SECTION 6
CONCRETE STRUCTURES

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SECTION 6
CONCRETE STRUCTURES

6.1 MATERIALS

6.1.1 Concrete

6.1.1.1 Cast-In-Place Concrete *(Rev. 04/19)*

Concrete shall conform to the **Standard Specification** requirements of "Section 6.01 – Concrete for Structures" and "Section M.03 – Portland Cement Concrete," including modifications by Supplemental Specifications and Owned Special Provisions. The class of concrete specified for bridge components shall generally conform to the following guidelines:

- Substructure Components - Class PCC03340*
- Bridge Superstructures – Class PCC04462

*If "Z" is other than "0," written permission shall be obtained from the Bridge Principal Engineer.

Occasionally, concrete classes that meet these guidelines are not appropriate for a specific use. In these instances and with permission from the **CTDOT**, Designers may modify the concrete class for the intended use as follows:

- For concrete components with extremely congested reinforcing, Designers shall consider specifying a concrete class with a smaller aggregate.
- Where higher 28-day strength or higher early strength is needed to resist applied loads, Designers may specify a class of concrete with a greater strength.

When the dimensions of a cast-in-place concrete component (not cast underwater) qualify it as "Mass Concrete," in accordance with the Standard Specification, the PCC classification system will still be used to specify the compressive strength, aggregate size and Exposure Factor. Concrete suppliers may tailor the mix to address temperature and cracking in the concrete, but the Contractor shall prequalify the proposed mix with ample time to place the concrete. Designers shall verify that sufficient time is available in the contract for the Contractor to prequalify the mix before its intended use.

"Underwater Concrete" will also be specified using the PCC classification system. The Designer shall include a cofferdam in the contract to construct underwater concrete components and clearly designate the concrete as "Underwater Concrete."
The density of cast-in-place concrete shall be assumed to be as follows, unless proof of another value is available:

- Normal Weight Concrete of all PCC Classes: 150 pounds per cubic foot
- Lightweight Concrete: 125 pounds per cubic foot

6.1.1.2 Precast, Non-Prestressed Concrete

Concrete for precast, non-prestressed members or components shall conform to the requirements in the **Standard Specifications** and **BDM** [6.3.3.1].

6.1.1.3 Precast, Prestressed Concrete

Concrete for prestressed concrete members or components shall conform to the requirements in the **Standard Specifications** and **BDM** [6.3.4.5].

6.1.1.4 Rapid Setting Concrete *(Rev. 12/19)*

Vacant

6.1.1.5 Ultra High Performance Concrete (UHPC) *(Rev. 12/19)*

Ultra High Performance Concrete (UHPC) shall conform to the requirements of the Owned Special Provision “Ultra High Performance Concrete”.

6.1.1.6 Lightweight Concrete *(Rev. 12/19)*

Vacant

6.1.2 Reinforcement

6.1.2.1 Non-Prestressed Steel *(Rev. 04/19)*

Non-prestressed steel shall conform to the following:

- Uncoated bar reinforcement shall conform to the requirements of ASTM A615, Grade 60.
- Epoxy coated bar reinforcement shall conform to the requirements of ASTM A615, Grade 60 and be epoxy coated to the requirements of ASTM D3963.
- Stainless steel bar reinforcement shall conform to the requirements of ASTM A955.
- Galvanized bar reinforcement shall conform to the requirements of ASTM A615, Grade 60 and be galvanized, after fabrication, to the requirements of ASTM A767, Class 1, including supplemental requirements.
- Weldable bar reinforcement shall conform to the requirements of ASTM A706.
- Welded wire fabric shall conform to the requirements in the **Standard Specifications**.

6.1.2.2 Prestressed Steel

Prestressing steel shall be 0.6 inch diameter, uncoated, low relaxation strands conforming to the requirements of AASHTO M203, Grade 270.

6.1.3 Protective Coating on Concrete Surfaces *(Rev. 04/19)*

All concrete surfaces subjected to salt spray from marine environments, or spray from de-icing chemicals, shall be sealed with a clear, 100% silane or siloxane in accordance with the specification, "Penetrating Sealer Protective Compound." It is anticipated that silanes and siloxanes will protect concrete for approximately 7-12 years, after which time, they should be re-applied. Designers shall specify the application of a penetrating sealer in rehabilitation projects – including bridge preservation projects to ensure the continued protection of concrete surfaces.

The use of colored sealers is permitted only with the written approval of the **CTDOT**. Such sealers may experience blistering or peeling over time, creating an undesirable appearance.

