Prestress - Post Tensioned Concrete

Civil Engineering Construction & Graphics

Lecture # 25

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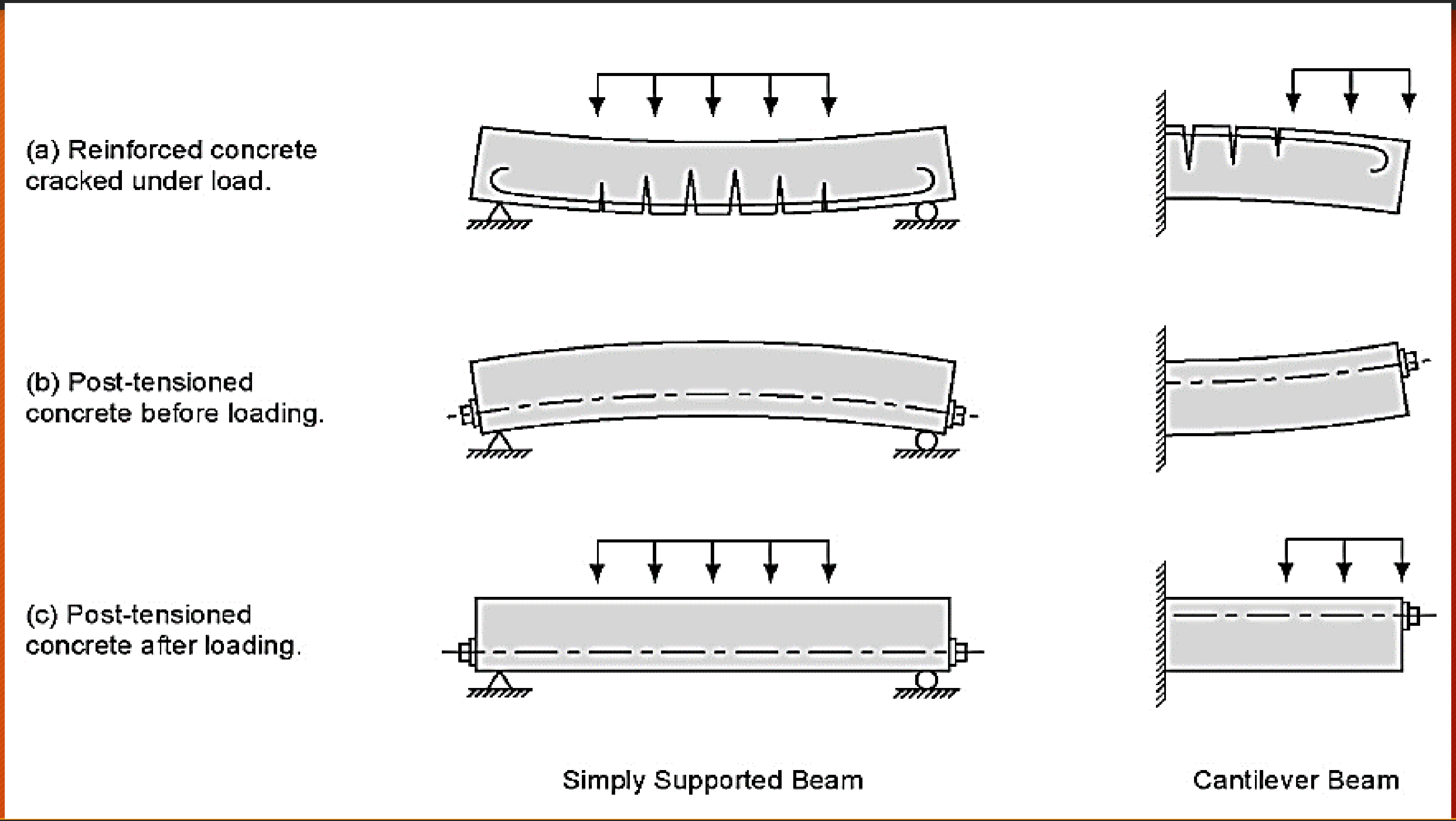
Pre-tensioned Concrete

- Pre-tensioned concrete is cast around already tensioned tendons.
- This method produces a good bond between the tendon and concrete, which both protects the tendon from corrosion and allows for direct transfer of tension.
- The cured concrete adheres and bonds to the bars and when the tension is released it is transferred to the concrete as compression by static friction.
- However, it requires anchoring points between which the tendon is to be stretched, and the tendons are usually in a straight line.
- Thus, most pre-tensioned concrete elements are prefabricated in a factory, and must be transported to the construction site, which put limits their size.
- Pre-tensioned elements in buildings may be balcony elements, lintels, floor slabs, beams or foundation piles.

Prestress - Post Tension Concrete Construction
Pre-tensioned Concrete



Prestress - Post Tension Concrete Construction
Post-tensioning

- In this method, the prestress is induced or tendons are tensioned only after the concrete has hardened.
- The concreting is done first and a duct is formed in the member with tube or with a metal sheathe.
- When concrete has sufficiently hardened then tendons or cable is passed from the tendon to the member through anchorage wedges. The space between the tendon and the duct is filled with cement grout.
- Post tensioning method of prestressing is used for both precast and cast in situ construction.
- The ducts for the tendons (or strands) are placed along with the reinforcement before the casting of concrete.
- The tendons are placed in the ducts after the casting of concrete.
- The duct prevents contact between concrete and the tendons during the tensioning operation.

Prestress - Post Tension Concrete Construction

Post-tensioning

- It is usually in-situ operation, used in large projects such as continuous long-span bridges.
- Use metal sheath to form a duct or use plastic duct instead.
- Use small number of large tendons as oppose to large number of strands in pretensioned concrete:
  - Pretensioned rely on bond between concrete and steel, thus we wish to maximize bond surface, whereas in post-tensioned we rely on mechanical anchorage at the ends.
  - Fewer larger tendons results in less labor.

Prestress - Post Tension Concrete Construction
Post-tensioning

- In post-tensioned members, tendons are usually grouted after anchorage to prevent corrosion:
  - Cement or epoxy grout, called bonded members
  - Grease or no grout, called unbonded members

- Grout is pumped into duct under pressure to ensure its full.
- The behavior of bonded and unbonded is the same until before cracking, cracking, after cracking they are different.

Prestress - Post Tension Concrete Construction
Bonded Post-tensioned Concrete

- Bonded post-tensioned concrete is the descriptive term for a method of applying compression after pouring concrete and the curing process (in situ).
- The concrete is cast around a plastic, steel or aluminium curved duct, to follow the area where otherwise tension would occur in the concrete element.
- A set of tendons are fished through the duct and the concrete is poured.
- Once the concrete has hardened, the tendons are tensioned by hydraulic jacks that react against the concrete member itself.
- When the tendons have stretched sufficiently, according to the design specifications (see Hooke's law), they are wedged in position and maintain tension after the jacks are removed, transferring pressure to the concrete.

Prestress - Post Tension Concrete Construction
Bonded Post-tensioned Concrete

- The duct is then grouted to protect the tendons from corrosion.
- This method is commonly used to create monolithic slabs for house construction in locations where expansive soils (such as adobe clay) create problems for the typical perimeter foundation.
- All stresses from seasonal expansion and contraction of the underlying soil are taken into the entire tensioned slab, which supports the building without significant flexure.
- The advantages of this system over un-bonded post-tensioning are:
    1. Large reduction in traditional reinforcement requirements as tendons cannot distress in accidents.
    2. Tendons can be easily 'weaved' allowing a more efficient design approach.
    3. Higher ultimate strength due to bond generated between the strand and concrete.
    4. No long term issues with maintaining the integrity of the anchor/dead end.

Prestress - Post Tension Concrete Construction
Un-bonded Post-tensioned Concrete

- Un-bonded post-tensioned concrete differs from bonded post-tensioning by providing each individual cable permanent freedom of movement relative to the concrete.
- To achieve this, each individual tendon is coated with a grease (generally lithium based) and covered by a plastic sheathing formed in an extrusion process.
- The transfer of tension to the concrete is achieved by the steel cable acting against steel anchors embedded in the perimeter of the slab.
- The main disadvantage over bonded post-tensioning is the fact that a cable can distress itself and burst out of the slab if damaged (such as during repair on the slab).

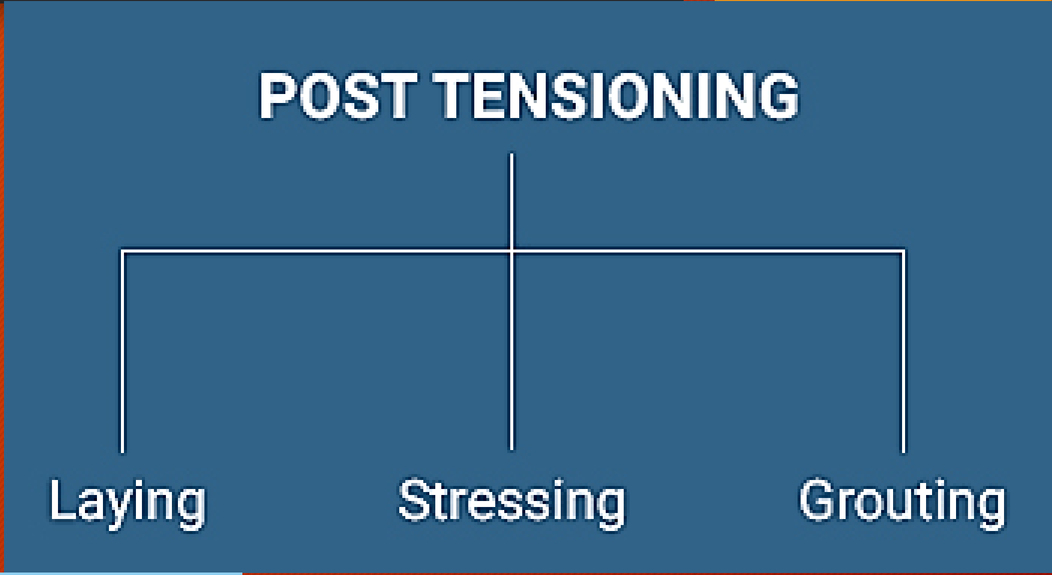
Prestress - Post Tension Concrete Construction
Un-bonded Post-tensioned Concrete

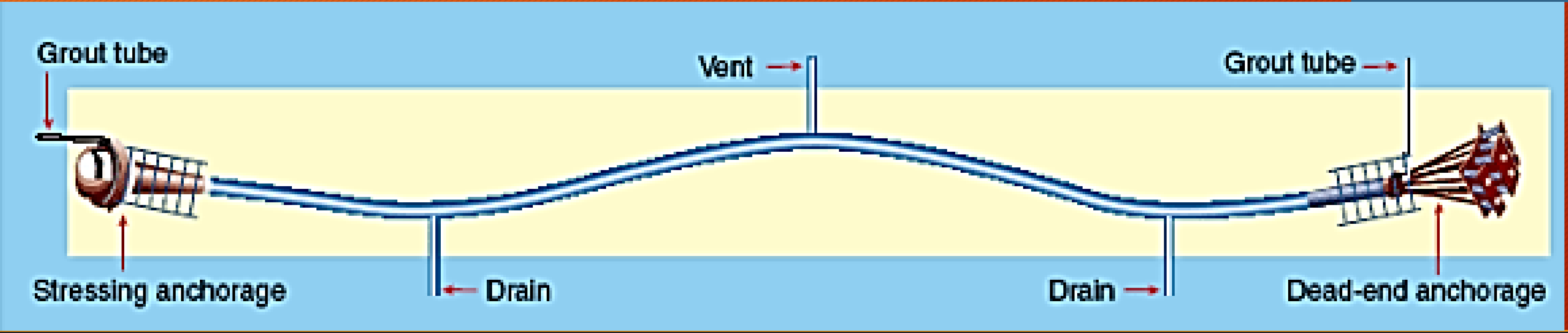
The advantages of this system over bonded post-tensioning are:

1. The ability to individually adjust cables based on poor field conditions (For example: shifting a group of 4 cables around an opening by placing 2 to either side).
2. The procedure of post-stress grouting is eliminated.
3. The ability to de-stress the tendons before attempting repair work.

Prestress - Post Tension Concrete Construction
Post-tensioning Sequence

1. Casting of concrete.
2. Placement of the tendons.
3. Placement of the anchorage block and jack.
4. Applying tension to the tendons.
5. Seating of the wedges.
6. Cutting of the tendons.

