not artificially raise the temperature of the concrete above 100°F (38°C) for a minimum of 2 hours after the units have been cast. After the 2 hour period, the temperature of the concrete may be raised to a maximum temperature of 160°F (71°C) at a rate not to exceed 25°F (15°C) per hour.
   - **e.** Hold the maximum temperature for a period sufficient to develop the strength required for release of prestress or for post tensioning, as the case may be.
   - **f.** Lower the temperature of the concrete at a rate not to exceed 40°F (22°C) per hour by reducing the amount of heat applied until the interior of the concrete has reached the temperature of the surrounding air.

4. In all cases, cover the concrete and leave covered until curing is completed. Side forms and pans forming the underside of channel shapes may be removed during this period if the cover is immediately replaced. Do not, under any circumstances, remove units from the casting bed until the strength requirements are met.

5. For pretensioned beams, maintain the temperature of the beams and exposed strands at normal curing temperature until the stress has been released from the end anchorages.

E. Placing Reinforcement.

1. Place all reinforcement carefully and accurately and secure in the proper position according to the contract documents. Apply Article 2404.03.

2. Only welders qualified according to Article 2408.03, B, may perform welding if it is employed in placement of reinforcing steel, or the interconnection of plate connectors, sole plates, or masonry plates. Apply Article 2408.03, B, to the period of effectiveness for all welders. For tack welding reinforcing bars, follow all other requirements as outlined in the latest edition of AWS D1.4, including Table 5.2, Minimum Preheat and Interpass Temperature, except do not allow the minimum preheat and interpass temperature to drop below 50°F (10°C). Ensure the

minimum preheat and interpass temperatures for structural steel remain as in Article 2408.03, B.

3. Protect prestressing tendons from heat and weld spatter. Tack welding of reinforcing steel at noncritical stress areas in combination with sacrificial reinforcing bars, if required, will be allowed without regard to preheat and interpass temperature restrictions. Obtain the Engineer's approval for any such modification.

F. Removal of Forms.

If forms are removed before the concrete has attained the strength which will permit the units to be moved or stressed, remove protection only from the immediate section from which forms are being removed. Immediately replace the protection and resume curing after the forms are removed. Do not remove protection any time before the units attain the specified compressive strength when the surrounding air temperature is below 20°F (-7°C).

G. Prestressing Steel Stresses.

1. Position the number and size of individual tendons (7wire strand) according to the contract documents. Prestress to the force shown in the contract documents.

2. If anchored at other than 70°F (20°C), adjust the initial prestressing force as shown in Table 2407.03-2:

Table 2407.03-2: Initial Prestressing Force

Temperature of Strands	Initial Prestressing Force
70°F (20°C)	As shown in the contract documents
Below 70°F (20°C)	Increase 1.0% per 10°F (5°C)
Above 70°F (20°C)	Decrease 1.0% per 10°F (5°C)

3. After tendons have been positioned, apply an initial force between 1000 and 4500 pounds (4.5 kN and 20 kN) to each tendon. Measure the initial force within a tolerance of:
   - ± 100 pounds (0.5 kN) for initial forces under 3000 pounds (13 kN), and
   - ± 200 pounds (1 kN) for initial forces of 3000 pounds (13 kN) or more.

4. The theoretical elongation of the tendons is calculated from material properties furnished by the manufacturer and allowable losses. Allowable losses may include seating losses, bed shortening, abutment movement, and temperature adjustments.

5. Measure the pretensioning by the net elongation of the tendons. Consider the calculated theoretical net elongation to be the target. A tolerance of ±1/2 inch (13 mm) from the calculated net elongation, after seating, may be allowed.

6. Conduct the tensioning procedure so the indicated stress, measured by the tensioning system, is within 5% of the calculated stress, based upon the corresponding elongation. Verify the distribution of the stress is within 5% of the calculated stress at all points along the tendon or when measured at the end of the bed.

7. Temporary overstressing of the tendons is allowed; however, at no time exceed 80% of the specified tensile strength of the tendons. Do not seat tendons in this overstress condition.

8. Tension tendons between fixed end anchorages by means of jacks either separately or in a group. Several units may be cast in one continuous line. In this case tension them simultaneously.