Colored stains for concrete shall not be considered to protect the concrete from de-icing chemicals. Stains may be incompatible with the penetrating sealer. Should colored concrete be desired, consideration shall be given to applying the pigment to the mix design so a penetrating sealer may be applied to the finished concrete.

For dampproofing requirements, see **BDM** [5].

6.2 FABRICATION REQUIREMENTS

6.2.1 General

The prestressed concrete fabricator's plant shall be certified by the Precast Prestressed Concrete Institute Plant Certification Program. The certification shall be as a minimum in the B3 Category, except for draped strand members, in which case a B4 Category certification is required. The certification requirements shall be shown on the plans.

6.2.2 Tolerances

Tolerances for prestressed members shall conform to the limits specified in the *Manual for Quality Control for Plants and Production of Precast Prestressed Concrete Products* (MNL-116).

6.3 DESIGN AND DETAILING REQUIREMENTS

6.3.1 Cast-In-Place, Non-Reinforced Concrete Members

Cast-in-place, non-reinforced concrete members and components are not permitted, except for the use of underwater concrete for cofferdam seals. A cofferdam seal shall not be considered a structural member or component.

6.3.2 Cast-In-Place, Reinforced Concrete Members

6.3.2.1 General

The use of cast-in-place reinforced concrete is acceptable for all types of members and components. Generally, cast-in-place concrete is used for substructure components, bridge decks and parapets. However, cast-in-place concrete may be used for superstructures when it is found to be economical and feasible.

6.3.2.2 Payment for Concrete Components *(Rev. 04/19)*

6.3.2.2.1 Selecting Item Names and Components to be Included

Pay item names reflect the character of the bridge components that will be measured for payment under the item. To reduce the number of item names, similar components may be included together under the same item. See Table 6.3.2.2.1-1 for a list of item names from which Designers may choose, and a list of components that may be considered similar enough to include with each item.

TABLE 6.3.2.2.1-1

<table>
<tr><th>ITEM NAME</th><th>COMPONENTS INCLUDED</th><th>Concrete Mix Class (PCCXXXYZ[1])</th></tr>
<tr><td>Footing Concrete</td><td>Footings, leveling pads, pile caps, cut-off and return walls</td><td rowspan="4">PCC0334Z</td></tr>
<tr><td>Footing Concrete (Mass)</td><td>Footings, pile caps</td></tr>
<tr><td>Abutment and Wall Concrete</td><td>Abutments, wingwalls, retaining walls, endwalls, headwalls, concrete bearing pedestals, cheekwalls, keeper blocks, curbs</td></tr>
<tr><td>Abutment and Wall Concrete (Mass)</td><td>Abutments, wingwalls, retaining walls, endwalls</td></tr>
<tr><td>Not Applicable</td><td>Steps, Copings</td><td>PCC0336Z</td></tr>
<tr><td>Surface Repair Concrete</td><td>Abutments, Walls, Columns, Caps, Parapets, Box Culverts</td><td rowspan="2">PCC04481, PCC05581</td></tr>
<tr><td>Structural Repair Concrete</td><td>Columns, Caps, Parapets, Box Culverts</td></tr>
<tr><td>Column and Cap Concrete</td><td>Pier columns, pier caps, concrete bearing pedestals, keeper blocks</td><td rowspan="4">PCC0446Z</td></tr>
<tr><td>Column and Cap Concrete (Mass)</td><td>Pier columns, pier caps</td></tr>
<tr><td>Approach Slab Concrete</td><td>Approach slabs, concrete aprons on grade</td></tr>
<tr><td>Barrier Wall Concrete</td><td>Barrier Walls (includes footing, stem and parapet)</td></tr>
<tr><td>Bridge Deck Concrete</td><td>Bridge decks, haunches, backwalls cast integral with the deck, concrete curbs</td><td>PCC04462</td></tr>
</table>

Bridge Deck Concrete (SIP-Forms)	Bridge decks, haunches, backwalls cast integral with the deck, concrete curbs	
Parapet Concrete	Parapets on bridge decks, parapets on wingwalls and parapets on retaining walls	
Bridge Sidewalk Concrete	Bridge sidewalks, curbs, raised medians	
[1]Exposure Factor, Z, shall be “0” unless another value is approved by the Bridge Principal Engineer		

When estimating the unit bid price of a cast-in-place concrete component, the largest contribution is not the cost of the concrete material. Additional factors that contribute to the cost of a concrete component are: complexity and congestion of reinforcing, forming and removal of forms, concrete placement and consolidation, sequence and timing of pours, finishing and access needs. When these factors are similar enough for different bridge components, those components may be included together in the same bid item.