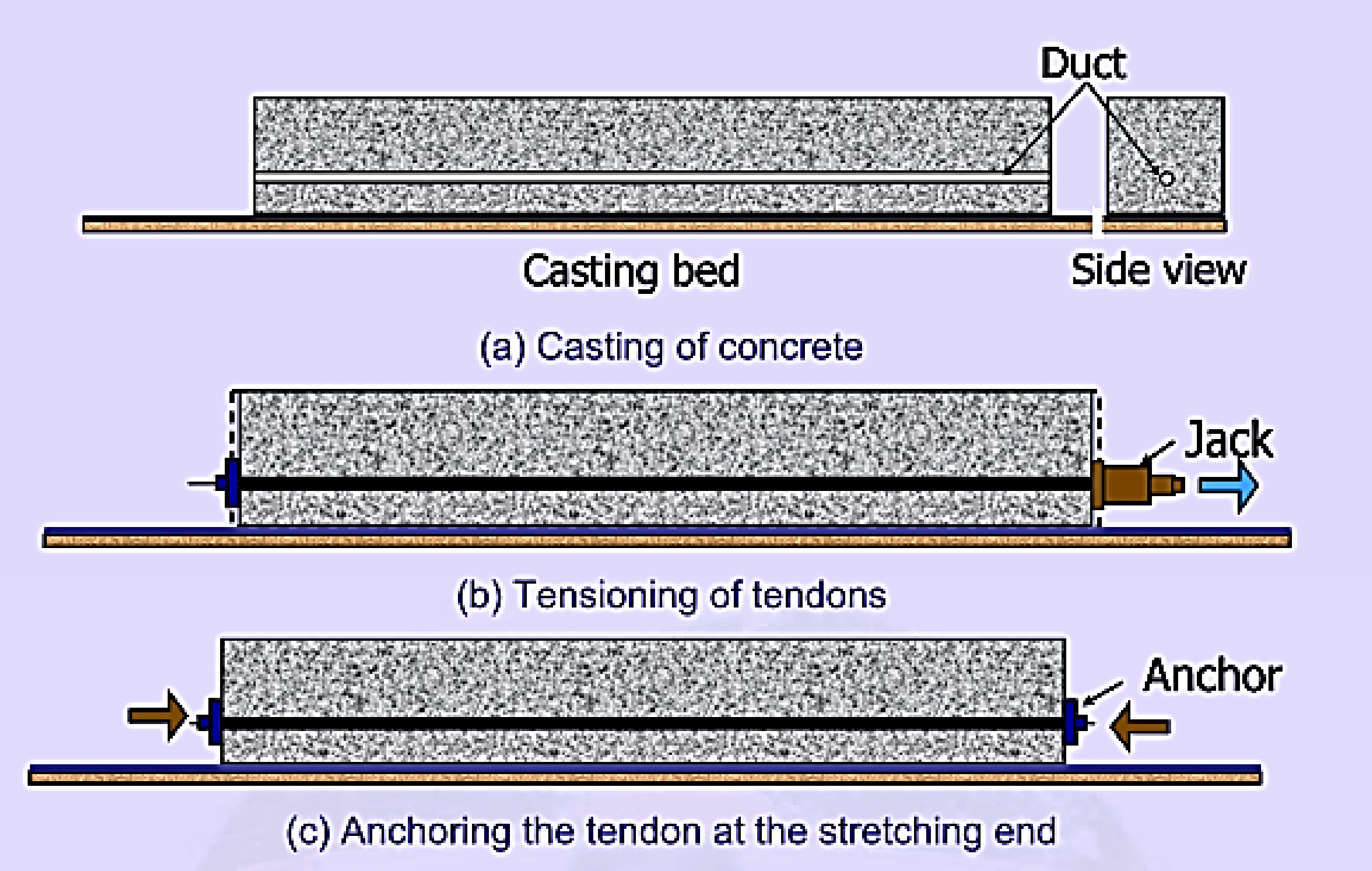




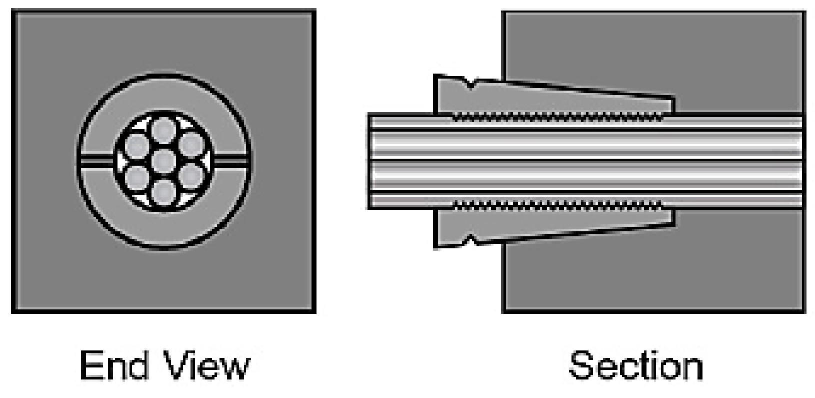
comparison between the pre tensioning and post tensioning method

Sr. No.	Pre-tensioning method	Post tensioning method
1	It is done in the factories thus suitable for precast construction works	It can be done in factories as well as on the site
2	Small sections are to be constructed	Size of member is not restricted, long span bridges are constructed by post tensioning
3	Loss of prestress is more (about 18 %)	Loss of prestress is less (about 15 %)
4	It is cheaper because the cost of sheathing is not involved	It is costlier because of the use of sheathing
5	It is more reliable and durable	The durability depends upon the two anchorage mechanism

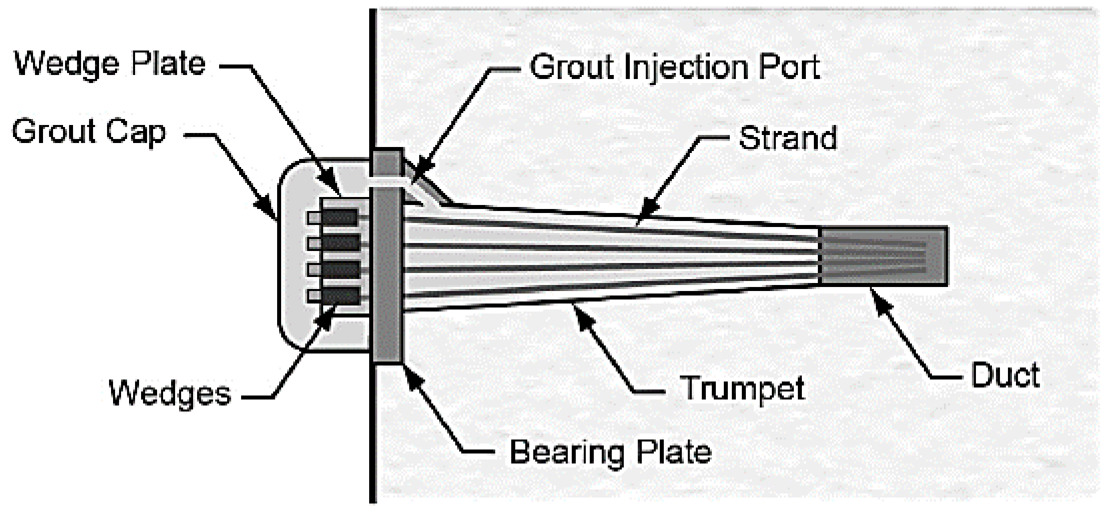
Prestress - Post Tension Concrete Construction
Schematic of Post-tensioning stages



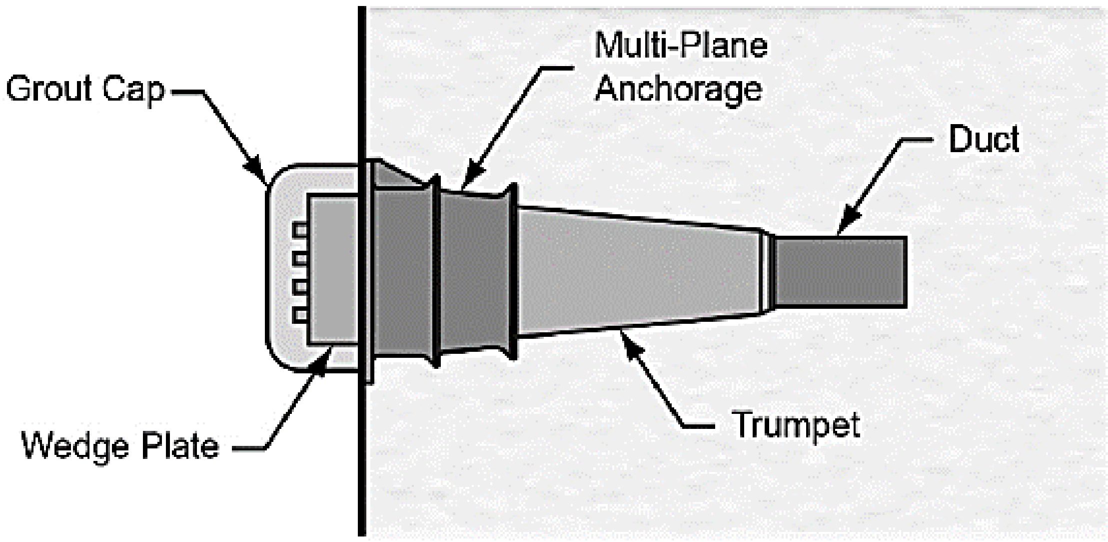
Prestress - Post Tension Concrete Construction
Anchoring Devices - Strand Tendons Anchorage



2-Part Wedge
(3-part wedges also available)



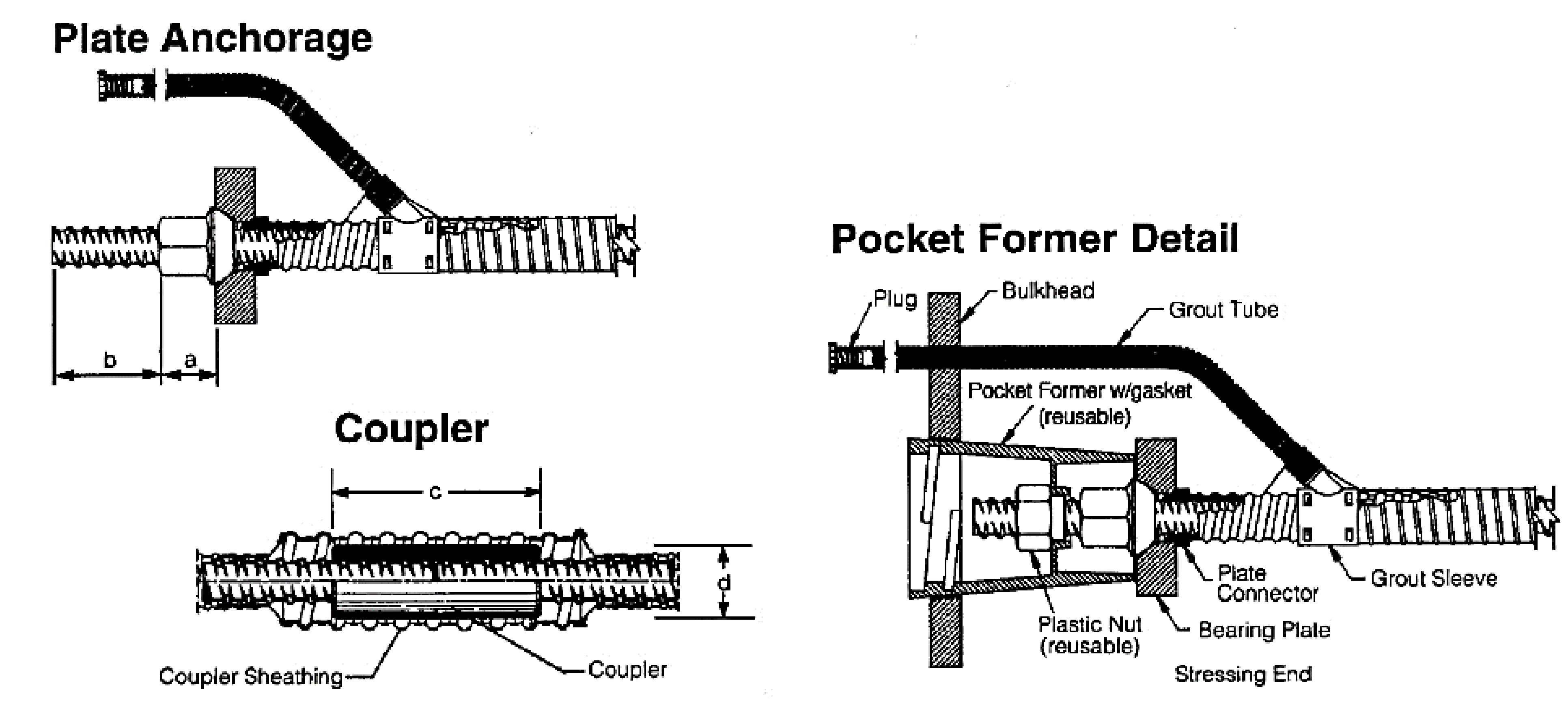
Normal Anchorage
(Plate Anchorage Shown)



Special Anchorage
(Multi-Plane Anchorage Shown)

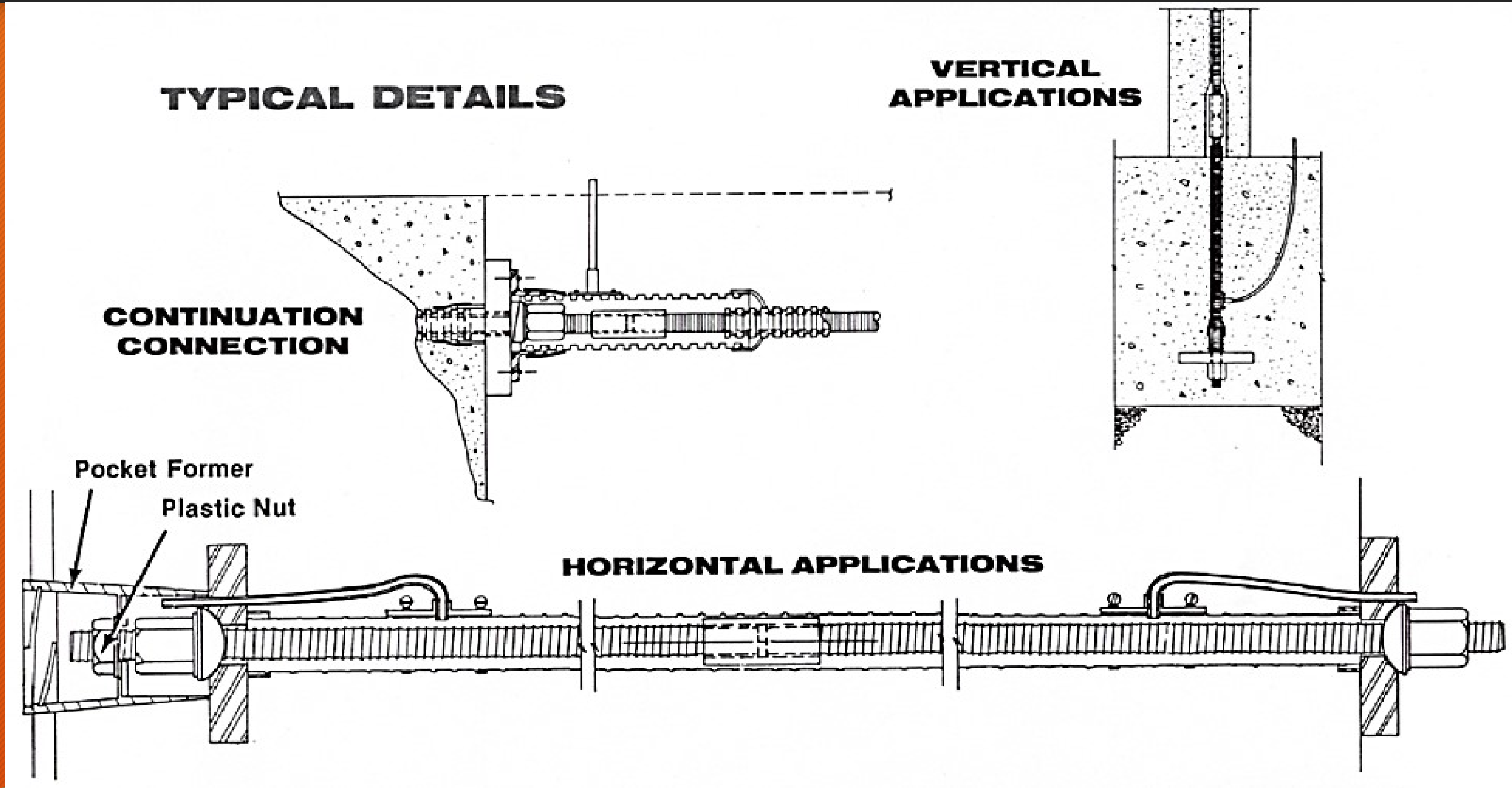
Typical Post-Tensioning Anchorage Hardware for Strand Tendons