9. Deflected tendons may be tensioned in place. Alternatively, deflected tendons may be partially tensioned and then raised to the predetermined final position at the beam ends, achieving the required prestressing force. Tendons may be raised simultaneously to the predetermined final position or at any one point, in a single lift, provided the sequence of lifting commences at the point nearest the center of the bed and then progresses alternately at points equidistant from the center to the ends.

10. Support tendons at each deflection point on a freely rotating metal pulley no less than 3/4 inch (19 mm) in diameter.

11. Limit the number of broken strand wires to no more than 2% of the total number of strand wires or no more than one broken wire of any one strand.

H. Prestress Transfer.

1. When accelerated heat curing is used, perform prestress transfer immediately after the curing period is completed and while the concrete is warm and moist.

2. Deflected tendons, if any, are to be released first either by:
- Lowering holdup devices at beam ends as nearly simultaneously as practical, or if this is not feasible,
- Flame cutting deflected tendons in each beam interval in rotation until all deflected tendons are released. Obtain the Engineer's approval for the procedure used to flame cut deflected tendons.

3. Next, release the hold down devices and simultaneously and gradually release the straight line tendons using the jack. If this is not feasible, heat the tendons as follows:
- **a.** For each tendon, simultaneously heat a minimum of two locations along the casting bed.
- **b.** Apply heat along the tendon over a minimum 5 inch (125 mm) distance.
- **c.** Control heat application so that failure of the first wire in the tendon does not occur for at least 5 seconds after heat is applied, followed by gradual elongation and failure of the remaining wires. Heat the tendon until failure occurs at each beam interval before proceeding to the next tendon.
- **d.** Sequence prestress transfer between individual tendons so that there is minimum eccentricity of prestress load.
- **e.** Alternate procedures for releasing deflected or straight line tendons may be submitted for the Engineer's approval.

4. Measure the camber due to prestress while the beam is on the bed by checking the beam profile within three hours after prestress transfer.

I. Post Tensioned Prestressed Concrete.
When post tensioned construction is designated, detailed procedures will be included in the contract documents.

J. Tolerances.
Apply the following tolerances for precast and prestressed units:

1. Precast Nonprestressed Units.
- **a.** Limit variation from dimensions shown in the contract documents to no more than 1/8 inch (3 mm). For overruns, greater deviation may be accepted if, in the Engineer's opinion, it does not impair the suitability of the member for its intended use.
- **b.** Ensure beam seat bearing areas at each end of the unit are flat and true and perpendicular transversely to the vertical axis of the beam.
- **c.** Limit the difference of cambers between two adjacent units, as assembled, to no more than 1/8 inch (3 mm).

2. Precast Prestressed Units.
Limit variation from dimensions shown in the contract documents to the tolerances shown in Table 2407.03-3:

Table 2407.03-3: Tolerances

Length	±1/4" per 25' and ±1" max. for beams 100' or longer (±6 mm per 8 m and ±25 mm max. for beams 30 m or longer)
Width (flanges and fillets)	+3/8" or -1/4" (+10 mm or -6 mm)
Depth (overall)	+1/2" or -1/4" (+13 mm or -6 mm)
Width (web)	+3/8" or -1/4" (+10 mm or -6 mm)
Depth (flanges and fillets)	±1/4" (±6 mm)

Bearing plates (ctr. to ctr.)	1/8” per 10’ of beam length, max. ±3/4” (1 mm per 1 m of beam length, max. ±20 mm)
Sweep (deviations from straight line parallel to center line of member)	L/80 (L in feet, sweep is in inches) L(L in meters, sweep is in millimeters)
Camber deviation from design camber	±30% of plan camber
Stirrup bars (project above top of beam)	+1/4” or -3/4” (+6 mm or -20 mm)
Individual tendon position	
Straight strands	±1/4” (±6 mm)
Draped strands at end of beam	±1/2” (±13 mm)
Tendon position	
Center of gravity of strand group	±1/4” (±6 mm)
Center of gravity of depressed strand group at end of beam	±1” (±25 mm)
Deviation from net theoretical elongation after final seating	± 1/2 inch (13 mm)
Position of deflection points for deflected strands	5% of beam span toward end of beam
Position of handling devices	±6” (±150 mm)
Bearing plates (ctr. to end of beam)	±3/8” (±10 mm)
Side inserts (ctr. to ctr and ctr. to end)	±1/2” (±13 mm)
Exposed beam ends (deviation from square or designated skew)	
Horizontal	±1/4” (±6 mm)
Vertical	±1/8” per foot of beam depth (±10 mm per 1 m)
Bearing area deviation from plane	±1/16” (±2 mm)
Stirrup bars (longitudinal spacing)	±1” (±25 mm)
Position of post tensioning duct	±1/4” (±6 mm)
Position of weld plates	±1” (±25 mm)
Elongation (standard gauge length to be a minimum of 20 feet (6 m))	±5% (±5%)

K. Handling and Storage.

1. When lifting and handling precast or prestressed units, support them at or near the points designated in the contract documents. Do not allow the overhang to exceed 5% of the length of the beam, unless specified otherwise in the contract documents.

