Section 25 - Precast/Prestressed Concrete

25.1 General Design Considerations

1. Subsection 5.9 of the *AASHTO LRFD Bridge Design Specifications* provides criteria on the design of prestressed concrete members.
2. The PCI publication, "*Precast Prestressed Concrete Bridge Design Manual*" also explains and applies major *AASHTO LRFD Bridge Design Specifications* provisions that pertain to prestressed concrete beams.
3. NJDOT stipulations provided in Section 3 of the Manual shall also be followed in the design of prestressed concrete members.

25.2 Precast/Prestressed Concrete Sections

Standardization of precast/prestressed concrete sections has simplified design, led to wider utilization of precast/prestressed concrete and has led to a reduction in cost when precast/prestressed concrete is selected. Designers should review the following guidance in evaluating precast/prestressed concrete usage.

1. Prestressed Concrete I-Girders. Details of AASHTO prestressed concrete I beams are illustrated on Standard Drawings 2.1-1 through 2.1-6 of this Manual.

   If continuity design for live load (see Subsection 25.9) is selected as a result of the bridge structure selection study, details for the positive restraint moment connection, sole and bearing plates, elastomeric bearing pads, and any other necessary details must be addressed in the design.

2. Prestressed Concrete Voided Slab and Box Beams. Standard drawings for prestressed concrete voided slab and box beams are not presently available. Complete details, including the prestressed strand pattern and bearing details shall be shown in the contract plans for each bridge. Refer to Subsections 25.5 through 25.7 for additional criteria on box and slab beam usage.

3. Prestressed Concrete Bulb Tee Shapes. Studies have concluded that bulb tee shapes are more efficient than I-girder shapes. When compared to the AASHTO Type VI girder an alternative bulb tee shape may lead to reduction in girder weights of up to 35%. Also when compared to the respective I-girder span length capability, a cost savings of 17% may be realized if a bulb tee section is selected. Guide Plate 3.10-26 has been developed to illustrate 3 New England Bulb Tee (NEBT) configurations. Other configurations are available. If a Designer wishes to pursue a NEBT design, he should contact prestressed fabricators to ascertain availability of forms for its casting.

   The Federal Highway Administration has initiated an effort to establish measures for the economic fabrication of prestressed concrete members. Toward that end a committee titled Prestressed Concrete Economic Fabrication (PCEF) was formed. The work of the committee has produced a bulb tee shape that they recommend be adopted as a standard shape by State agencies. Guide Plate 3.10-27 details 3 configurations of the PCEF Bulb Tee Shape. Other configurations are available. If a Designer wishes to pursue use of the PCEF shape, he should contact fabricators for availability of forms for its casting.

4. Spliced Prestressed Concrete I-Girders. Spliced concrete I-girder bridges have been shown to be cost-effective for a span range of 120 to 300 feet. A feature of spliced bridges is the flexibility they provide in selection of span length, number

and locations of piers, segment lengths and splice locations. Spliced girders have the ability to adapt to curved superstructure alignments by utilizing short segment lengths and accommodating the change in direction in the cast-in-place joints.

5. Precast Concrete Segmental. Segmental concrete bridges have become an established type of construction for highway and transit projects on constrained sites. Typical applications include transit systems over existing urban streets and highways, reconstruction of existing interchanges and bridges under traffic or projects that cross environmentally sensitive sites. In addition, segmental construction has proved to be appropriate for large-scale, repetitive bridges such as long waterway crossings or urban freeway viaducts or where the aesthetics of the project are particularly important.

   Current developments suggest that segmental construction will be used on a larger number of projects in the future. Standard cross sections have been developed to allow for wider application of this construction method to smaller-scale projects. Surveys of existing segmental bridges have demonstrated the durability of this structure type and suggest that additional increases in design life are possible with the use of HPC.