Prestress - Post Tension Concrete Construction
Anchoring Devices - Bar Anchorage



Typical Post-Tensioning Bar System Hardware

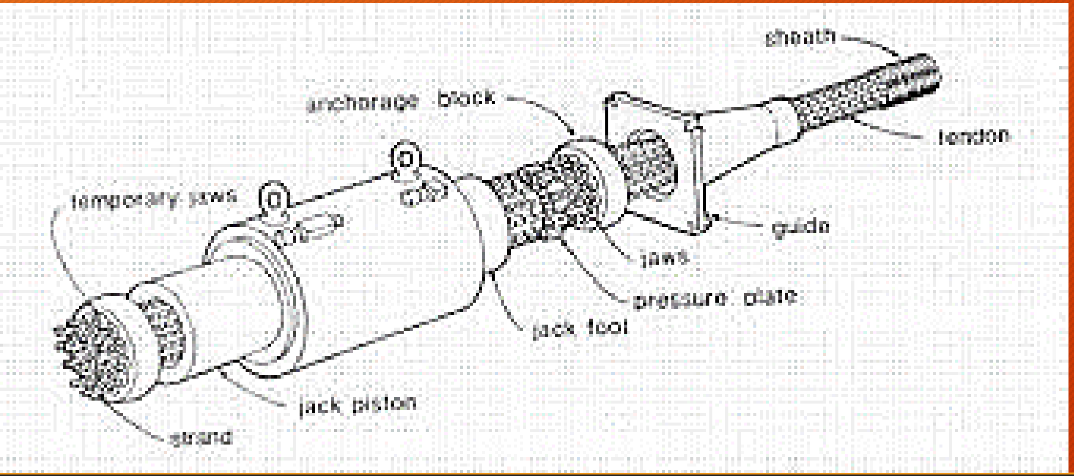
Prestress - Post Tension Concrete Construction
Anchoring Devices - Bar Anchorage

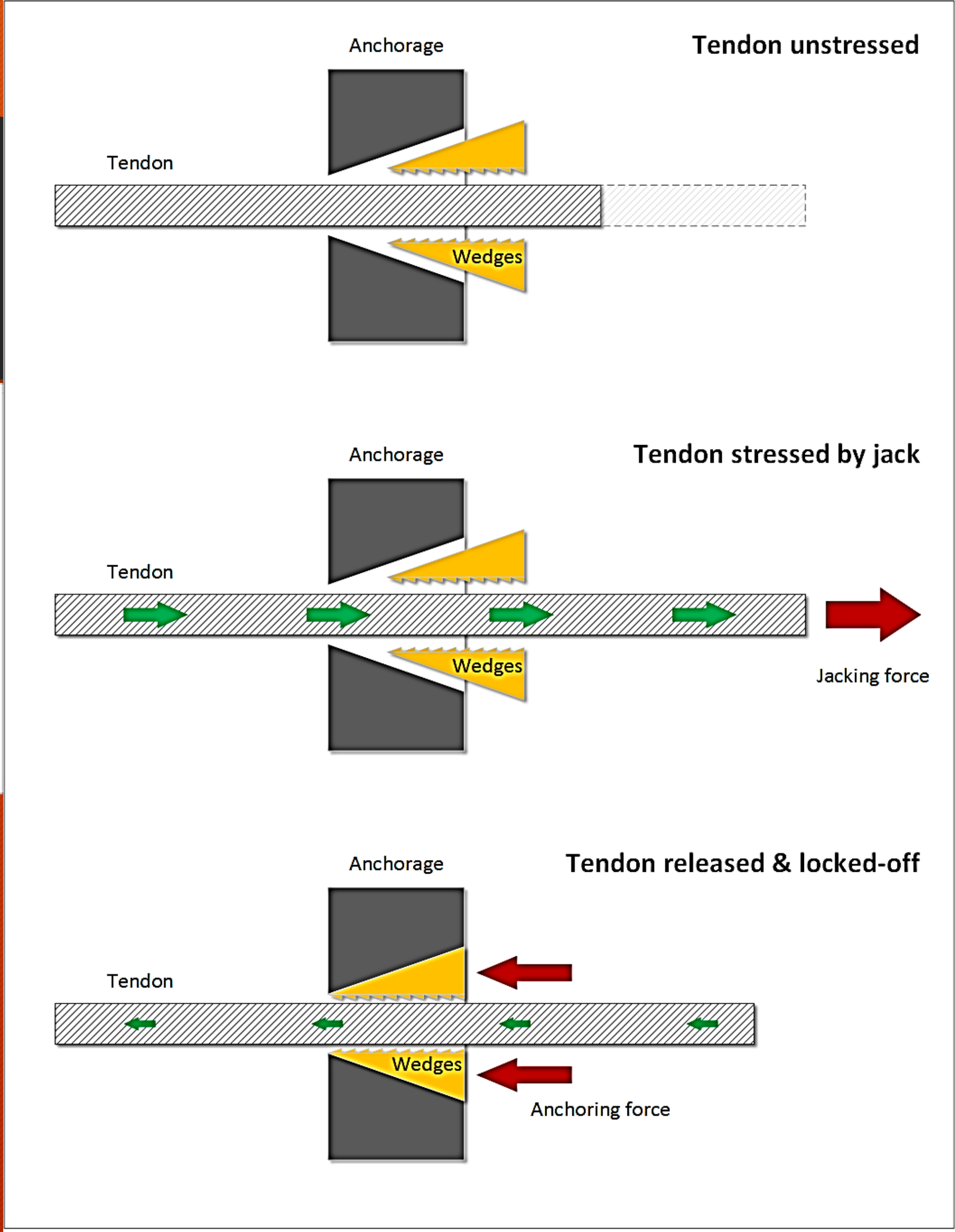


Typical Post-Tensioning Bar System Hardware

Prestress - Post Tension Concrete Construction
Jacking and Anchoring with Wedges

Anchoring devices are used to enable the tendon to impart and maintain prestress in concrete; often made on the Wedge andFriction Principle.





Wedge Anchoring System

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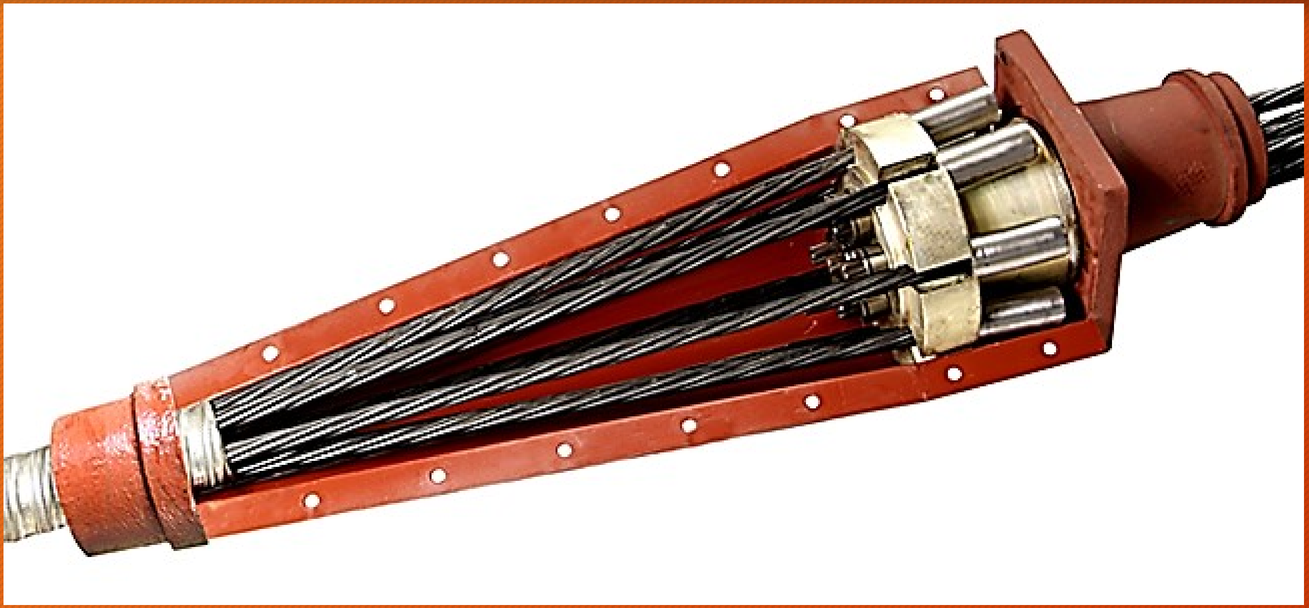
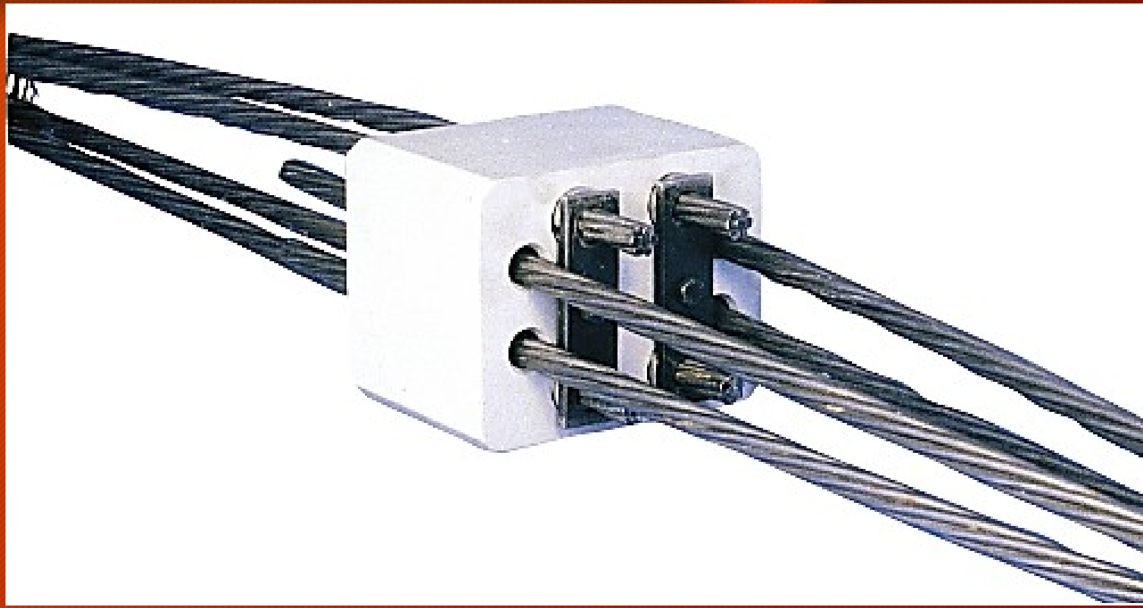
Prestress - Post Tension Concrete Construction

Couplers for Strands





Grouting Equipment

Prestress - Post Tension Concrete Construction

Post-tensioned Bridge Girders

(1) Fabrication of reinforcement

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Prestress - Post Tension Concrete Construction
Post-tensioned Bridge Girders
(2) Placement of tendons

Prestress - Post Tension Concrete Construction
Post-tensioned Bridge Girders
(3) Stretching and anchoring of tendons

Prestress - Post Tension Concrete Construction

Post-tensioned Bridge Girders

(4) Reinforcement cage for box girder

Prestress - Post Tension Concrete Construction
Post-tensioned Bridge Girders
(5) Formwork for box girder

Prestress - Post Tension Concrete Construction
Post-tensioned Bridge Girders
(6) Post-tensioning of box girder

Prestress - Post Tension Concrete Construction
Post-tensioned Bridge Girders
(7) Transporting of box girder

Prestress - Post Tension Concrete Construction
Post-tensioned Bridge Girders
(8) Completed bridge

Precast Concrete Construction
Precast Concrete in Bridges

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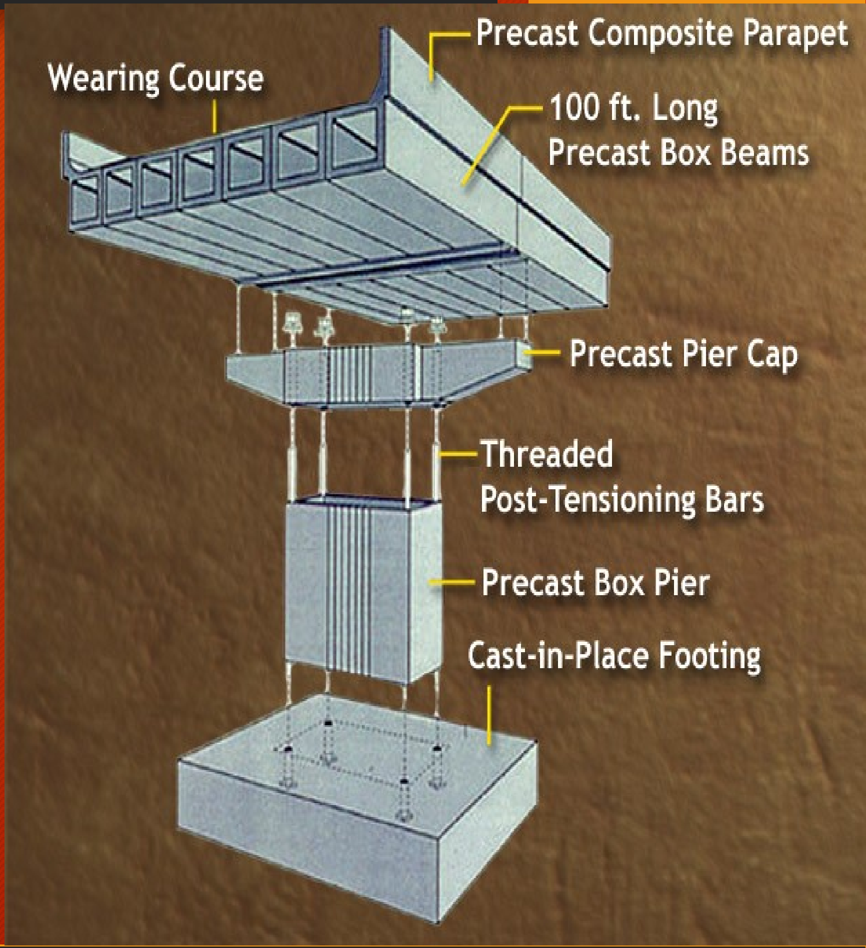
Precast Concrete Construction
Precast Concrete in Bridges

- Bridge can be also construct with precast.
- Parts of a bridge, Substructures and Superstructures
- In Pakistan, growth of precast in bridge is slow
- But, Precast is growing continues very rapidly in other countries, not only for bridges in the short span range, but also for spans in excess of 45m.
- Based on type of bridge and site condition method of construction is to be adopted.