2. Do not lift or strain units in any way before they have developed the strength specified. In storage, support units at points adjacent to the bearings.

3. Support piles near the one-fifth points measured from the ends. In stacking units for storage, arrange the bearings one directly above another.

4. Legibly mark piles with the casting date in fresh concrete near the head of the pile, using numerals only.

5. During fabrication, storage, handling, and hauling take care to prevent cracking, twisting, unnecessary roughness, or other damage. In particular, do not allow tiedowns to come in direct contact with concrete surfaces. Do not subject units to excessive impact. Replace at no additional cost to the Contracting Authority units that are, in the Engineer’s opinion, damaged in a way to impair their strength or suitability for their intended use.

L. Finish.

1. Finish all surfaces which will be exposed in the finished structure as provided in Article 2403.03, P, 2, b, and ensure they are free of honeycomb or surface defects. Submit Structural Repair procedures to the Engineer for approval.

2. Finish the outer surface of exterior beams as follows:
   - **a.** As soon as practical after removal of the forms, remove all fins and other surface projections.
   - **b.** Brush or spray a prepared grout onto the prewetted surface. Use a grout consisting of one part of silica sand and one part of Portland cement blended with acrylic bonding agent and water to produce a consistency sufficient to fill the cavities. The Engineer may require white Portland cement to be used in amounts necessary to obtain a uniform finish.
   - **c.** Immediately after applying the grout, float finish the surface with a cork or other suitable float. Ensure this operation completely fills all holes and depressions on the surface.
   - **d.** When the grout is of such plasticity that it will not be pulled from holes or depressions, use a sponge rubber float to remove all excess grout.
   - **e.** When the surface is thoroughly dry, rub it vigorously with dry burlap to completely remove excess dried grout.
   - **f.** Cure the surface finish in a manner satisfactory to the Engineer. Heat curing may be required in cold weather.
   - **g.** Ensure, when finished, the surface is free from stains and has a uniform color.

3. Cut and bend tendon projections as detailed in the contract documents. Cut the tendon off flush with the concrete where the tendon end will be exposed in the complete structure. Clean the end of each cut off tendon to a bright appearance.

4. Coat and seal beam ends exposed in the complete structure with an approved gray or clear epoxy listed in Materials I.M. 491.12, Appendix A. Coat and seal beam ends as indicated on the plans. Apply the epoxy coating and beam end sealing at the fabricating plant.

2407.04 METHOD OF MEASUREMENT.

A. For precast or prestressed structural units, the Engineer will determine the number of units of each of the various respective sizes, lengths, and types from actual count. Measurement of precast sheet piles or precast or prestressed bearing piles will be according to Article 2501.04.

B. For cast-in-place prestressed concrete, measurement for concrete, reinforcing steel, and structural steel will be according to Article 2403.04 for structural concrete, and the prestressing will be a lump sum item.

2407.05 BASIS OF PAYMENT.

A. Payment will be the contract unit price for the number of approved precast or prestressed structural units of each size and length incorporated in the project.

B. Payment is full compensation for:
- Producing and furnishing the units complete as shown in the contract documents, with all plates, pads, bolts, grout enclosures, reinforcing steel, prestressing material, coil rods, hold down devices, and any other items to be cast in the concrete,
- Transporting units to the site and placing them in the structure,
- Furnishing and installing bearing plates and anchor bolts or neoprene pads when specified in the contract documents.

C. Payment for furnishing precast sheet piles or precast or prestressed bearing piles will be as provided in Article 2501.05.

D. Payment for cast-in-place prestressed concrete will be according to Article 2403.05. The prestressing will be paid for as a lump sum item. The lump sum amount is full payment for furnishing and placing the required material and stressing, anchoring, and grouting the prestressing steel according to the contract documents.