   Subsection 5.14.2 of the *AASHTO LRFD Bridge Design Specifications* provides criteria for the design and construction analysis of segmental bridge construction. Section 10 of the *AASHTO LRFD Bridge Construction Specifications* should also be studied for information on post tensioning requirements that must be applied to segmental concrete construction. Also, the American Segmental Bridge Institute (ASBI) provides a forum where owners, designers, contractors and suppliers can gather information on segmental bridge construction.

25.3 Materials

1. Strands
   a. Uncoated seven-wire prestressing steel low relaxation strands, conforming to ASTM A416 (AAHSTO M 203) Grade 270, shall be used. Complete prestressing details shall be provided on the plans.
   b. If determined to be more suitable; such as, to offset the potential of corrosion due to the environmental location, epoxy-coated seven-wire prestressing steel low relaxation strands conforming to ASTM A882/A 882M, Supplements S1, Grade 270 may be used.
2. Bars
   a. Uncoated high-strength steel bars for prestressing concrete conforming to AASHTO M 275, including Supplements S1 and S2 shall be used.
   b. If determined to be more suitable, zinc-coated reinforcing bars conforming to ASTM A767 shall be used or epoxy-coated reinforcing bars conforming to ASTM D3963 (AASHTO M284) shall be used.
3. Wire

   Uncoated stress-relieved wire for prestressed concrete conforming to ASTM A421 (AASHTO M204) shall be used.
4. Post-Tensioning Anchorages and Couplers.

Refer to Subsection 5.4.5 of *AASHTO LRFD Bridge Design Specifications* for guidance concerning use of these devices.

5. Ducts

   Refer to Subsection 5.4.6 of *AASHTO LRFD Bridge Design Specifications* for guidance concerning use of those devices.

6. Concrete

   Generally the design strengths for prestressed/precast concrete shall be based on properties of Class P, P-1 or P-2 concrete. The NJDOT Standard Specifications can be referred to for guidance concerning use of these classes of concrete.

   Use of HPC prestressed concrete girders should be evaluated by Designers in their appraisal of alternative bridge structure types. HPC in prestressed girders will optimize their performance with respect to service loads and exposure conditions.

   If a design compressive strength greater than 6,000 psi is necessary for the design of precast/prestressed concrete elements, then the use of High Performance Concrete (HPC) should be pursued. The Designer shall familiarize himself with the following HPC performance criteria for the design and fabrication of precast/prestressed concrete beams.

   Refer to Section 20 of this Manual for a basic definition of HPC.

Performance Characteristics	**Standard Test Method**
Creep (x = inch/pressure unit) @ 180 days	ASTM C 512
Modulus of Elasticity @ 28 days of age	ASTM C 469
56 Day Design Compressive Strength	AASHTO T 22 ASTM C39
Shrinkage (x = length change in microstrain)	ASTM C157
Chloride Permeability (x = coulombs)	AASHTO T 277

   Note: All tests to be performed on concrete samples that are moist or Submersion cured for 56 days.

   The chloride permeability performance criteria will only be required when prestressed concrete beams are constructed at a height that is less than 15 feet above brackish water.

25.4 Design/Construction Criteria

1. Drilling for inserts into prestressed concrete members is not permitted.
2. For any pre-tensioning application ½ inch or 0.6 inch diameter strands shall be used. Minimum spacing of prestressing strands shall be as specified in Subsection 5.10.3.3.1 of the *AASHTO LRFD Bridge Design Specifications*.