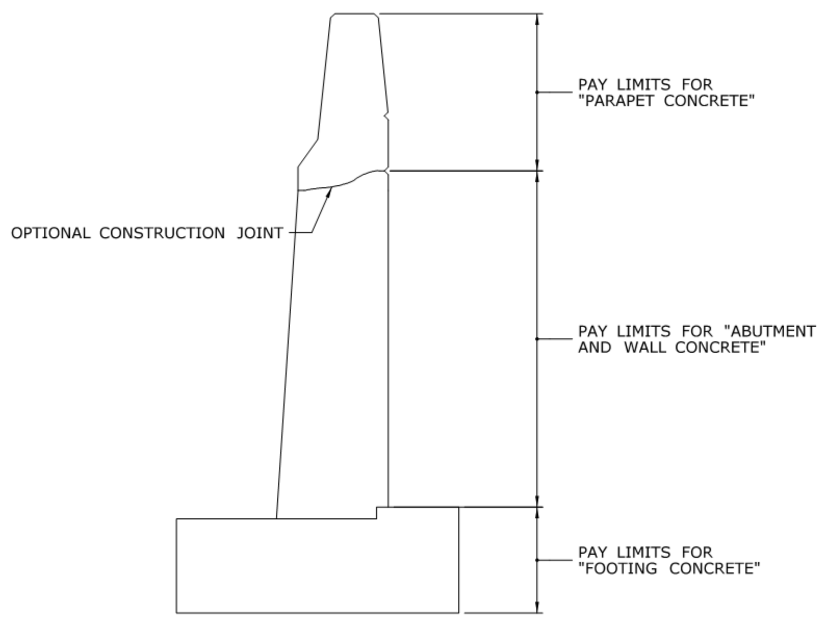
Note that a component such as a concrete curb does not have its own pay item. This component may be measured for payment with the item in the contract whose character of work is most similar. The concrete curb may be included for measurement under the item, “Bridge Deck Concrete,” but if a “Bridge Sidewalk Concrete” item were included in the contract, it would be the preferable item with which to include the concrete curb because the character of work is more similar. If the structure were a box culvert with shallow fill, the contract may not include an item for “Bridge Deck Concrete” or “Bridge Sidewalk Concrete.” In such a case, if the item, “Abutment and Wall Concrete” is included for wingwalls, the curb could be measured for payment under that item. Note that in this situation, the character of work is not a close match, but the volume of concrete in the concrete curb may be small enough to have little effect on the unit bid price for “Abutment and Wall Concrete.” The total cost of the concrete curb will also be affected insignificantly by applying the unit bid price for “Abutment and Wall Concrete.” It would not be necessary to include an additional item exclusively to pay for the small volume of concrete curb.

New items may be created when, in the opinion of the **CTDOT**, no item exists in the Master Bid List that adequately describes the bridge component in question, or when the character of work of similar components is significantly different for a specific situation.

6.3.2.2.2 Plan Requirements

Concrete pay items shall be clearly listed in the General Notes within the plans. Adjacent to each pay item in the General Notes, list the cast-in-place concrete components to be measured for payment under that item. Following the list of components, specify the concrete mix class. Although components are grouped together under a pay item to reflect the character of work, the mix class may vary among components within the pay item. In such a case, separate and group the components in the note by mix class.

Listing pay items and components in the General Notes may not provide sufficient clarity for measuring quantities and distinguishing pay limits between items. To provide clarity, drawings with pay limits may be needed. One such example is the item, “Parapet Concrete.” Where a parapet is constructed at the top of a wall, delineation between the items, “Parapet Concrete” and “Abutment and Wall Concrete” is needed. A convenient limit for this is the optional construction joint between the two components (see Figure 6.3.2.2.3-1). Whether the Contractor elects to construct the wall with the joint or not, the drawing defines the pay limits for the items.



CONCRETE WALL WITH PARAPET PAY LIMITS

NOT TO SCALE

FIGURE 6.3.2.2.3-1

6.3.2.3 Reinforcement

Bar reinforcement shall meet the requirements of ASTM A615, Grade 60, and shall be galvanized after fabrication to the requirements of ASTM A767, Class 1, including supplemental requirements. Other reinforcement may only be specified with the approval of the Bridge Principal Engineer.

The minimum size bar shall be #4, unless otherwise authorized. The minimum cross sectional area of load-carrying reinforcement shall be that supplied by #5 bars spaced at 12 inches. Temperature and shrinkage reinforcement in walls will typically be #5 bars spaced at 18 inches.

