Payment for each item includes all direct and indirect costs and expenses required to complete the work.

Payment will be made under:

Item No.	**Pay Item**	**Pay Unit**
7031100	Reinforcing Steel for Structures (Roadway)	Pound
7031105	Reinforcing Steel for Structures (Retaining Wall)	Pound
7031200	Reinforcing Steel for Structures (Bridge)	Pound
7031210	Spiral Reinforcing Steel for Structures (Bridge)	Pound
7031400	Galvanized Reinforcing Steel for Structures (Bridge)	Pound

SECTION 704

PRESTRESSED CONCRETE

704.01 Description. This work shall consist of the manufacture, handling, and installation of precast, prestressed concrete beams, slabs, channels and other prestressed concrete members in structures. The manufacture and handling of precast prestressed concrete piles is also a part of this section. The work shall be in accordance with the plans, Sections **701**, **702**, **703**, **709**, **712**, and other sections that are pertinent to such prestressed members, except that this section shall govern where at variance from the other section or sections. Prestressing shall be of the pretensioning or post-tensioning type, or a combination of two methods, as required by the plans and special provisions.

704.02 Concrete. Unless otherwise specified on the plans or special provisions, concrete for prestressed concrete members shall be Class 5000, and shall attain a minimum 28-day cylinder compressive strength of 5000 psi. All concrete shall conform to the provisions of Section **701**, except for the following modification:

Slag material will not be permitted as a coarse aggregate. Type I, Type II, or Type III cement, an approved admixture to secure high-early-strength, an approved admixture to secure a retardation in the initial set of concrete, or an approved air-entraining admixture to secure more workability may be used at the Contractor's option. Where an air-entraining admixture is used, the proportions of ingredients shall be adjusted to produce 27 cubic feet per cubic yard.

704.03 Prestressing Steel. Prestressing steel shall be high-tensile-strength steel wire, high-tensile-strength seven-wire strand, or high tensile-strength alloy bars as called for on the plans or in the special provisions. All wire, strand or bars shall be assigned a lot number and tagged for identification purposes before shipment. Anchorage assemblies to be shipped shall be likewise identified. Reels of prestressing strands stored on the prestressed plant yard and intended for the Department's use shall be stored off the ground and protected from the weather by means of a building or other approved cover.

Prestressing steel shall meet the requirements of the following:

A. High-Tensile Strength Steel Wire. High tensile-strength wire shall conform to the requirements of AASHTO M 204 (ASTM A 421), latest edition.

B. High-Tensile Strength Seven-Wire Strand. High-tensile-strength seven-wire strand shall conform to the re-

quirements of AASHTO M 203 (ASTM A 416), latest edition.

C. High-Tensile Strength Alloy Bars. High-tensile-strength alloy bars shall conform to the requirements of AASHTO M 275 (ASTM A 722), latest edition.

704.04 Anchorage Devices. The end fitting anchorage for post-tensioning steel wire cables shall be wedge type anchorage cone approved by the Engineer. The wedge type anchorage cones shall be strong enough to develop at least 95% of the total specified ultimate strength of the tendons. The anchorage cones shall bear against embedded grids of reinforcing steel of approved type. The wedge type anchorage device for alloy bar post-tensioning shall be of sufficient strength to develop the minimum ultimate stress specified for the nominal bar diameter; and the anchorage plates shall be fabricated of hot rolled steel having physical characteristics not less than that specified for AASHTO M 270 (ASTM A 709), Grade 36, latest edition.

704.05 Testing Prestressing Steel and Anchorages. Testing of prestressing steel will be arranged for by the Department without cost to the Contractor. The manufacturer shall supply the Department with typical curves obtained from mill tests of the material furnished for use in checking stresses by means of observed elongation. In addition, the manufacturer of the strand shall furnish affidavits certifying as to the required properties. Where the Engineer intends to require nondestructive testing of one or more parts of the structure, special specifications will specify the required details of the work.

All of the materials specified for testing shall be furnished without cost to the Department and shall be delivered in time for tests to be made well in advance of anticipated time of use. All samples submitted shall be representative of the lot to be furnished and in the case of wire or strand, shall be taken from the same master roll.