3. Stress limits of tendons for pre-tensioning and post-tensioning applications shall be as specified in Subsection 5.9.3 of the *AASHTO LRFD Bridge Design Specifications*.
4. Shipping and handling stresses shall be considered when designing prestressed concrete beams. This is especially important for long span members (over 130 feet) with slender webs and small flanges.
5. Epoxy-coated low-relaxation strands have significantly higher relaxation potential than that of uncoated strands. The use of a relaxation loss value that is equal to doubling the relaxation loss that is calculated for uncoated strands has been recommended by manufacturers. Strand manufactures should be contacted to account for suitable relaxation loss values.
6. Anchorage seating losses are typically higher for epoxy-coated strands than for uncoated strands. This should be considered in stressing and elongation calculations.
7. One of the most important decisions of precast component design is the ability to move the member from the precast plant to the job site. Weight and size limitations for the mode of transportation (truck, rail and barge) should be taken into consideration in the design of precast members. Designers should consult with fabricators on transportation considerations.
8. Various decisions in the design of prestressed concrete members determine the bridge construction cost. The PCI Bridge Design Manual, Chapter 4 describes strategies for economy, and may be referred to as an aid in decision making.
9. When considering prestressed beam layouts, a minimum of four girder lines should be provided to account for redundancy concerns and to account for future repair needs.
10. Standard Drawing 2.1-6 provides detailing for use of steel diaphragms. Steel diaphragms shall be used where intermediate diaphragms are required for prestressed beam configurations. Cast-in-place concrete diaphragms shall be used at end diaphragm locations.
11. Draped, straight and straight/unbonded strand patterns shall be considered as potentially equal solutions for prestressed beam analysis and fabrication. Designers should consult prestressed fabricators to ascertain use of strand patterns in their fabrication process. Alternative patterns, to what is detailed on the plans, subject to the conditions stated herein, may be proposed during fabrication.

25.5 Adjacent Voided Slab And Box Beam Design

1. It is recommended that adjacent slab and box beams not be utilized for bridges with skew angles greater than 30 degrees.

   Prestressed concrete box beam bridges shall utilize 4 foot wide box beams whenever possible. All efforts should be made to avoid a mixture of 4 foot and 3 foot wide box beams in satisfying geometrical constraints.

2. Prestressed concrete adjacent slab and box beams shall be surmounted with a minimum 5 inches thick concrete deck slab designed for composite action. Reinforcement steel shall be #16 @ 12 inch centers, both directions, with 2½″ cover (see Guide Sheet Plate 3.10-7) and shall be corrosion protected.

In order to achieve a composite connection, Guide Plates within this Manual detail provision of a "camel back" arrangement of the composite reinforcement steel. Designers are advised that an alternate arrangement that eliminates the "camel back" appearance is permitted. The elimination of the "camel back" arrangement has been found to be cost effective.

3. Non-composite design (but with composite details and construction) should also be considered. Additional reserve strength may be gained by adding several strands without a significant increase in the cost of fabricating the slab and box beams.
4. The *AASHTO LRFD Bridge Construction Specifications* allow a tolerance of plus/minus ¼ inch in the width of box beams. Abutment seats shall be detailed of sufficient length to accommodate this possible dimensional overrun in a group of beams.

   Abutment seats may be sloped in the transverse direction to conform with the deck cross slope; however, bearing seats shall generally be set level in the longitudinal direction parallel to the direction of the beams. If the bearing seats are not set level in this direction, gravity loads will cause shear in the elastomer.

   The use of a tapered sole plate or tapered grout pad may be required so that the bearing surfaces are set level. This will avoid imposing excessive rotation and resulting stresses on the bearing (see Guide Sheet Plate 3.10-9).

25.6 Transverse Ties And Keyway Grouting

1. Construction plans must be consistent with the Construction Specifications. Accordingly, the following criteria shall be followed in the plan development of adjacent prestressed slab and box beam construction:
   a. Transverse ties shall be installed and tensioned before the longitudinal keyways are grouted.
   b. Keyways shall be filled with nonmetallic, nonshrink grout.
2. See Guide Sheet Plates 3.10-13 and 3.10-14 for transverse tie details. Transverse ties shall be high tensile strength steel bars conforming to AASHTO M 275 or one-half inch diameter, Grade 270 strands. Bars should preferably be 1 inch in diameter; however, bars up to 1-3/8" in diameter may be used, if necessary.