Bar spacing shall meet the **LRFD** and, allow for proper placement and consolidation, based on the maximum aggregate size specified for the concrete mix class. It is desirable for the spacing of bar reinforcement to be in 6-inch increments for ease of placement and inspection. However, for bridge decks, columns, pier caps and other components, such a spacing may not be practical. Flexural reinforcement in walls and abutments may be adjusted to 9-inch increments to better align with temperature and shrinkage reinforcement.

Bar lengths shall be specified in 1-inch increments. The maximum length of bar reinforcement detailed shall be 40 feet. Where longer bars are required, splices shall be detailed. The use of mechanical connections to splice reinforcement is permitted, provided the connectors meet the **LRFD**. Mechanical connectors used to splice galvanized reinforcement shall be galvanized. Mechanical connectors shall be measured for payment by the number of connectors installed and accepted.

The designer is responsible for providing all of the details necessary to ensure that the reinforcement is embedded, developed and spliced in accordance with the **LRFD**.

The concrete cover over reinforcement shall conform to the requirements in the **LRFD**, unless otherwise noted. The concrete cover over the reinforcement shall be shown on the plans.

The reinforcement pay items shall be clearly noted on the plans.

6.3.3 Precast, Non-Prestressed Concrete Members

6.3.3.1 General

Precast, non-prestressed superstructure members supporting vehicular traffic are not permitted.

For permanent and temporary precast concrete barrier requirements, see **BDM** [12]. For precast concrete box culvert requirements, see **BDM** [13].

6.3.3.2 Concrete

The design of precast, non-prestressed members shall be based on a minimum concrete compressive strength (f'_c) of not less than 5000 pounds per square inch.

6.3.3.3 Reinforcement

Reinforcement shall conform to the requirements of **BDM** [6.3.2.3].

6.3.4 Precast, Pretensioned Concrete Members

6.3.4.1 Structure/Member Types

6.3.4.1.1 Standard Members *(Rev. 04/19)*

Precast, prestressed concrete members used in superstructures are generally limited to those available from area fabricators. Available member types include solid slabs, voided slabs, box beams, Northeast Bulbtee (NEBT) girders, Northeast Deck Bulb Tee (NEDBT) girders, Northeast Extreme Tee (NEXT) beams and Precast Concrete Economical Fabrication (PCEF) girders. For the latest listing of area fabricators and the bridge members produced, refer to the PCI Northeast website, www.pcine.org.

Prestressed deck units are precast, pretensioned rectangular sections with or without voids. Sections with circular voids are referred to as voided slabs and sections with rectangular voids are referred to as box beams. Sections without voids are referred to as solid slabs.

Prestressed concrete bulb tee superstructure designs should consider the Northeast Bulbtee (NEBT) and the Precast Concrete Economical Fabrication (PCEF) beams with dimensions nominally equivalent to the NEBT dimensions. The prestressing shall be designed based on the NEBT dimensions and section properties, and shall be presented in the contract plan details with the following note to allow the use of the NEBT or PCEF section:

"Prestressed concrete Northeast Bulbtee (NEBT) sections and Precast Concrete Economical Fabrication (PCEF) sections with dimensions nominally equivalent to one another are considered equivalent members for bidding purposes. The Contractor may select either section for fabrication. When selecting the PCEF section, the Contractor shall submit the actual section properties of the PCEF section for the Designer's use in updating the bridge load rating."

6.3.4.1.2 Modifications to Standard Members *(Rev. 04/19)*

6.3.4.1.2.1 NEBT Girders

These girders shall not be altered or modified, except as follows:

- The top flange at the girder ends may be clipped to minimize the bridge seat widths at abutments
- Minor variations of NEBT girders are allowed for equivalent PCEF sections

6.3.4.1.2.2 Prestressed Deck Units

- Where the roadway vertical geometry will allow it, a 6 inch thick (minimum) concrete deck slab shall be cast on top of the prestressed deck units, designed to provide shear transfer between beams, and eliminate the need for transverse post-tensioning. In such cases, holes for post-tensioning shall not be formed in the beams. Shear keys of adequate width shall be shown between adjacent members. Transverse reinforcement from the deck unit shall protrude from the side of the deck unit and be developed within the shear key to assist in distributing loads between beams. An attempt shall be made to design and detail the deck unit width and protruding transverse reinforcement to fit within a form width of 4 feet.
- Prestressed deck units may be modified to facilitate the placement of reinforcement that extends from the tops of the members for components such as parapets and sidewalks or to accommodate drilled-in anchors for temporary precast barrier curb.
- The circular and rectangular voids in the deck units may be reduced in size or removed for placement of the reinforcement. Generally, the voids shall be placed symmetrically about the vertical axis of the member. The designer shall calculate the section properties for the modified sections.
- Spread deck units shall be detailed without shear keys and holes for post-tensioned transverse strands.
- The fascia members of structures composed of butted deck units shall be detailed without a shear key at the outside face, unless provision is being made for a future widening.