Precast Concrete Construction
Types of Bridges

1. Culvert
2. T-beam Deck Slab Bridge
3. Arch Bridge
4. Cantilever Bridges
5. Continuous Bridges
6. Suspension Bridges
7. Cable-stayed Bridges

Precast Concrete Construction
Advantages

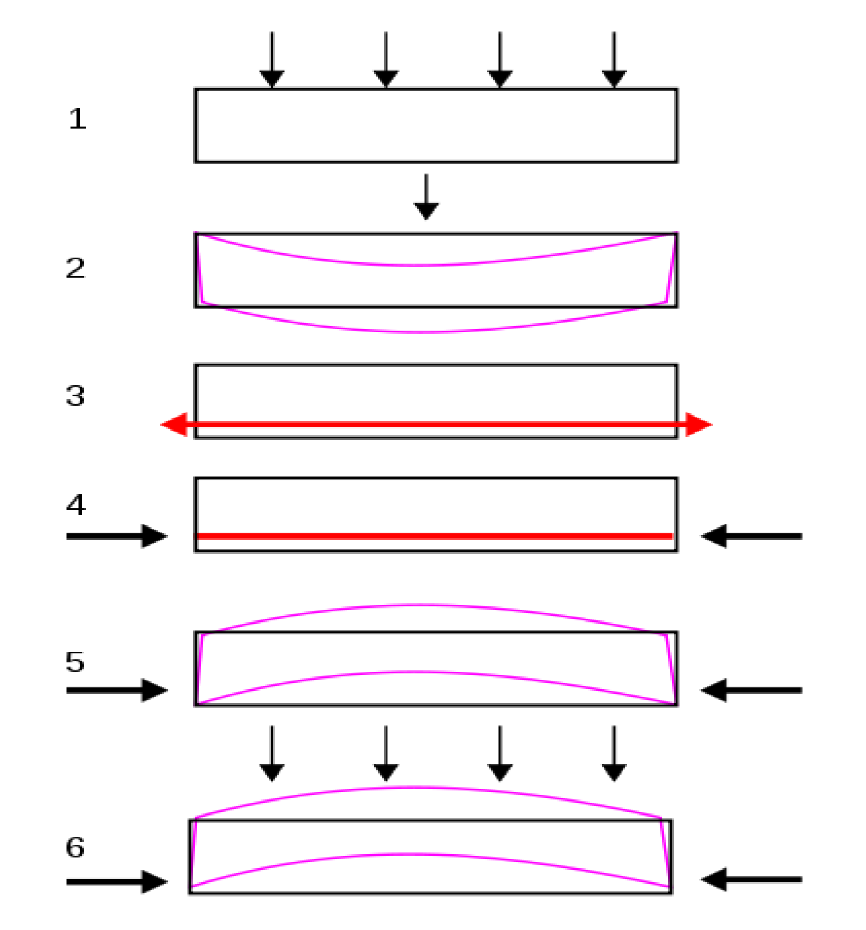
- Prestressed concrete bridges are usually lower in first cost than all other types of bridges.
- With savings in maintenance, precast bridges offer maximum economy.
- Every operation in the manufacturing process provides a point of inspection and control over quality
- Faster construction
- Formwork of the superstructure can be eliminate
- Piers, Abutments, and wing walls can be made of precast concrete pieces quickly assembled on the field.
- Precast concrete bridges can be installed during all seasons
- The durability of precast prestressed concrete bridge is good and resulting in low maintenance requirements.
- No painting is needed.
- Greater fire resistance and design aesthetic is another advantage.

Precast Concrete Construction
Precast Bridge Construction

- T-Beam deck slab bridge
- Simplest type of Precast bridge,
- Substructure is cast in situ
- In superstructure, Main girders are precast post tensioned, casted away from site and are transported to site.
- Secondary girders and Deck slab are casted on precast post tensioned girders on site or precast slab can be used.

Precast Concrete Construction
Prestressed Girders

- Post tensioning technique is to be used in girders
- In post tensioning, the concrete units are casted by incorporating duct to house the tendons, when concrete attains sufficient strength, high-tension wires are tensioned by means of jacks, after then the duct is grouted.
- Forces are transmitted to the concrete at the end anchorage.



Precast Concrete Construction
Permanent Post-Tensioned Applications
1. Cast-in-Place Bridges on Falsework

- Bridges of this type have a superstructure cross-section of solid or cellular construction.
- They are built on-site using formwork supported by temporary falsework.
- Formwork creates the shape of the concrete section and any internal voids or diaphragms.
- Reinforcement and post-tensioning ducts are installed in the forms and then the concrete is placed, consolidated and cured.

Precast Concrete Construction
Permanent Post-Tensioned Applications
1. Cast-in-Place Bridges on Falsework

- When the concrete attains sufficient strength, post-tensioning is installed and stressed to predetermined forces.
- Longitudinal post-tensioning typically comprises multi-strand tendons draped along the length of the girder to a designed profile.
- In continuous spans, the tendon profile lies in the bottom of the girder in the mid-span region and rises to the top of the section over interior supports.
- In simple spans and at the expansion ends of continuous spans, post-tensioning anchors are arranged vertically so that the resultant of the tendon anchor force passes close to the centroid of the section.
- A draped profile of this type provides the most effective distribution of internal prestress for this type of construction.

Precast Concrete Construction
Permanent Post-Tensioned Applications
2. Post-Tensioned AASHTO, Bulb-T, and Spliced Girders

- Post-tensioning ducts that are cast into the webs are spliced at the cast-in-place joints.
- The ducts follow a smoothly curved, draped profile along each girder line, rising to the top of the girders over the interior piers and draping to the bottom flange in mid-span regions.
- Before the deck slab is cast, some or all of the tendons running the full length of the multi-span unit are installed and stressed, making each simple span I-girder into a series of continuous spans.



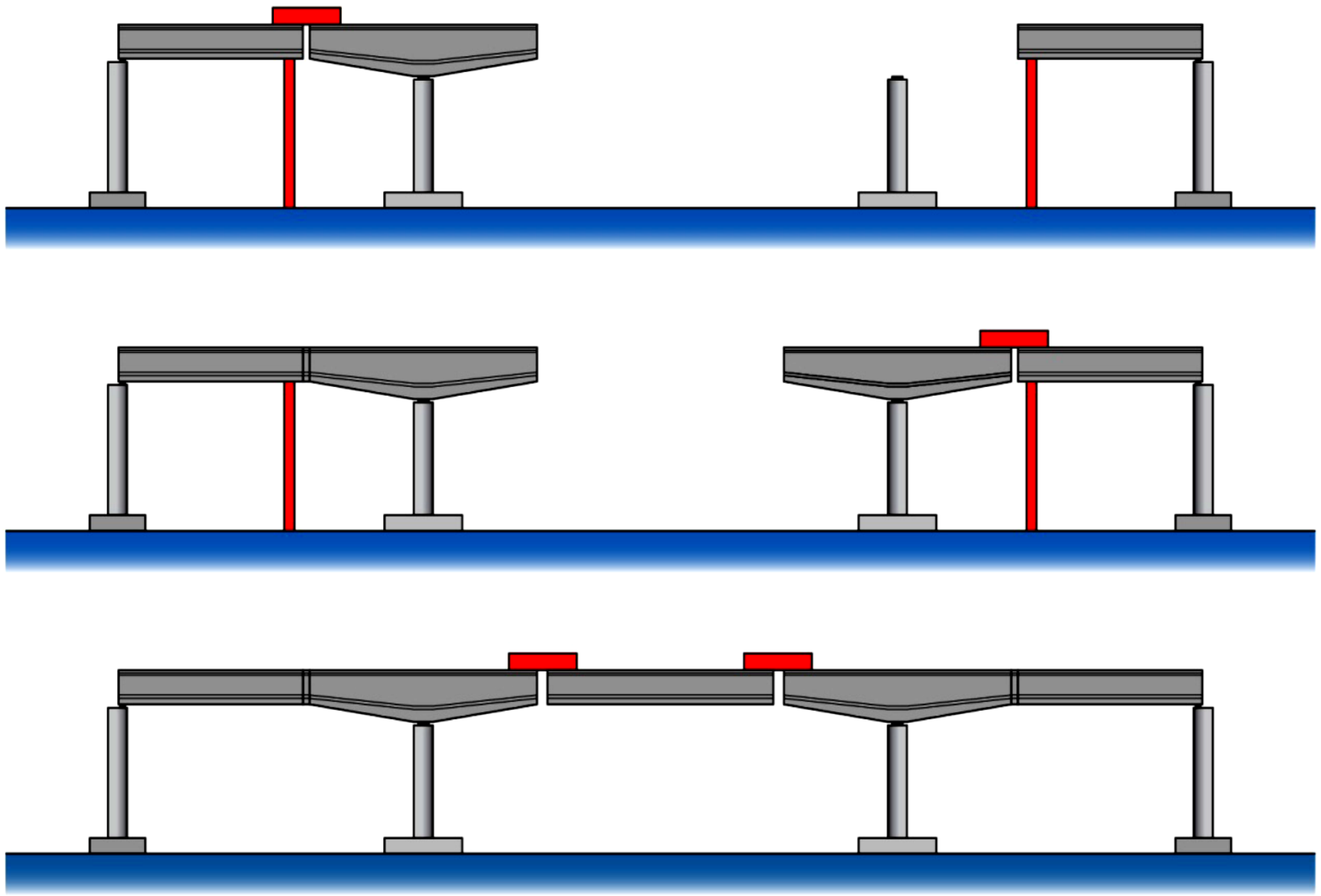

Permanent Post-Tensioned Applications

2. Post-Tensioned AASHTO, Bulb-T, and Spliced Girders

- When the deck slab has been cast and cured, additional tendons may be installed and stressed on the fully composite section. Tendons may be anchored in a variety of configurations at the ends of each continuous unit.
- Longer spans can be built using similar techniques. A variable depth girder section cantilevering over a pier can be spliced to a typical precast girder in the main and side-spans.
- Temporary supports are needed at the splice location in the side spans. The ends of girders have protruding mild reinforcing to help secure the girder to the closure concrete and ducts that splice with those of other girder segments to accommodate tendons over the full length of the main unit.
- The variable depth girder sections are placed over the piers, aligned with the girders of the side spans, and closures cast. Usually, temporary strong-back beams support the drop-in girder of the main span while closures are cast.

2. Post-Tensioned AASHTO, Bulb-T, and Spliced Girders

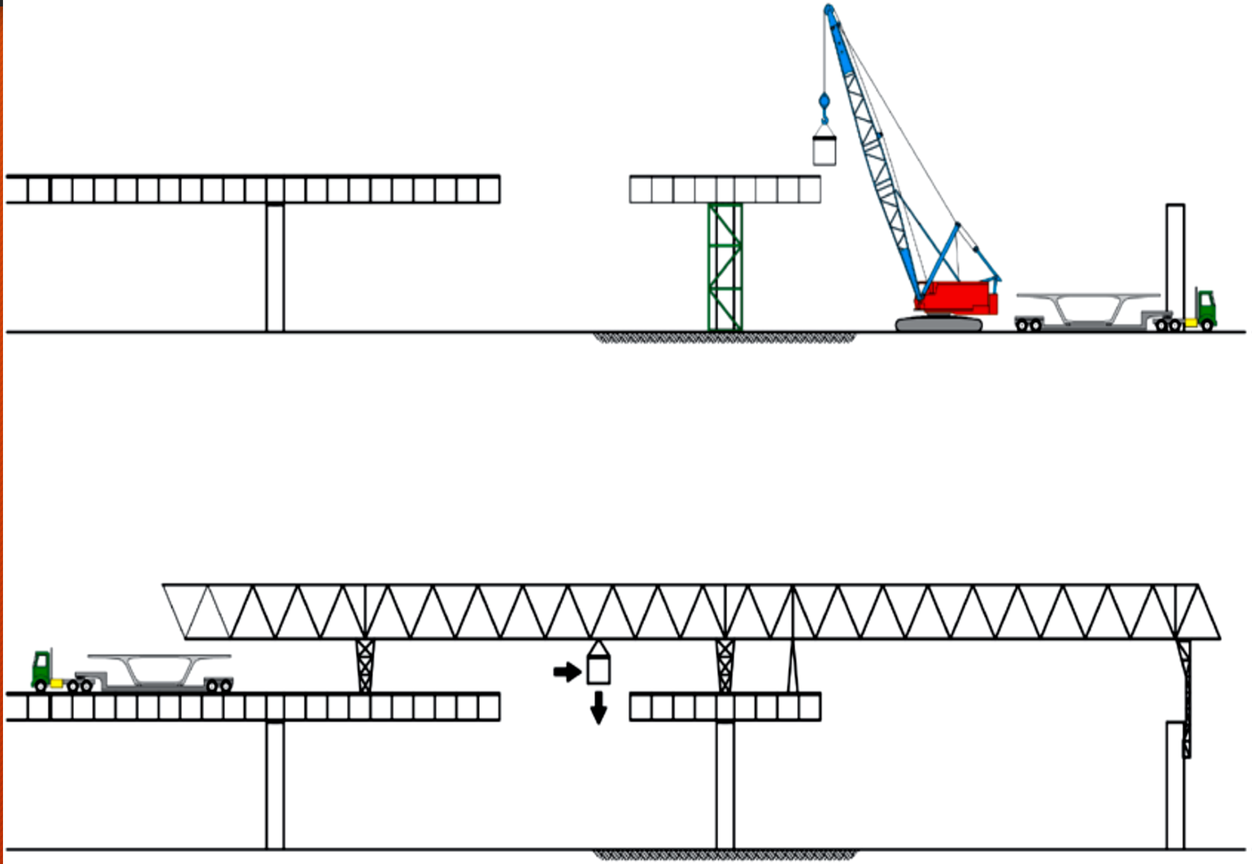
- After all closures have been cast and have attained the necessary strength, longitudinal post-tensioning tendons are installed and stressed.
- To maximize the efficiency of the post-tensioning, phased stressing is necessary.
- Some of the longitudinal tendons are stressed on the I-girder section alone (i.e. while it is non-composite).
- The remaining tendons are stressed after the deck slab has been cast and act upon the full composite section.