   The end anchorage hardware shall be galvanized.
3. The force required per transverse tie duct per span is computed by dividing one third of the span superstructure dead load including the beams, deck, sidewalk, utilities and parapets by the number of transverse tie ducts within the fascia beam. The computed value shall be stated on an appropriate contract plan sheet.

   Refer to Subsection 5.9.3 of the *AASHTO LRFD Bridge Design Specifications* for the stress limits of Prestressing tendons.

   Generally rods are preferred over strands for transverse ties because the end anchorage details are less complicated. If prestressing strands are utilized as transverse ties instead of high strength rods, more than one 7 wire strand may be utilized per transverse duct, if necessary.

Anchorages in prestressed beams shall develop at least 95% of the actual ultimate strength of prestressing steel.

The total force required per transverse duct and the individual strand forces, if applicable, shall be shown on the contract plans.

4. Special design considerations may be required in cases where channel beams are placed next to box beams. Adequate reinforcement shall be designed in the area of the transverse ducts and/or the configuration of the shear key shall be modified such that any allowable beam sweep can be taken into consideration before the beams are tensioned.

25.7 Spread Box Beam Design

1. Spread box beams are particularly useful for structures supporting utilities or where a shallower superstructure is needed than can be provided by Prestressed Concrete I-Beams or Steel Plate Girders.
2. It is recommended that spread box beams not be utilized for bridges with skew angels greater than 30 degrees.
3. Variations on standard spread box beam design (i.e., double spread boxes or a multi-beam structure with spread boxes under sidewalks for utilities) can be considered as alternates where applicable. These arrangements may provide shallower beams and/or a thinner deck slab and may be more economical than standard spread boxes.
4. Spread box beam bridges shall utilize wide beams whenever possible based on cost advantage or other consideration. All efforts should be made to avoid a mixture of 4 foot and 3 foot wide box beams in satisfying geometrical constraints.
5. Prestressed concrete spread box beams and bridge deck slabs shall be designed in accordance with the AASHTO LRFD Specifications and as modified by Section 3 of this Manual. Reference Guide Sheet Plates 3.10-19 through 3.10-25 inclusive, for details on spread box beams.

   The maximum spacing center to center of beams shall be 12 feet unless otherwise approved by the Manager, Bureau of Structural Engineering.
6. Prestressed concrete spread box beams shall be designed assuming full composite design between the deck slab and the beams. Deck slab thicknesses, reinforcing steel and haunches shall be in accordance with Section 20 of this Manual.
7. Load distribution factors shall be selected in accordance with Subsection 4.6 of the *AASHTO LRFD Bridge Design Specifications*.
8. Guidance for continuity design for live load shall be in accordance with Subsection 25.9 herein. Continuity design for live load details shall be similar to those for I-beams except that a minimum of three 1¼ inch anchor dowels will be required at the fixed end pier. Corrosion protected reinforcement steel, as required by design, shall be placed in the top of the deck slab in the negative moment region. For Positive Restraint Moment Connection details, refer to Guide Sheet Plates 3.10-16 and 3.10-17.
9. The Abutment seat slope in the transverse and longitudinal direction, shall be similar to that of adjacent voided slab and box beam specified in Section 25.5

Item 4 herein. Complete details shall be shown on the contract plans. Elastomeric bearing pad selection shall be according to Subsection 25.8 herein.

10. Diaphragms shall be provided at the following points: at the ends of each beam, at midspan for spans up to and including 80 feet and at third points for spans longer than 80 feet.

End diaphragms shall always be placed parallel to the centerline of the bearing. Intermediate diaphragms shall be placed parallel to the centerline of the bearing for skews up to and including 15 degrees and shall be placed perpendicular to the beam for skews greater than 15 degrees.

Threaded inserts shall be cast into the box beams to connect the box beams and the exterior diaphragms.