6.3.4.2 Layout and Framing

6.3.4.2.1 Approximate Span Lengths *(Rev. 04/19)*

Vacant

6.3.4.2.2 Oversized Members

Precast members over 120 feet in length or over 120,000 pounds will not be allowed due to shipping limitations. For members in excess of 120 feet, the use of field spliced post-tensioned bulb tees should be considered. For additional information, see **BDM** [1].

6.3.4.2.3 Skew Angle

On structures composed of butted deck units, the maximum allowable skew angle is 45 degrees.

6.3.4.2.4 Member Dimensions

Preferably, all members in a span shall have the same dimensions to facilitate fabrication and minimize costs. Generally, on multi-span structures, the individual span lengths may vary but the member depth should be constant.

Preferably, structures composed of butted deck units shall be designed with 3'-11½" wide members. Typically, the cost per square foot of deck surface is less for 3'-11½ " wide members than it is for 2'-11½ " wide members due to high fabrication costs.

If members with varying section properties are used in the same cross section, the distribution of loads must take into account the stiffness of each member. For more information, see **BDM** [3].

6.3.4.2.5 Member Spacing

In structures composed of bulb tee girders or spread deck units, the member spacing should be maximized in order to reduce the number of members required and to develop the full potential of each member, thereby reducing the costs for fabrication, shipping and erection. However, in order to provide redundancy, a minimum of 4 stringer lines should be used in a cross section.

In structures composed of butted deck units, the members shall be placed at a nominal spacing to provide a gap between the adjacent members that accommodates the sweep of the members. The 1'-11½" wide members should be nominally spaced at 3 feet. The 3'-11½" wide members should be nominally spaced at 4 feet. The nominal spacings were determined by increasing the actual member width to a convenient value. The spacings have not been set at the maximum allowable sweep, since it varies with the span length. If the actual sweep of the members will not allow the members to be placed at the nominal spacing shown, the members should be butted up to and placed parallel with the adjacent member.

6.3.4.2.6 Framing Geometry

Members should be placed parallel to traffic and each other, and shall be uniformly spaced as much as practical. If this is unavoidable, the live load distribution factors as outlined in the **LRFD** shall not be used. The designer should carefully investigate these situations to account for the variation in live load and member stiffness.

6.3.4.2.7 Cross Section

Structures composed of bulb tee girders or spread deck units require a composite concrete deck. The deck shall be detailed to match the roadway cross section. The members shall be placed plumb.

On structures composed of butted deck units, the members may be placed on either a straight (level or sloped) or broken cross section alignment. The alignment of the members need not match the roadway cross section. The bituminous concrete overlay shall be placed to match the roadway cross section.

6.3.4.2.8 Deck Overhang

The concrete deck overhang, measured from the centerline of the fascia member to the outside edge of the deck, should be limited to four feet or the depth of the member, whichever is less.

6.3.4.3 Composite Construction

6.3.4.3.1 General

All structural members in contact with and supporting a concrete deck shall be designed for composite action. The members shall be designed assuming construction without shoring (unshored construction).

6.3.4.3.2 Design Requirements

The composite section used for computing live load stresses shall also be used for computing stresses induced by composite dead loads.

The elasticity ratio for composite design shall be computed based on the modulus of elasticity of the concrete deck and the modulus of elasticity of the prestressed concrete member.

The shear reinforcement used in the design of the members should be used to achieve composite action with the deck. Additional reinforcement may be added if the area of shear reinforcement is not sufficient to produce composite action. There is no need to extend all shear reinforcement into the deck if it is not required for composite action.

6.3.4.3.3 Detailing Requirements

Shear reinforcement used for composite action shall be extended into the concrete deck. In deck unit members, the reinforcement shall be fabricated from one bar and have two loops that extend into the deck. In bulb tee members, the reinforcement shall be terminated with a 90 degree hook.

The top surface of the members shall be roughened with a raked finish to assist in composite action. The following note, with a leader pointing to the top surface of the member, shall be shown on the plans:

Raked Finish

6.3.4.4 Continuity on Multi-Span Structures

6.3.4.4.1 General

Deck joints should be eliminated wherever possible. The number of deck joints over piers shall be minimized on multiple span structures by using continuous decks.