Erection Sequence and Temporary Supports for Spliced I-Girder

Precast Concrete Construction
Permanent Post-Tensioned Applications
3. Precast Segmental Balanced Cantilever Bridges

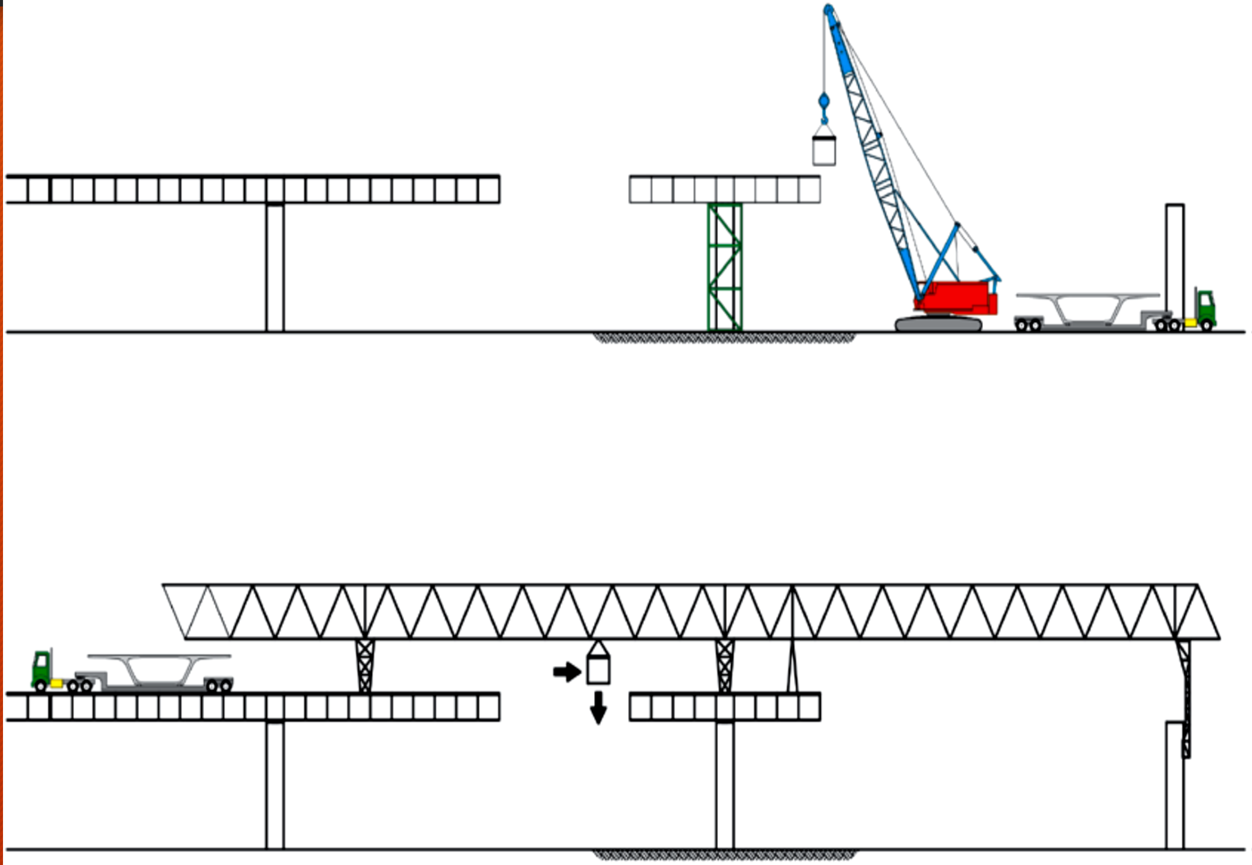
- Precast segmental balanced cantilever construction involves the symmetrical erection of segments about a supporting pier.
- When a segment is lifted into position, adjoining match-cast faces are coated with epoxy and temporary post-tensioning bars are installed and stressed to attach the segment to the cantilever.
- Typically, after a new, balancing segment, is in place on each end of the cantilever, post-tensioning tendons are installed and stressed from one segment on one end of the cantilever to its counter-part on the other.



Precast Segmental Balanced Cantilever Construction

3. Precast Segmental Balanced Cantilever Bridges

- Consequently, as segments are added, more top cantilever tendons are added.
- Using cranes with stability towers at each pier and using an overhead launching gantry. When all segments of a new cantilever have been erected and tendons stressed, a closure joint is made at mid-span. Continuity post-tensioning tendons are installed and stressed through the closure to make the cantilevers into continuous spans.

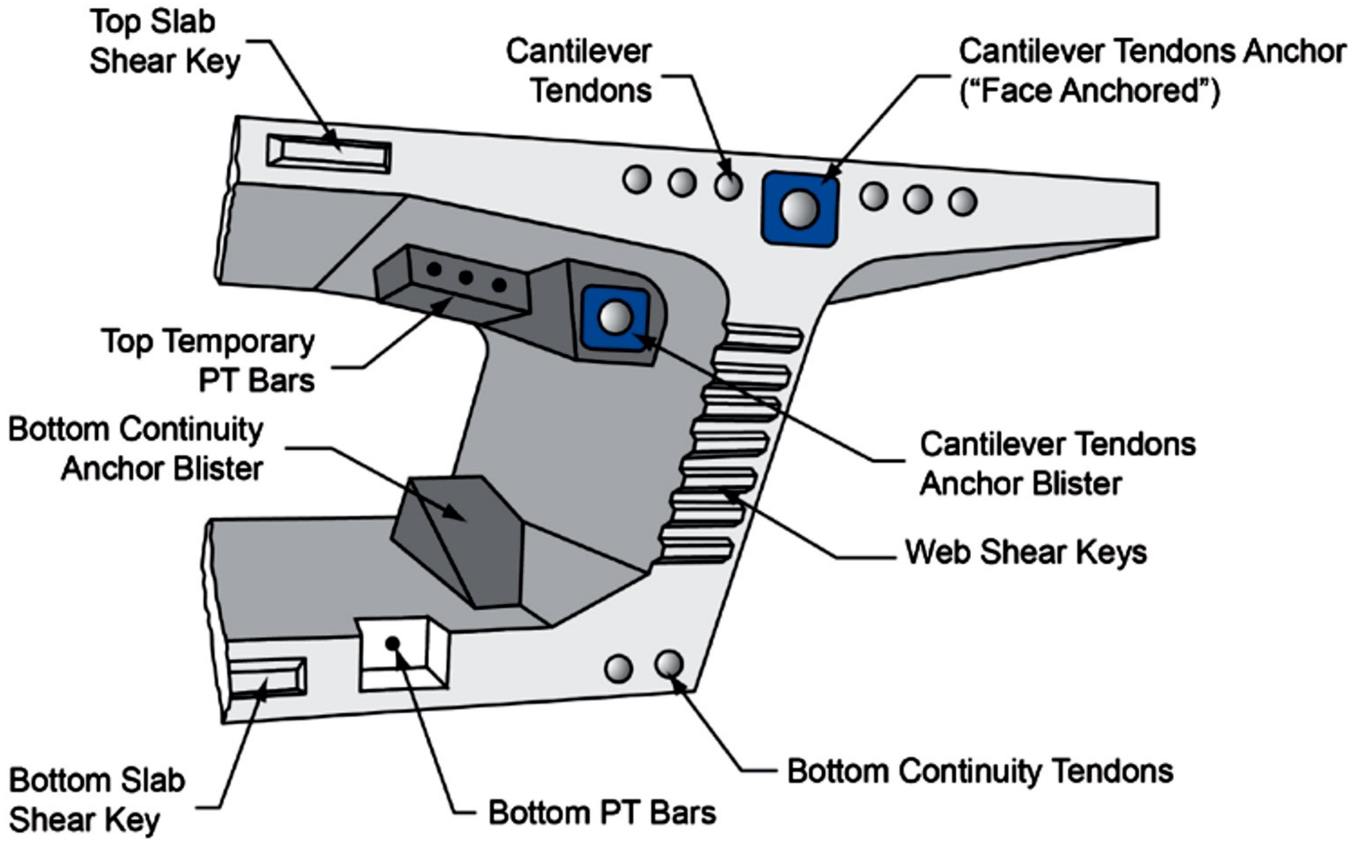


Precast Segmental Balanced Cantilever Construction

3. Precast Segmental Balanced Cantilever Bridges

3.1 Typical Features of Precast Cantilever Segments

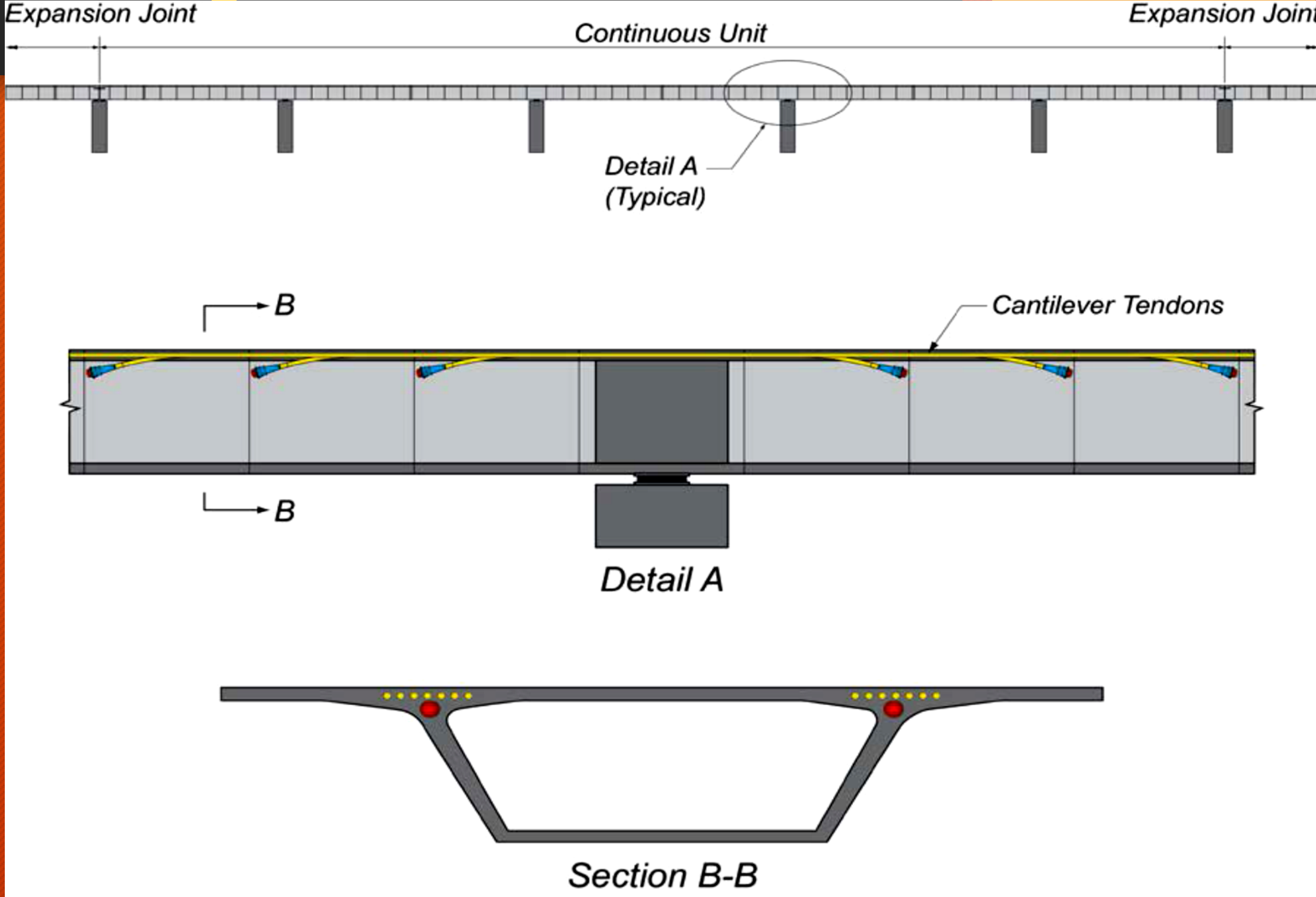
- The principal types of post-tensioning tendons in these bridges are cantilever and continuity tendons.
- Cantilever tendons are stressed to resist the cantilever dead load moments during construction and the effects of superimposed dead loads and live loads on the continuous bridge.
- Continuity tendons are stressed to join adjacent cantilevers and resist positive moments from superimposed dead loads, creep redistribution, and live loads.



Typical Balanced Cantilever Segment

3.2 Cantilever Tendons

- Longitudinal post-tensioning tendons for cantilever construction are contained within the top slab, usually spaced in a single layer over each web.
- For long spans, a second layer of tendons in the thickened haunch of the top slab may be required.
- The layout of the ducts is always the same at each side of the match-cast joint, and ducts shift sideways or up and down within a segment to make up the full tendon profile from an anchor at one end of the cantilever to that at the other.