End diaphragms which are located at fixed bearings shall be the full depth of the box beams and shall be a minimum of 12 inches wide. Reference Guide Plates 3.10-20 and 3.10-21 for more information. End diaphragms which are located at expansion bearings shall be 12 inches above the bottom of the beam and shall be a minimum of 12 inches wide. Reference Guide Sheet Plate 3.10-22 for more information.

Intermediate diaphragms shall be 12 inches above the bottom of the beam and shall be of minimum of 10 inches wide. Reference Guide Sheet Plate 3.10-21 for more information. Pier diaphragms on structures continuous for live load shall be at least 8 inches wider than the positive restraint moment connection.

All dimensions shall be perpendicular to the respective diaphragms. Reinforcing steel size, embedment and spacing shall be by design and shall be shown on the contract plans.

Class A concrete shall be used for the diaphragm work and the quantity shall be included in the Deck Slab pay item.

Use of steel diaphragms is permitted. Standard Drawing number 2.1-6 provides details for intermediate steel diaphragms for prestressed concrete beams. This drawing may be studied for its suitability to the spread box beam concept.

11. When utilities are less than half the depth of the end diaphragm and are approximately centered in the diaphragm, they shall pass through the end diaphragm in a sleeve. Where multiple ducts pass between two beams, it might be necessary to cast a rectangular hole in the end diaphragm. Partial depth end diaphragms at expansion bearings can be lengthened for that purpose.

Utilities which are sleeved through end diaphragms should generally pass through the end diaphragm as close to the center as possible. Other utility arrangements not stated may require the end diaphragm to be shortened to a minimum depth of 18 inches and the utilities be hung from an adjacent support system.

In all cases, the designer shall secure approval from the representative of the utility company and the NJDOT Bureau of Structural Engineering for the location and method of support of all utilities.

12. If Stay-in-Place forms are utilized, weld anchors shall be embedded into each beam for the purpose of attaching the form support angles. Reference Bridge Construction Detail BCD-9 for more information.

13. Standard Drawings provided in this Manual provide details for installing strip seal expansion joint assemblies. Modification to these details or a different design may be necessary to accommodate field conditions or for attachment to a deck slab greater than 8½ inches.

14. For Epoxy Waterproofing Seal Coat limits, refer to Section 25.10.

25.8 Bearings

1. Subsection 24.20 of this Manual provides criteria for bearing systems that satisfy seismic needs. Such type bearing systems should be provided for all new precast prestressed concrete superstructure designs.

   In the rehabilitation of existing prestressed concrete I-beam structures, that utilize steel rocker bearings, Section 45 of this Manual should be referred to for guidance in retrofitting such type bearings.

2. The effects of seismic forces shall be considered in the design of bearing systems for precast/prestressed slab and box beam bridges. Elastomeric bearing pads are known to satisfy seismic demands and thus may be used. Elastomeric bearing pads shall be designed in accordance with Section 14 of the current *AASHTO LRFD Bridge Design Specifications*.

   For the purpose of bearing design, the bridge site shall be classified as being in temperature Zone C and the elastomer shall be Grade 3.

25.9 Continuity Design For Live Load Concept

1. The concept of continuity design for LL + I + DL2 load moments may be considered for multi-span precast prestressed concrete I-beams and spread box beam designs unless foundation conditions preclude consideration of continuous design (see Subsection 24.3c). This concept shall not be considered for bridges where the skew angle is greater than 30 degrees.

2. Example details of the continuity concept, which illustrate the diaphragm at the pier, continuity rebars in the deck slab, positive restraint moment connection in the bottom of the prestressed concrete I-beam, and use of preformed elastomeric bearings are illustrated on Guide Sheet Plates 3.10-15 to 3.10-18.

   However, the results of different research efforts recommend use of other concepts that may be more workable from a design and construction perspective. Accordingly, use of other concepts is permitted. Use of alternate concepts shall be approved by the Manager, Structural Engineering.