The following described samples shall be selected from each lot of material by the Department's inspector:

A. Pretensioning Method. For pretensioning strands, samples consisting of two pieces, one at least 40 inches and one approximately 12 inches long, shall be furnished for each shipment, each strand size, and each heat number, per five reels or part thereof, of regular or high strength strand.

B. Post-Tensioning Method. The following lengths shall be furnished:

1. For wires requiring heading: 5 feet.

2. For wires not requiring heading:
   Sufficient length to make up one parallel-lay cable 5 feet long consisting of the same number of wires as the cable to be furnished.

3. For strand to be furnished with fittings:
   5 feet between near ends of fittings.

4. For bars to be furnished with wedge anchors:
   5 feet between faces of anchor plates.

C. Anchorage Assemblies. Two anchorage assemblies shall be furnished complete with distribution plates of each size or type to be used if anchorage assemblies are not attached to prestressed steel samples.

704.06 Steel Reinforcement. Steel reinforcement that is not prestressed, shall conform to the requirements of Section **703**.

704.07 Post-Tensioning Grout. The grout shall consist of a commercial premix approved by the Engineer or a mixture of cement, water and sand in the proportions of one bag of cement to 50 pounds of sand (all passing the No. 30 sieve) to

about 5 1/2 gallons of water. The water may be varied so that the grout shall be of the consistency of thick paint. The sand may be omitted if desired, but care shall be taken to secure the consistency stated above. The grout shall be mixed in a mechanical mixer for at least two minutes and shall be kept constantly agitated.

EQUIPMENT

704.08 Jacks. The Contractor or fabricator shall provide all equipment necessary for the construction and the prestressing. Prestressing shall be done with approved jacking equipment. If hydraulic jacks are used, they shall be equipped with accurate pressure gauges. The combination of jack and gauge shall be calibrated and a graph or table showing the calibration shall be furnished the Engineer. The calibration shall be rechecked at least once each year. Should other types of jacks be used, calibrated proving rings or other devices shall be furnished so that the jacking forces may be accurately known.

CONSTRUCTION REQUIREMENTS

704.09 General. All fabrication of prestressed concrete members in structures shall be performed by a fabricator certified in accordance with the Prestressed Concrete Institute (PCI) Plant Certification Program for the category of work to be done. The Contractor or prestressed concrete fabricator shall have a PCI certified technician at the plant at times to supervise all work done on prestressed concrete members for SCDOT projects. This technician shall insure that all prestressing operations are performed properly and shall assist the Engineer in making tests and measurements that may be necessary.

A permanent beam identification marking showing name or symbol of manufacturer, date cast, a number identifying the beam in the structure and file number shall be placed in permanent paint on each beam at a location that is readily

accessible and that will not be covered by diaphragms, etc. Where orientation of the direction of the beam in the span is necessary, this information shall be painted clearly with appropriate arrows to show the proper erection of beam. Information, as described above, shall be placed on piles in an area that will not be covered by the cap.

704.10 Shop Plans. Before commencing fabrication, the Contractor shall submit for review by the Engineer seven sets of the complete shop plans sealed by a South Carolina registered Professional Engineer, showing details covering the plant, forms, equipment and method proposed to be used, including pickup devices, and tensioning and de-tensioning procedure in detail for manufacturing the precast, prestressed concrete members. These drawings shall also include strand elongation computations, procedure and sequence of jacking and release of the deflected strands and description of the devices that hold up or down the deflected strands, complete post-tensioning details and other methods or procedures that may be desired by the Engineer in order to fully describe the fabrication of the prestressed members.

Shop plans shall be prepared and submitted in accordance with Subsection **725.02**.

After a central prestressing plant has established a satisfactory operating routine, the Department may waive some or all of the requirements for working drawings on standard prestressed members.

704.11 Forms. Forms for continual reuse shall be of steel. All forms shall have smooth joints so that the surfaces of the concrete members shall be free of fins and shall be well braced to maintain true shape and dimension. Forms ties, if used, shall be of the snap-off or threaded type so that no tie metal will remain closer than 3/4 inch from the surface of the concrete. The bottom corners of the beams shall be formed with 3/4-inch x 3/4-inch (45 degree) chamfer whether or not the same is shown on the plans. The holes for diaphragm tie bars shall be carefully and accurately located. Where voids

are formed in a prestressed member, a positive means shall be used to hold the voiding device accurately in position. All forms must be approved by the Engineer before casting any concrete. If at any time during the course of construction any form becomes damaged or deformed so that it will not produce members of the proper dimensions, it shall be repaired or replaced.