6.3.4.4.2 Continuous Decks Supported by Simple Spans

On multi-span structures composed of simple spans, the decks shall be made continuous over the piers with no positive moment connection, wherever practical. The supporting members shall be designed as simple spans.

National Cooperative Highway Research Program (NCHRP) Report Number 322 "Design of Precast Prestressed Bridge Girders Made Continuous" suggests that consideration should be given to the design of jointless bridges (that is, members with a continuous slab with no moment connection), since there is little or no structural advantage to designing for live load continuity.

On structures composed of bulb tee girders or spread deck units, the deck shall be placed continuous over a full height diaphragm. The diaphragm shall be placed at the piers between the ends of the members in adjacent spans and extend transversely between the parallel members.

On structures composed of butted deck units, the ends of the members shall be connected with a "T - shaped" closure pour.

6.3.4.4.3 Continuous Decks Supported by Continuous Members

Multi-span structures composed of continuous spans shall be designed with field spliced post-tensioned bulb tee girders. The bulb tee girders shall be pretensioned to control cracking during shipping and handling. The pretensioning of the girders shall be accounted for in the final design. Field splices in the members should be made near points of low dead load moment.

6.3.4.5 Concrete *(Rev. 04/19)*

The concrete design strength for prestressed members shall be as follows:

- The design of prestressed members shall be based on a minimum concrete compressive strength (f'_c) of not less than 5000 pounds per square inch. The recommended concrete compressive strength is 6500 pounds per square inch. Concrete compressive strengths greater than 6500 pounds per square inch may be used subject to approval by the **CTDOT**.

- The compressive strength of the concrete at the time of transfer (f'_{ci}) shall not be less than 4000 pounds per square inch.

The concrete stresses in the prestressed members shall conform to the **LRFD.**

The required compressive strength at the time of transfer f'_{ci} and the required 28-day compressive strength of concrete f'_c shall be clearly noted on the plans.

6.3.4.6 Reinforcement

6.3.4.6.1 Non-Prestressed Steel *(Rev. 04/19)*

In prestressed concrete members, the non-prestressed steel, including the reinforcement extending out of the units, shall be galvanized bar reinforcement.

The minimum size bar shall be #3. In general, the spacing of bar reinforcement shall be limited to four-inch increments.

Bar lengths, if specified, shall be in one-inch increments. The maximum length of bar reinforcement detailed shall be 40 feet. Where longer bars are required, splices must be detailed.

The designer is responsible for providing all of the details necessary to ensure the reinforcement is embedded, developed and spliced in accordance with the **LRFD**.

The concrete cover over reinforcement shall conform to the requirements in the **LRFD**, unless otherwise noted. The concrete cover over the reinforcement shall be shown on the plans.

The reinforcement pay items shall be clearly noted on the plans.

6.3.4.6.2 Prestressed Steel

The prestressing strands shall be tensioned to the allowable stresses listed in the **LRFD**.

Typical strand patterns and the maximum number of strands for the various prestressed members are shown in **BDM** [Division 3]. Generally, the strands are spaced two inches apart, both horizontally and vertically. The strand patterns are for design purposes only and shall not be shown on the plans.

Preferably, all members in a span shall have the same number of strands, prestressing force and distance to the center of gravity of the strands to facilitate fabrication and minimize costs.

Strands may be either draped or de-bonded to reduce the tensile stresses at the member ends. Mixing draped and de-bonded strands in a member is permitted.

If draped strands are used, the total hold down force of all the draped strands for each member should not exceed 75% of the total weight of the member.

If de-bonded strands are used, no more than 25% of the total number of strands may be de-bonded. All de-bonding shall be located within a distance of 15% of the span length from the end of the member. The de-bonded strands shall be well distributed across the member cross section. No two adjacent strands (either horizontally or vertically) shall be de-bonded, although diagonally adjacent strands may be de-bonded. The outermost strands of each layer shall not be de-bonded.

The following information shall be shown on the plans:

- the ultimate tensile strength of the strands,
- the jacking force per strand,
- the number of strands,
- the center of gravity of strands,
- the strand diameter,
- de-bonding locations (if required), and
- the approximate location of drape points (if required).

6.3.4.7 Camber

6.3.4.7.1 General

Camber induced by prestressing shall be computed in such a manner as to include the effects of creep and growth in the modulus of elasticity. Sufficient camber should be induced in each member such that a net positive camber will remain under all dead loads.