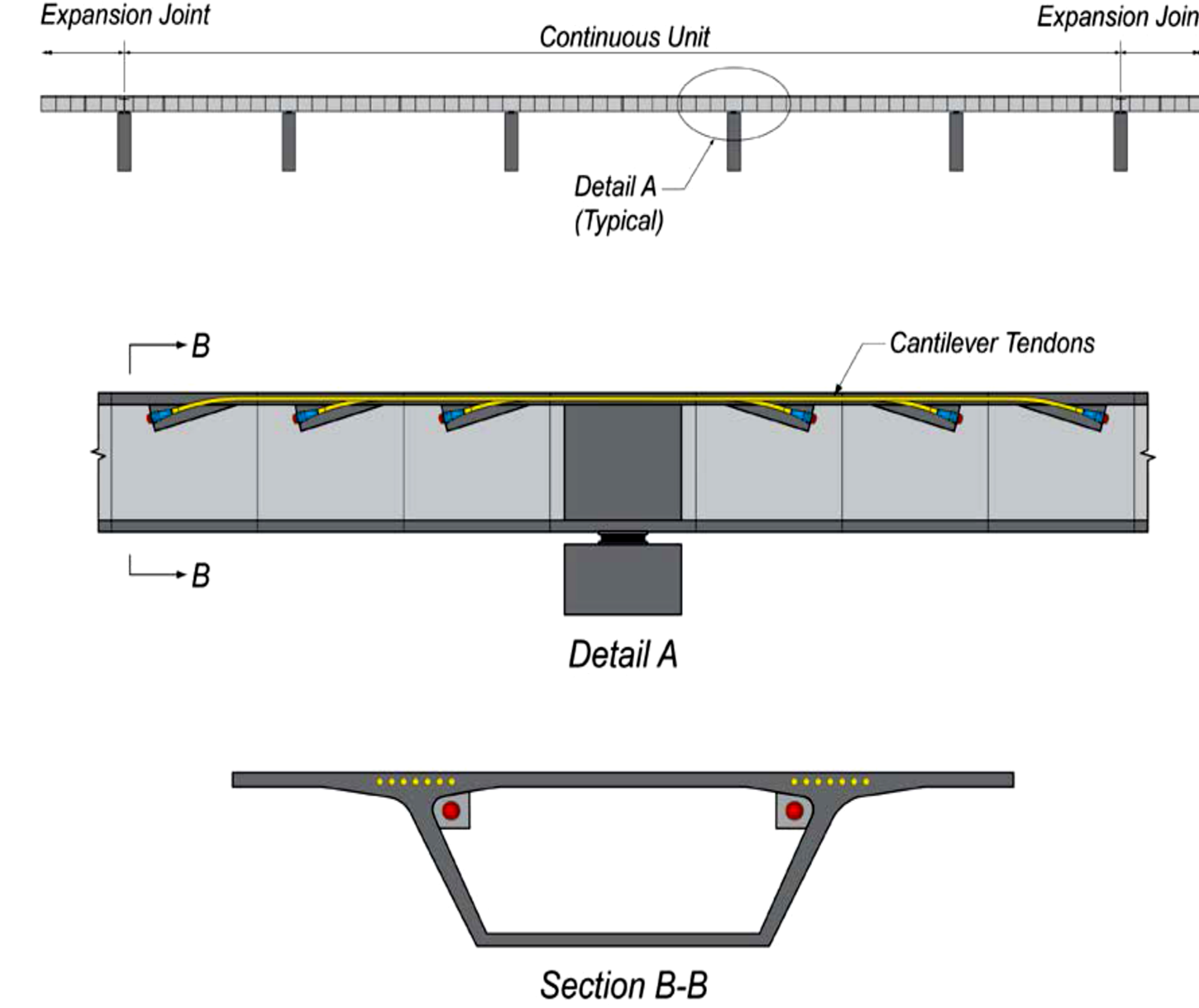
Cantilever Post-Tensioning Tendons Anchored on End Faces

Precast Concrete Construction
Permanent Post-Tensioned Applications
3. Precast Segmental Balanced Cantilever Bridges
3.2 Cantilever Tendons

- Relative to each segment, cantilever tendons always anchor in the same location. This may be in the end face of the segment or within an anchor block (or “blister”) on the interior of the segment.
- Cantilever tendons in the top slab of a box section counteract the bending effect from the self-weight of the cantilever during construction.
- This bending induces a longitudinal tension stress in the top, reaching a maximum over the pier.
- The top cantilever post-tensioning counters these effects by inducing a compression stress of equal or greater magnitude at each cross section along the cantilever.

Precast Concrete Construction
Permanent Post-Tensioned Applications
3. Precast Segmental Balanced Cantilev
3.2 Cantilever Tendons

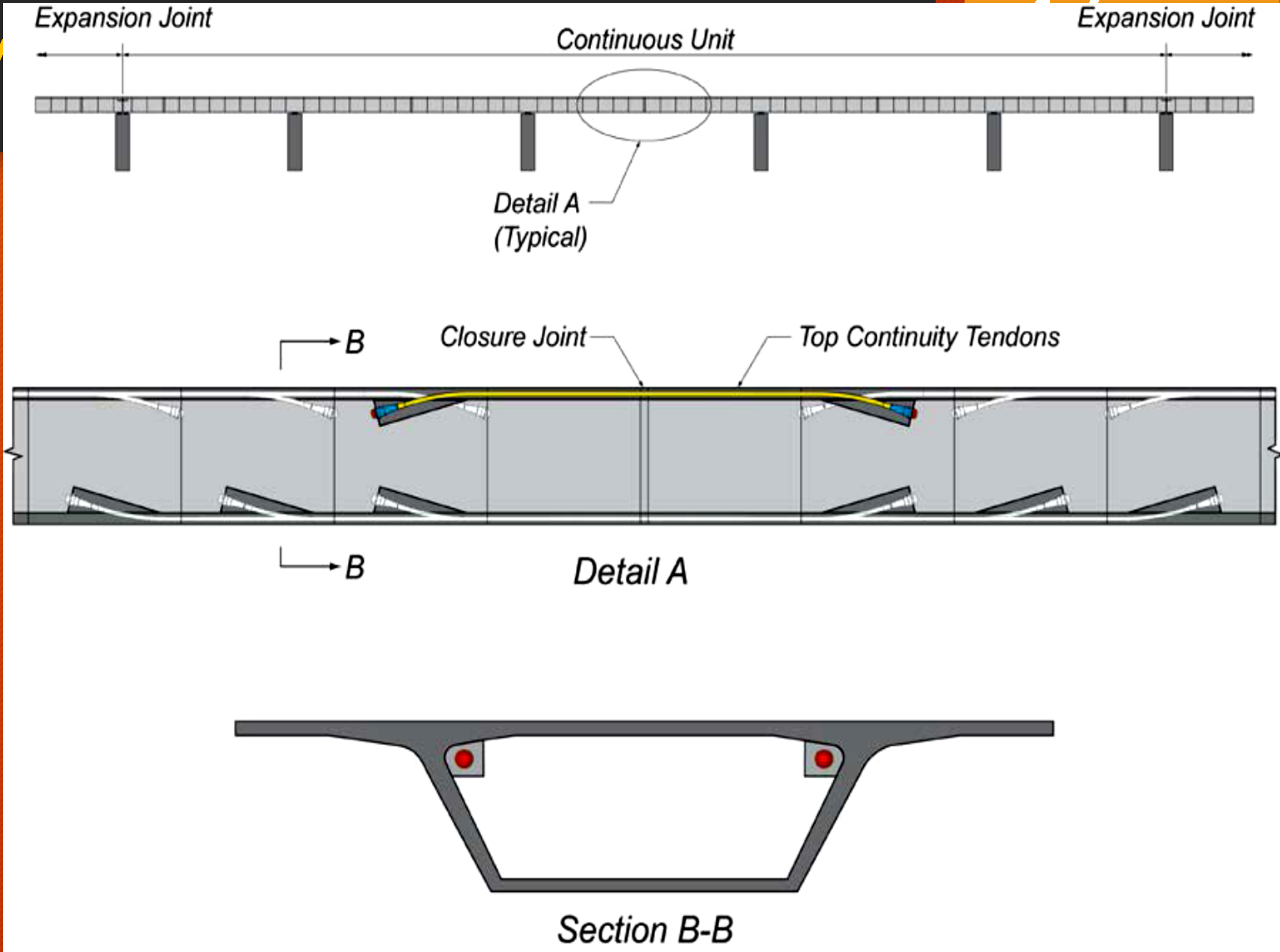
- An alternate approach is to anchor cantilever tendons in blisters (anchor blocks) cast into the segments at the intersection of the top slab and web.
- Anchorages of these tendons can be inspected at any time during and after construction.



Cantilever Post-Tensioning Tendons Anchored in Top Blisters

Precast Concrete Construction
Permanent Post-Tensioned Applications
3. Precast Segmental Balanced Cantilev
3.2 Cantilever Tendons

- Midspan bottom continuity tendons, along with live loads in adjacent spans, produce tensile stresses in the top slab that need to be counteracted with top continuity tendons. Subsequent application of the barrier railing and possible wearing surface should produce top compression at this location, minimizing the need for the top continuity tendons. In time, internal redistribution of forces and moments due to the creep of the concrete will induce compression in the top at midspan, further reducing the need for top continuity tendons.



Top Continuity Tendons for Balanced Cantilever Construction

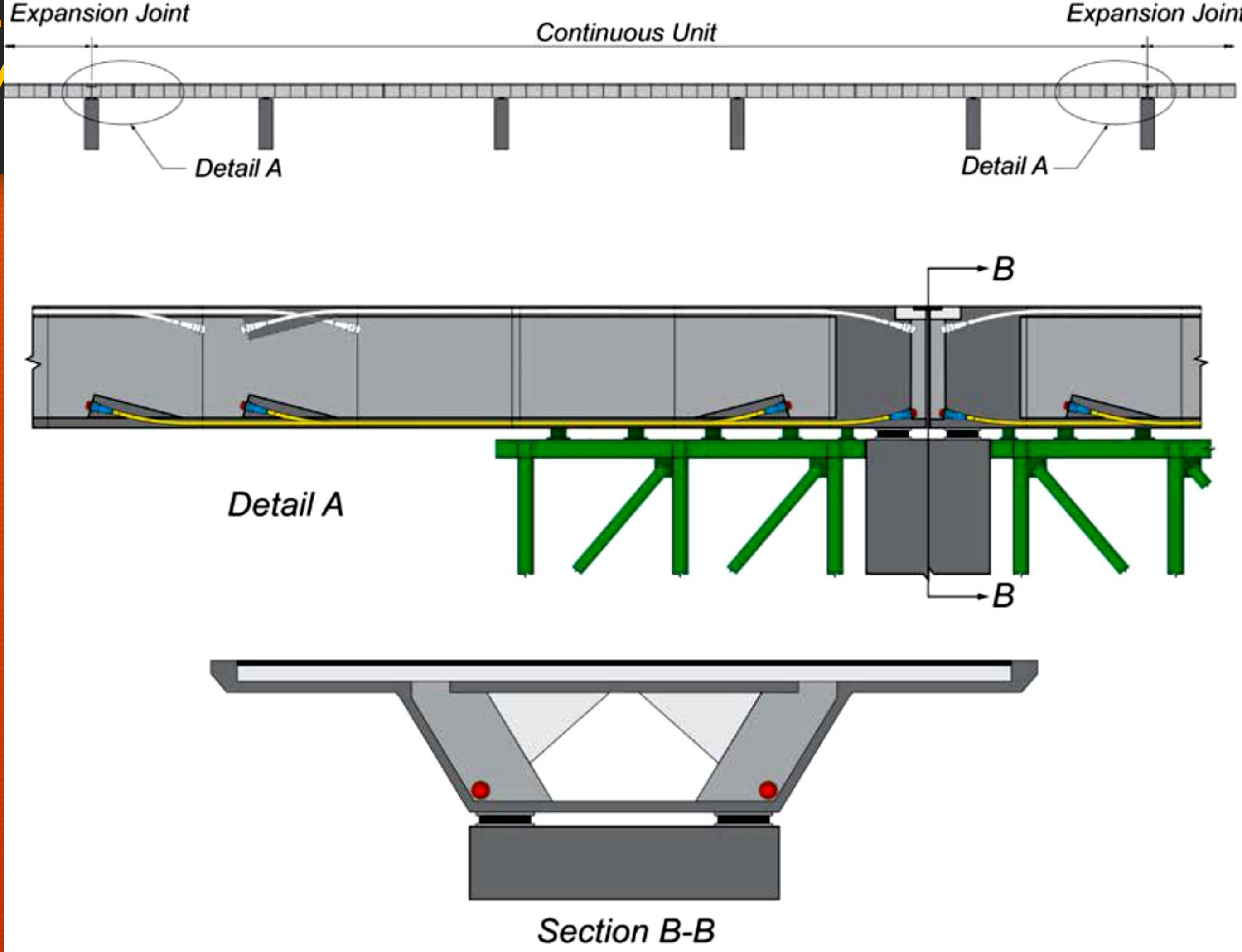
Precast Concrete Construction

Permanent Post-Tensioned Applications

3. Precast Segmental Balanced Cantilev

3.3 Continuity Tendons in End Spans

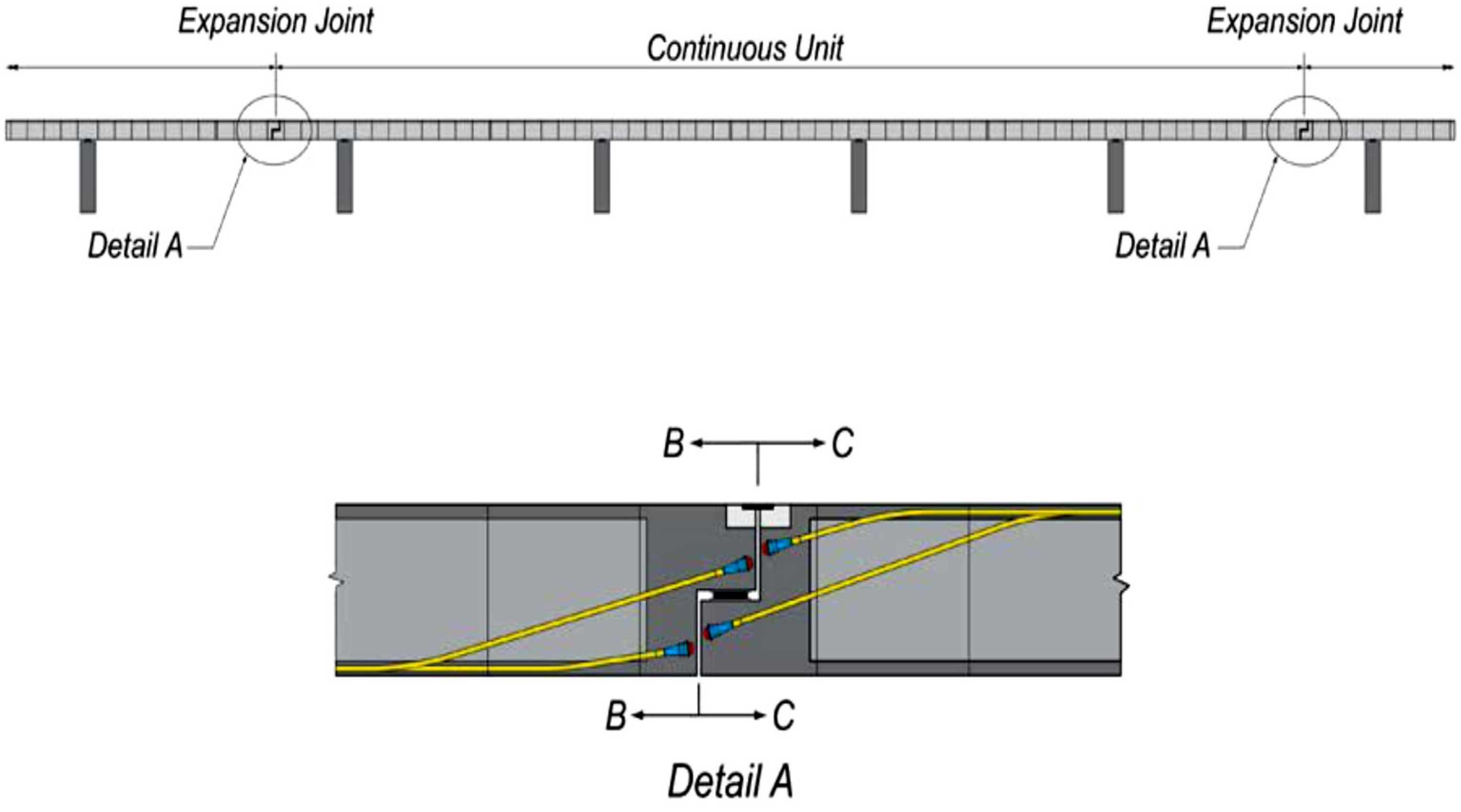
- Usually, more continuity tendons are needed in the bottom than the top.
- Although continuity tendons may not always be needed in the top, it is good practice to provide at least two, one over each web.