3. Design shall be in accordance with Subsection 5.14.1.4 of the *AASHTO LRFD Bridge Design Specifications*.

4. A comparison of the concept indicates the following differences in details when compared to simple span design:

Simple Span Design For DL Continuous Span Design For LL + I + DL2 Deck Slab:	Simple Span Design for DL + LL +I +DL2 Deck Slab:
N/A	Preformed elastomeric compression seal or glandular type strip seal
N/A	Steel joint armor
Concrete placing sequence	N/A
Continuity rebars	N/A
Deck Diaphragms at Pier:	**Deck Diaphragms at Pier:**
One Diaphragm, ______ inches wide(depends on skew)	Two Diaphragms, 9 inches wide
PC I-Beams:	**PC I-Beams:**
Possible reduction in the beam size-force combination	N/A
Possible fewer strands	N/A
Positive restraint moment connection	N/A
Bearings:	**Bearings:**
Refer to Subsection 24.20	Refer to Subsection 24.20
Width usually greater because of space needed between beams for positive restraint moment connection and bridge skew	N/A
Keeper block	N/A
N/A	Corrosion protected rebars (Epoxy coated,Stainless Steel or Galvanized)
N/A	Epoxy waterproofing seal coat

5. The same size, number and arrangement of prestressed concrete beams shall be used within a series of spans made continuous for live load. Cut-off points for the continuity rebars in the cast in place deck slab shall be staggered in a minimum of three increments. A concrete deck slab placing sequence shall be shown.
6. The principal reason for the possible use of this concept is the reduction in the number of deck slab joints rather than economy. Continuity design for live load may not be practical or economical for a bridge of a few short spans, but substantial economy could result for multiple (nine or more) spans between 80 and 110 feet.
7. If indicated as a possible alternative for the bridge type, the continuity design for live load concept shall be used for all precast prestressed concrete I-beams. The simple span design concept shall be used if approved by the Manager, Bureau of Structural Engineering, prior to the Preliminary submission.
8. Precast prestressed concrete slab and box beam bridges are generally utilized on short span structures. They are usually designed as simple spans for DL+ LL+ I+ DL2 with transverse deck slab expansion joints. Transverse cracking in the deck slab overlay at the pier is more likely to occur because of the shallow deck if the continuity concept is used in the construction.

Generally, the continuity design for live load concept need not be considered for the typical adjacent slab and box beam bridges, but may be considered for the occasional multi-span bridge where long span/deep box beams are required or where seismic considerations warrant.

25.10 Epoxy Waterproofing Seal Coat Limits

Precast prestressed concrete beams shall be treated with an epoxy waterproofing seal coat. The limits for sealer application shall be shown on the construction plans and shall conform to the following:

Beam Type	**Areas to be Treated**	**Application limits (*), (**)**
I-beams	Ends, sides bottoms	4 foot length from the beam and end for exterior surfaces and 8” length from the beam end for interior surfaces
Beam Type	**Areas to be Treated**	**Application limits (*), (**)**
Adjacent box beams, channel beams, voided slabs	Ends, bottoms and exterior face of fascia beams	4 foot length at the ends of beams subject to deck joint leakage
Spread box beams	Ends, sides and bottoms	4 foot length at the ends of beams subject to deck joint leakage

Epoxy waterproofing seal coating is not required for diaphragm connection areas.

As per bearing manufacturer’s recommendations, epoxy waterproofing shall be omitted from the bearing contact area. This requirement shall be reviewed.

* For continuous bridges epoxy waterproofing seal coat shall be applied only to the beam ends located under or near deck joints.

** If the structure is located in a severe salt intrusion zone or a salt splash zone, (Zone 3A or 3B, see chart entitled "Zonal Areas of New Jersey Affected by Salinity" in Subsection 24.18 of this Manual) and is located less than 15 feet above the mean high salt water mark, the entire beam, along with both sides, bottom and ends shall be treated with epoxy waterproofing seal coat.