6.3.4.7.2 Simple Spans

Dead load deflection and camber diagrams are not required for simple span bridges. Dead load deflections and cambers shall be calculated at the mid-span of the structure for the following listed items for each member and tabulated on the plans:

- <u>Prestressed Beam Deflections</u>. Deflections due to the weight of the beams calculated using the moment of inertia of the prestressed beam.
- <u>Additional Dead Load Deflections</u>. Deflections due to the uncured concrete slab, haunches, diaphragms, utilities and any other loads supported by the prestressed beam section alone.
- <u>Composite Dead Load Deflections</u>. Deflections due to the parapets, curbs, sidewalks, railings, bituminous concrete overlay and any other loads that are placed after the slab has cured and are supported by the composite section. (Structures composed of prestressed beams with a composite deck only).
- Member Cambers (calculated at the following stages):

- At Transfer. Camber due to pretensioning force at transfer minus the deflection due to the dead load of the member.
- At Erection. Camber (due to pretensioning force minus the deflection due to the dead load of the member) that is present at approximately 30 days after transfer.
- Final. Camber after all dead loads are applied to the structure, and after long term creep and relaxation have taken place.

An acceptable method for estimating cambers and deflections in simple span members using multipliers can be found in the "PCI Design Handbook - Precast and Prestressed Concrete."

6.3.4.7.3 Continuous Spans

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6.3.4.8 Diaphragms

Structures composed of prestressed concrete beams with a composite concrete deck shall have intermediate and end diaphragms.

On bridges with spans less than or equal to 80 feet, one intermediate diaphragm shall be placed between the members at mid-span. On bridges with spans greater than 80 feet, intermediate diaphragms shall be placed between the members at third points along the span.

On bridges skewed less than or equal to 30 degrees, the intermediate diaphragms shall be placed in line along the skew. On bridges skewed more than 30 degrees, intermediate diaphragms shall be placed normal to the main members and staggered, not placed in a line, across the width of the bridge.

End diaphragms shall be placed between members at all abutments and piers. End diaphragms shall be placed over and aligned with the centerline of each bearing line.

Intermediate and end diaphragms shall be comprised of cast-in-place concrete and be monolithic with the concrete deck. The use of steel diaphragms will not be permitted. The intermediate and end diaphragms shall be detailed to accommodate utilities as required. Diaphragms shall be completely cured prior to placement of the deck concrete in order to provide stability to the superstructure members.

6.3.4.9 Post-Tensioned Transverse Strands

Structures composed of deck units placed butted to each other without a composite deck shall be post-tensioned transversely with prestressing strands.

The number and location of these transverse ties is dependent upon the following: the length of the member, the depth of the member, the skew angle of the structure, and stage construction. Based on the skew angle of the structure, the ties may be placed parallel to the skew of the structure or normal to the sides of the member. See Division III for additional details.

The appropriate post-tensioning procedure along with the following note shall be shown on the plans:

No additional dead loads or live loads shall be applied to the butted deck units until the transverse ties have been fully tensioned and the grout in the longitudinal shear keys has reached a seven-day compressive strength of 4500 psi.

The transverse strands shall be post-tensioned in accordance with one of the following procedures:

For structures with skew angles less than or equal to 30 degrees:

TRANSVERSE STRAND POST-TENSIONING PROCEDURE

1. After erecting the prestressed deck units for the construction stage, install the transverse ties.

2. Tension each transverse tie to 5 kips.

3. Seal the bottom of the longitudinal shear keys with closed cell polyethylene foam backer rod and place non-shrink grout in the longitudinal shear keys and internal diaphragms. The grout shall be rodded or vibrated to ensure that all the voids in the shear keys are filled.

4. On shallow members with <u>one</u> row of ties, include the following note:

   When the grout has attained a compressive strength of 1500 psi, tension each transverse tie to 30 kips.

   On deep members with <u>two</u> rows of ties, include the following note:

   When the grout has attained a compressive strength of 1500 psi, at each transverse tie location tension the bottom tie to 15 kips, then the top tie to 15 kips. Repeat this tensioning sequence once more so that each tie is tensioned to 30 kips.

NOTE: Where the total initial post-tensioning force of all the transverse ties is sufficient to displace the exterior members, the designer shall modify the post-tensioning procedures to require placement of hardwood shims between the members. The designer shall specify the number and location of these shims. The shims shall be placed between as many members as is required such that the total initial post-tensioning force does not displace any members.

For structures with skew angles greater than 30 degrees:

TRANSVERSE STRAND POST-TENSIONING PROCEDURE

1. As each member is being erected, install the transverse ties and place hardwood shims between the adjacent deck units at each transverse tie hole location on the top and bottom.