Bottom Continuity Tendons near Expansion Joint at a Support

Precast Concrete Construction
Permanent Post-Tensioned Applications
3. Precast Segmental Balanced Cantilever Bridges
3.4 In-Span Hinges in Balanced Cantilever Construction

- Midspan hinges have again been used satisfactorily. Deflection may be controlled by using steel beams on sliding bearings placed inside a box girder, between cantilever tips, to allow for expansion and contraction, but restrain rotation. Care should be exercised in the design and detailing of any type of in-span hinge because local details may be subject to complex force and stress distribution.



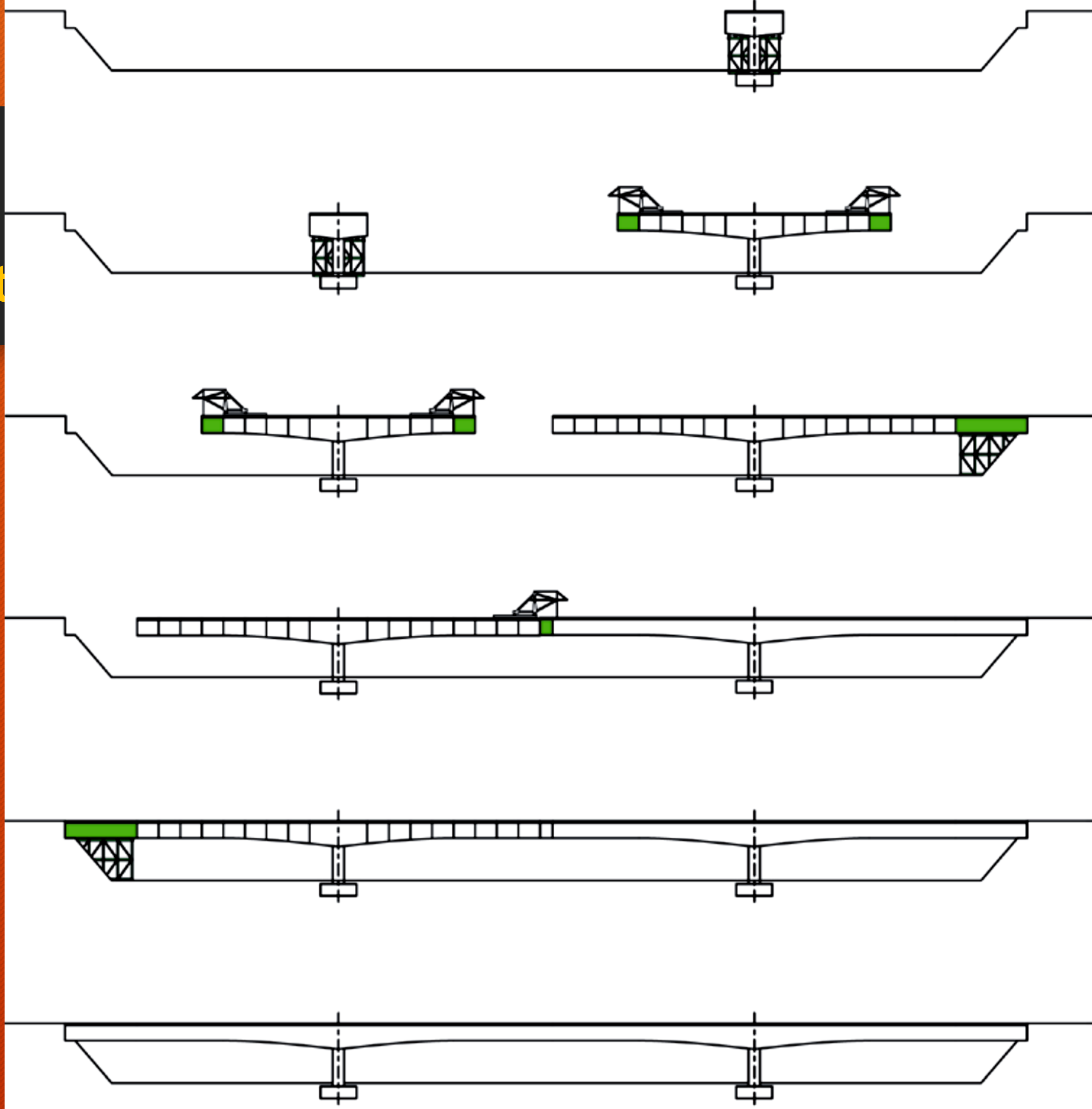
In-Span Hinges in Balanced Cantilever Construction

4. Cast-in-Place Segmental Balanced Cantilever Bridges

- An often used alternate to balanced cantilever construction using precast segments is cast-in-place balanced cantilever construction using form travelers. Form travelers support the concrete of the newly cast segment until it has reached a satisfactory strength for post-tensioning. The types of longitudinal post-tensioning tendons used in cast-in-place balanced cantilever construction are the same as for precast segment balanced cantilever.

Cast-In-Place Segmental Construction using Form Travelers

Precast Concrete Construction
Permanent Post-Tensioned Applications
4. Cast-in-Place Segmental Balanced Cant



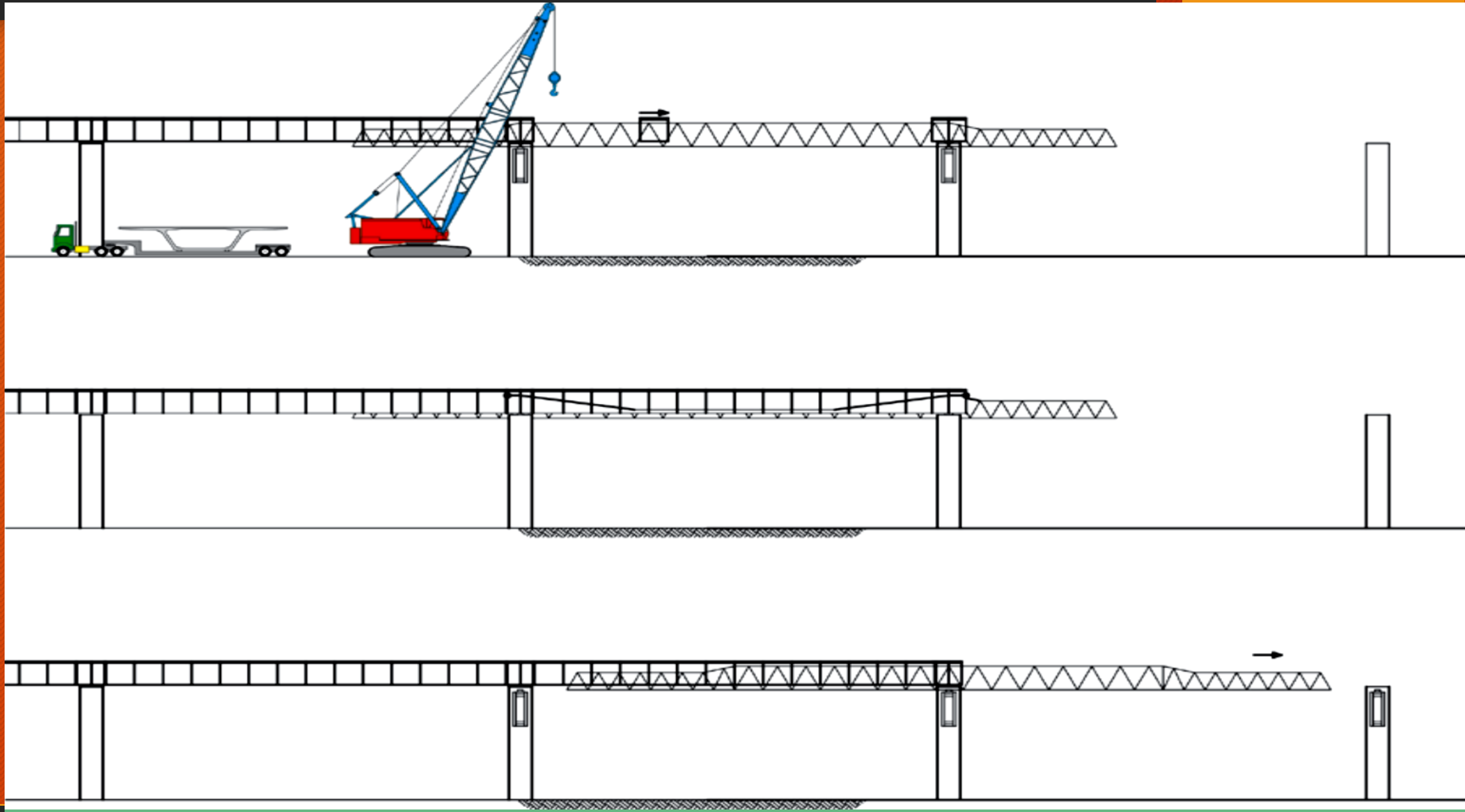
Typical Construction Stages for Cast-In-Place Balanced Cantilever Construction

Precast Concrete Construction
Permanent Post-Tensioned Applications
5. Precast Segmental Span-by-Span Bridges

Span-by-span construction involves the erection of all segments of a span on a temporary support system with small closure joints cast at one or both ends next to the segments over the pier.

The erection schematic shown in Figure shows temporary erection trusses used to support the precast segments during construction.

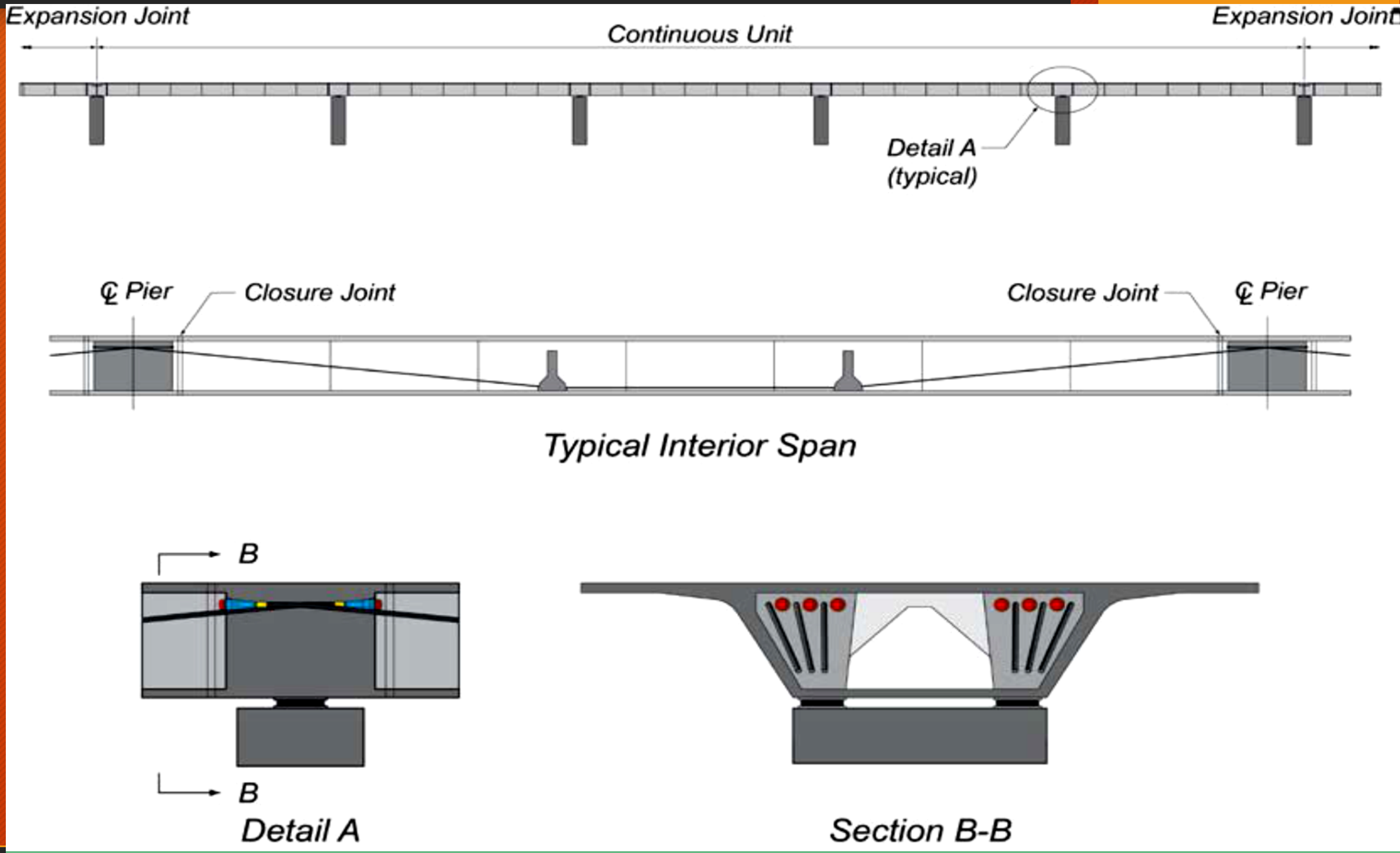
Overhead erection gantries are also commonly used to support the



Span-By-Span Construction

Precast Concrete Construction
Permanent Post-Tensioned Applications
5. Precast Segmental Span-by-Span Bridges
5.1 External Tendons

- For span-by-span construction, the use of external tendons provides for greater efficiency in the cross section of the box for both longitudinal and transverse efficiency, by facilitating a web thicker at the top than bottom. This raises the centroid of the whole cross section, and maximizes the eccentricity and efficiency of the post-tensioning in the mid-span region needed for the dominant effect of longitudinal flexure of this method.