The finished prestressed girder must meet the tolerances shown on the *Standard Beam Details* sheet included in the plans.

704.12 Concrete Work.

A. Placing Concrete. Concrete shall not be deposited in the forms until the Engineer has inspected the placing of the reinforcement conduits, anchorages and prestressing steel; and has given his approval thereof. The concrete shall be vibrated internally and/or externally. The vibration shall be done with care and in such a manner as to avoid displacement of reinforcing, conduits, or wires.

B. Finishing Concrete. Irregularities in the surface of the beams shall not be corrected without the prior approval of the Engineer. Excessive surface defects may be cause for rejection of a member. Except for the outside faces of exterior beams, all surface air and water holes greater than 1/4 inch shall be filled with mortar and the entire surface shall be smooth and free from irregularities. The outside faces of exterior beams shall be given the surface finish as set forth in Section **702**.

The top surfaces of beams against which cast-in-place concrete will be placed later shall be rough floated with a wooden float to bring grout to the surface and cover all aggregate. At this time, the top surface shall be intentionally roughened to a full amplitude of approximately 1/4 inch.

C. Concrete Curing. Curing may be by the moist curing

method or accelerated curing with low pressure steam or radiant heat. All wet mats and covers shall be approved by the Engineer.

1. Moist Curing Method. Under normal curing temperatures the following shall apply:

As soon as possible after the units have been cast, they shall be covered with mats that shall be kept wet until the side forms are removed. After the side forms are removed, the units shall be protected with wet mats and a vapor proof cover until they have attained the strength requirements for detensioning.

In case it is necessary to remove the protective covering to point up honeycomb areas or to give the units a surface finish, the surfaces of the units shall be kept moist during the entire time that the units are uncovered. During the curing period, the concrete shall not be exposed to temperatures below freezing.

2. Accelerated Curing with Low Pressure Steam or Radiant Heat. Low pressure steam curing or radiant heat curing shall be done under a suitable enclosure to contain the live steam or the heat. The enclosure shall cover the units as soon as possible after the concrete has been finished. The concrete shall be allowed to attain its initial set before application of the steam or the heat. The minimum time of application of the steam or the heat shall be two hours (four hours if retarders are used) after the final placement of concrete to allow the initial set of the concrete to take place. The time of initial set may be determined by the Method of Test for Time of Setting of Concrete Mixtures by Penetration Resistance, AASHTO T 197, and the time limits described above may then be waived. During the waiting period, in cold weather, the temperature within the curing chamber may be main-

tained between 50°F and 80°F with live steam or radiant heat.

To avoid localized high temperatures, the application of steam shall not be directed on the concrete forms.

Radiant heat may be applied by means of pipes circulating steam, hot oil, or hot water, or by electric hearing elements. Moisture loss shall be minimized by covering all exposed concrete surfaces with wet mats.

During the application of live steam or radiant heat, the ambient temperature within the curing enclosure shall increase at a rate not exceeding 40°F per hour until the desired curing temperature is reached. The average curing temperature within the enclosure shall not exceed 160°F. The curing temperature at any single point shall not vary more than 10°F from the selected average curing temperature and shall not exceed 170°F maximum.

Recording thermometers shall be provided at the one-third and two-thirds points of the bed to verify the curing period and the curing temperature from the time of final placement of concrete to the time of cover removal. The covers shall be removed in a manner to avoid rapid temperature changes in the concrete.

D. Detensioning Prestressed Units. Units may be detensioned as soon as they have attained the required initial minimum compressive strength. If the units have been cured by accelerated curing methods, they shall be detensioned as soon as possible after the required initial minimum compressive strength of the concrete has been reached and while the concrete is still warm. Additional curing will not be required after detensioning.

E. Inspection and Testing. The Engineer or his representative shall have free access to the fabrication plant at

all times for the purpose of inspecting materials, plant facilities and fabrication and curing procedures. The fabricator shall inform the Engineer of his planned concrete placement and curing schedule in advance of the start of any work to afford time for the testing of materials, the inspection of equipment and reviewing of procedures that will be used in casting the units.