2. On shallow members with one row of ties, include the following note:

   Secure each member to the preceding member by tensioning each transverse tie to 30 kips before erecting the next member.

   On deep members with two rows of ties, include the following note:

   Secure each member to the preceding member by first tensioning the bottom tie at each transverse tie location to 15 kips, then the top tie to 15 kips. Repeat this tensioning sequence once more so that each tie is tensioned to 30 kips.

3. After all the members have been erected, seal the bottom of the longitudinal shear keys with closed cell polyethylene foam backer rod and place non-shrink grout in the longitudinal shear keys and internal diaphragms. The grout shall be rodded or vibrated to ensure that all the voids in the shear keys are filled.

4. When the grout has attained a compressive strength of 1500 psi, remove the hardwood shims. The voids left in the grout from the top shims shall be filled with grout. The voids in the grout from the bottom shims may be left unfilled.

6.3.4.10 Drilling Holes

The drilling of holes in (or the use of power actuated tools on) prestressed members shall not be permitted. However, inserts for attachments may be placed in the members during fabrication.

The following note shall be shown on the plans:

The drilling of holes in (or the use of power actuated tools on) prestressed members will not be permitted.

6.3.4.11 Seismic Restraint

6.3.4.11.1 General

All structures shall include restraint devices or connections, such as keeper blocks, bearings or dowels, designed to transfer seismic forces from the superstructure to the substructure.

The design and detailing of the restraint devices or connections shall account for thermal movement of the structure.

6.3.4.11.2 Transverse Seismic Restraint

On structures composed of prestressed concrete beams, supported by seat type abutments, the superstructure shall be restrained transversely by a keeper block placed between the center members at abutments. If necessary, multiple keeper blocks may be used at each abutment to resist the forces. At piers supporting members with a continuous deck, the superstructure shall be restrained with dowels projecting from the pier into the full height diaphragm. At piers supporting members with a discontinuous deck, the superstructure shall be restrained transversely by a keeper block placed between the center members at abutments.

On structures composed of butted deck units, the superstructure shall be restrained transversely by cheekwalls located at each end of the abutments and piers.

6.3.4.11.3 Longitudinal Seismic Restraint

On structures composed of bulb tee girders or spread deck units, the superstructure shall be restrained longitudinally by keeper blocks placed behind the end of each member at abutments after their erection.

On structures composed of butted deck units, the superstructure shall be restrained longitudinally by a backwall placed behind the ends of the members at the abutments after their erection.

6.3.4.12 Bearings

In general, elastomeric bearings shall be used to support prestressed deck units and prestressed concrete girders. The bearings may be either plain or steel-laminated.

On structures composed of butted deck units, the use of a single sheet of elastomer, placed continuous between the fascia units, is not permitted. Each deck unit shall rest on two individual bearings.

For additional bearing requirements, see **BDM** [9].

6.3.4.13 Superstructure Jacking Requirements

6.3.4.13.1 General

Since future maintenance of the elastomeric bearings is not anticipated, provisions for jacking the superstructure of prestressed concrete bridges supported by elastomeric bearings are not required. For other prestressed concrete bridges that incorporate sliding bearings, the following provisions shall apply.

6.3.4.13.2 Design Requirements

Provisions for jacking of the superstructure shall be provided at all locations that have bearings that will require future maintenance. These bearings include all types that have sliding or rolling surfaces such as pot, disc, spherical, etc. Supports designed with non-sliding type bearings such as elastomeric and fixed steel bearings do not need to have jacking provisions specifically designed.

Lift points shall be located adjacent to the bearings and may be on main or secondary members. Preferably, lift points shall be over the bridge seats of abutments and the tops of piers so that jacks may be founded on these components minimizing the need for extensive temporary structures.

The jacking lift points shall be designed for the total dead load and the live load plus impact. If there are more than five lines of girders, the jacking lift points shall be designed for 150% of these values in order to jack individual girders in the future.

Superstructure and substructure members and components shall be strengthened as required to support the jacking loads.

6.3.4.14 Utilities

On structures composed of prestressed concrete girders or spread deck units, the utilities may be placed between adjacent members. The intermediate and end diaphragms shall be detailed to accommodate utilities as required.

On structures composed of butted deck units, the utilities may be placed between two members in a utility bay located under a sidewalk. Under no circumstances will utilities be permitted to be located inside deck units.

For additional information, see **BDM** [15].

6.3.5 Cast-In-Place Concrete Beams

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6.3.6 Precast, Post-Tensioned Concrete Beams

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