F. Cylinder Molds. The fabricator shall furnish an ample supply of cylinder molds for the casting of test cylinders. All molds shall be subject to the approval of the Engineer. A mold size of 4 inches x 8 inches is acceptable.

G. Compression Machine. The fabricator shall furnish a machine capable of measuring the compressive strengths of concrete cylinders cast during the fabrication of the units. All testing machines used to determine the stress release time for the units shall be calibrated annually and by an independent recognized calibration service. Calibration reports shall be made available for review on request of the Engineer.

704.13 Tensioning Procedure.

A. General. During the course of construction, special care must be taken to protect the prestressing wire, strand or bars from damage due to use of welding or cutting equipment. This provision, however, is not to be taken as excluding the use of burning torches to cut the strand beyond the ends of the casting bed before stressing the strands nor to cut the strands or wires projecting from the ends of the members. Care must be taken to see that no lubricant, dirt, paint or other bond-reducing material is deposited on the strand. If any is so deposited, the strand must be cleaned to the satisfaction of the Engineer. Any loose rust shall be removed before concreting.

B. Pretensioning. The number, size and location of the strands required to induce the necessary prestress force shall be as shown on the plans. At the request of the

Contractor, the Department will give consideration to the use of other size strands or to the use of strands of higher ultimate unit stress, provided approximately the same concrete stress pattern and approximately the same beam camber is obtained in the substitute beam as would have been obtained in the original beam design. Written permission must be obtained from the Department before any such changes are made. Each strand of all sizes, shall be given an initial tension as approved in the shop drawings. This initial tension shall be measured by some suitable means indicating the stress directly from the jacking gauge or a dynamometer and shall not be measured by elongation of the stands. The remaining prestressing force shall be applied to the strands by means of hydraulic jacks equipped with gauges graduated to indicate the load applied to the strands within an accuracy of two percent. In general, the final force shall be measured by elongation of the strands and checked by the calibrated pressure gauge. Any discrepancy between the pressure gauge and the strand elongation greater than 5% shall be reported to the Engineer and corrections made as directed by him.

The force applied as described above shall be maintained until the concrete is deposited and has reached a minimum compressive strength of $0.8 \times f'_c$ for beams, or $0.7 \times f'_c$ for piles, at which time the strands may be released to transfer the prestress to the concrete. The releasing of the strands shall be done so that there will not be a sudden imposition of bond stress between the concrete and the strands. The releasing shall be effected symmetrically about the vertical axis of the concrete member. Side forms may be removed when in the opinion of the Engineer the concrete has hardened sufficiently to permit such removal without damage to the concrete member.

Where deflected pretensioned strands are required, these strands shall be first stressed in a horizontal position by a partial force in the amount as shown on the approved

shop drawings. The final stress shall be secured by deflecting upward at points at or beyond the ends of the concrete beams, progressing from the center of the bed outward in both directions. The strands may be tensioned in their deflected position where suitable rollers are used and where it can be shown that the variation in tension throughout the length of the strand will not exceed two percent.

C. Post-tensioning. Jacks used for post-tensioning shall have been re-calibrated subsequent to use if the calibration date is past six months. The calibration results of the jack and gauge shall be certified to the Engineer with a graph or table showing the calibration data. The calibration shall be rechecked every six months or the Contractor may furnish a proving ring to check calibration of the jack.

Post-tensioning of beams shall not be begun until the concrete has reached a minimum compressive strength of $0.8 \times f'_c$. All tendons in one cable must be stressed simultaneously. Tendons not on the vertical axis of beam shall be stressed in such manner that the force during tensioning on one side of the vertical axis will not be greater than that on the other side of the vertical axis to an extent to cause undesirable bending about such axis. The applied tension in each tendon shall be in accordance with that specified on the plans. Jacking shall be carried out by means of hydraulic jacks equipped with pressure gauges. The gauges shall read within 2% of the true jack force. The elongation of tendons shall be measured and the stresses checked in accordance with the requirements of the current the *AASHTO Standard Specifications*. The elongation of the tendons shall be increased by the amount of observed slip occurring in the end anchorages. The prestress force shown on the plans must be applied to the beam. After this force has been transferred to the concrete by means of the end anchorages, the ducts containing the tendons shall be pressure grouted. The method of anchoring post-tensioning tendons must be ap-

proved by the Department before use.

The grout shall be forced into one end of the duct to be grouted until all entrapped air and water are forced out through the other end and/or through an orifice located at the high point of the duct, and a steady stream of grout is emitted. The outlet end and orifice shall then be closed while the grout is under pressure and the pressure increased to about 75 psi and held at this pressure for approximately ten seconds. The entrance end shall then be plugged under this pressure. Beams may be lifted before grouting, but after grouting, shall not be lifted until the grout has cured for at least 36 hours.

The plans may show the post-tensioning tendon enclosed in steel ducts. The Contractor may, at his option, form channels by means approved by the Engineer and pull the tendons into these channels instead of using ducts. The diameter of such channels shall not exceed the outside diameter of the duct shown on the plans. The ducts or channels shall be accurately located in a parabolic or a circular curve. Ducts shall be secured by wire or bar ties fastened to the vertical bars in the beams. If rubber or plastic ducts are used to form the holes, such material shall be removed before inserting the wires or strands. A lubricant shall not be used to coat the outside of the ducts for ease of removal.

D. Combined Pretensioning and Post-Tensioning. When the plans call for or allow a combination of pretensioning and post-tensioning, all of the requirements of both the pretensioning and post-tensioning shall apply and the requirements shall overlap as necessary to fulfill the intent of this specification.

704.14 Handling and Erection. Prestressed piles, beams, slabs, channels, and other components may be handled as necessary immediately after the pretensioned stress is released. Care shall be taken in handling, storing and transporting to prevent damage to the components by excessive

vibration, impact, improper supports or other faulty methods of handling, transporting and storing. Beams shall be lifted by attachments located near the beam ends and stored in an upright position by supporting as simple beams with the supports near the end bearing areas. Temporary lateral stiffening of beams may be necessary to avoid buckling tendencies. Prestressed members may be transported and erected or piles driven after three (3) days of curing and attainment of the required concrete compressive strength

704.15 Method of Measurement.

A. Prestressed Concrete Beams. Prestressed concrete beams and girders shall be measured by the linear feet of beam of the type and size specified, accepted, erected in place in the bridge or bridges, and in accordance with the plans and special provisions.

B. Prestressed Concrete Piling. Prestressed concrete piling will not be measured for payment under this section of the specification, but will be measured and paid for as specified in Subsections **711.32** and **711.33**.

C. Other Prestressed Members. Other prestressed members shall be measured and paid for as specified elsewhere in the plans or special provisions.

704.16 Basis of Payment. Prestressed concrete beams will be paid for at the contract unit price, complete and in place, which price and payment shall be full compensation for furnishing all materials (including strands, cables, anchorages, bearing plate assemblies, sole plates, reinforcing steel, concrete and all other necessary material) and all equipment tools, labor, shop plans, insurance and other items necessary for fabricating, curing, hauling, erecting and furnishing the beam or girder.

Partial payment for prestressed concrete beams may be made in accordance with the schedule in Subsection **109.06**.

Payment for this item includes all direct and indirect costs and expenses required to complete the work.

Payment will be made under:

Item No.	**Pay Item**	**Pay Unit**
704XX00	Prestressed Concrete Beam *(type)*	Linear Foot

SECTION 705

BRIDGE RAILING

705.01 Description. This work shall consist of the furnishings and erection of bridge railing of cast-in-place concrete, precast concrete, aluminum, steel, or other specified materials, or a combination of these materials on bridges, walls, or incidental structures as shown on the plans.

Unless otherwise stated, bridge railing shall include that portion of the structure erected on and above the bridge deck, curb or sidewalk, or above the top of retaining walls for the protection of traffic and pedestrians.

Bridge railing shall be constructed in accordance with the details shown on the plans and shall include the necessary devices for anchoring or attaching the railing to the main structure.

MATERIALS

705.02 Concrete Railing Wall and Barrier Parapet. Concrete shall not be less than Class 4000 unless otherwise

specified and shall conform to the requirements of Sections **701** and **702**. Reinforcing steel shall conform to the requirements of Section **703**.