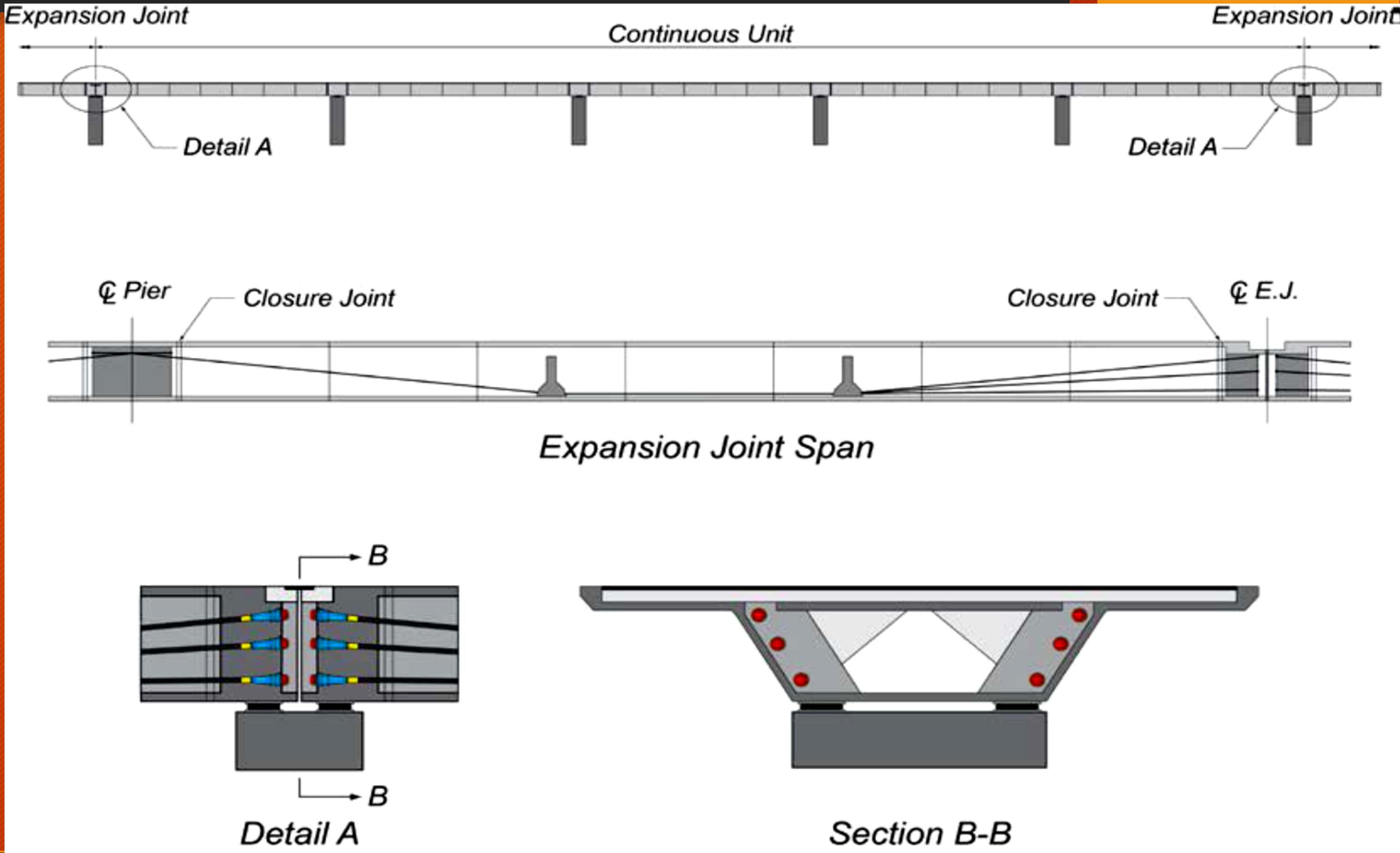


Typical Span Post-Tension for Span-By-Span Construction

5. Precast Segmental Span-by-Span Bridges

5.1 External Tendons

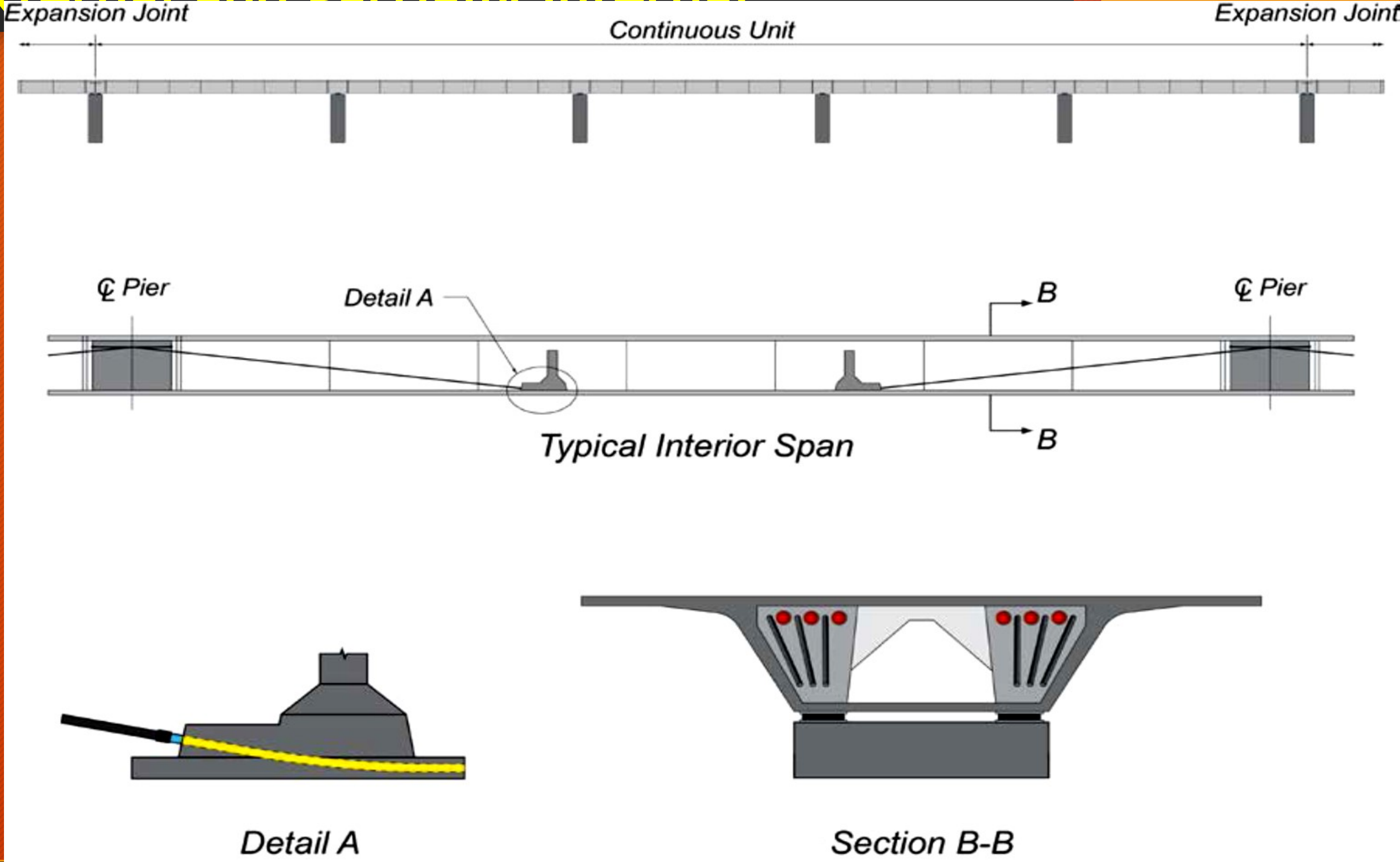
- The tendons from one span overlap with the tendons of the next in the top of the pier segment to achieve continuity between the spans. At the very ends of each continuous unit, the ends of the tendons anchor in the diaphragm of the expansion joint segment with anchors dispersed vertically and approximately parallel to the web of the box.



Expansion Joint Span Post-Tensioning for Span-By-Span Construction

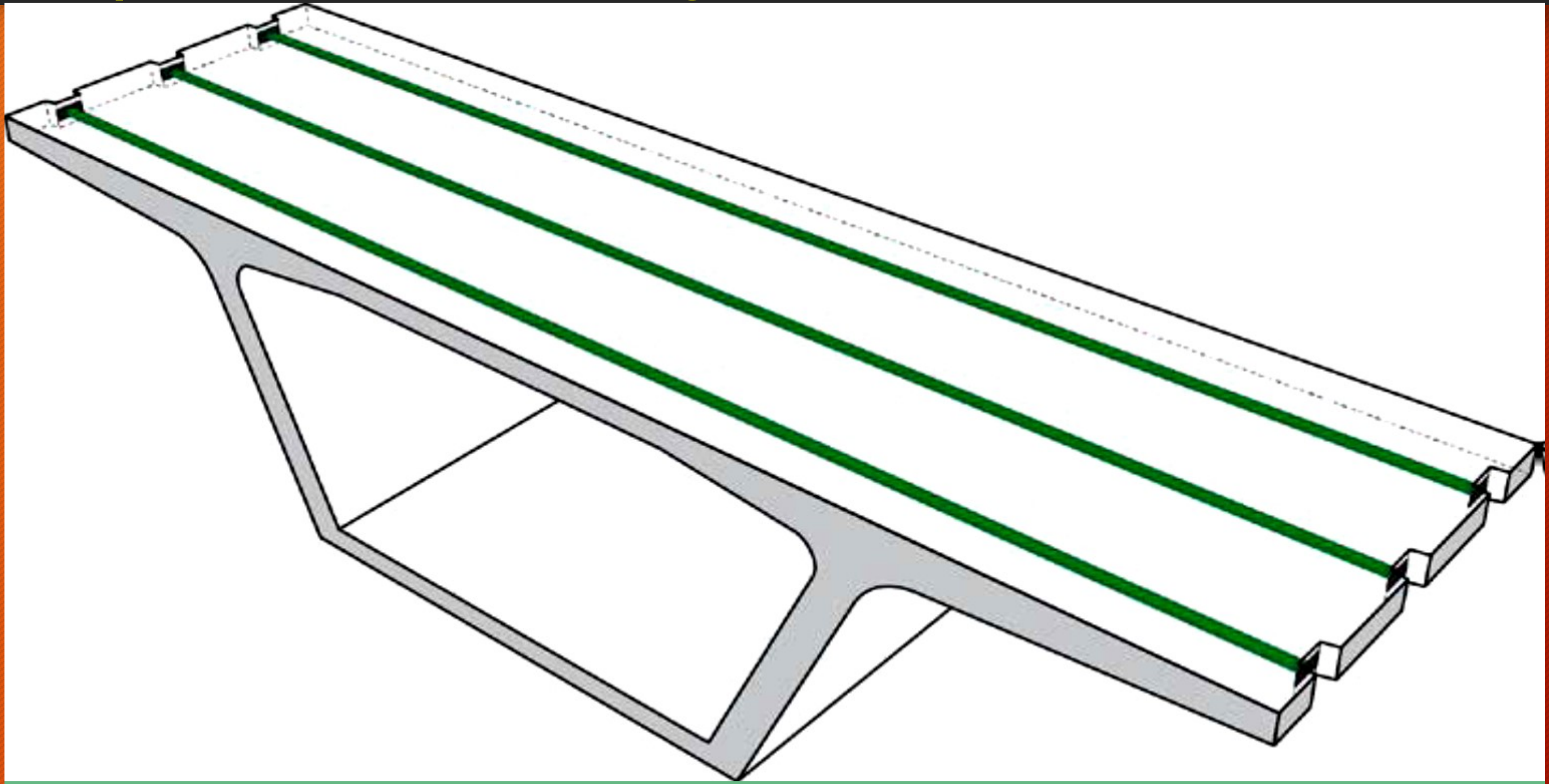
Precast Concrete Construction
Permanent Post-Tensioned Applications
5. Precast Segmental Span-by-Span Bridges
5.2 Tendons that are Partially External and Partially Internal

- In some cases, a post-tensioning tendon in a span-by-span bridge may be both external and internal to the concrete. The profile of such a post-tensioning tendon is similar to that of an external tendon except that between the deviators, it enters the bottom slab.



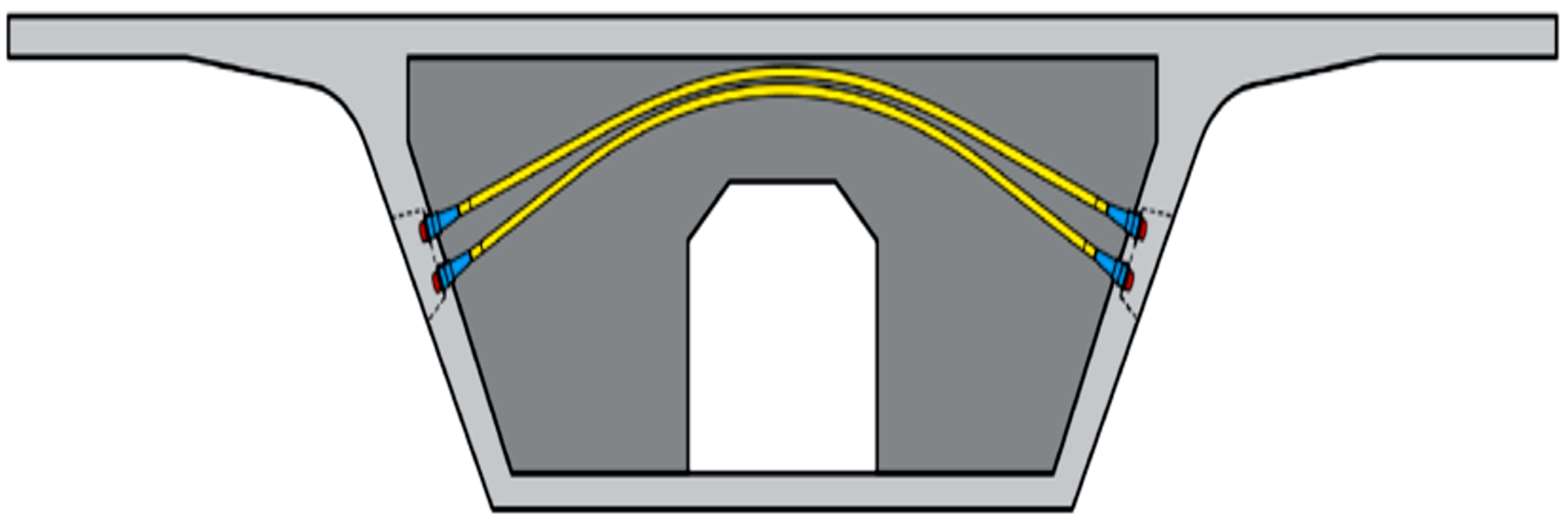
External/Internal Span-By-Span Tendons

Precast Concrete Construction
Permanent Post-Tensioned Applications
6. Transverse Post-Tensioning of Superstructures
6.1 Transverse Top Slab Post-Tensioning



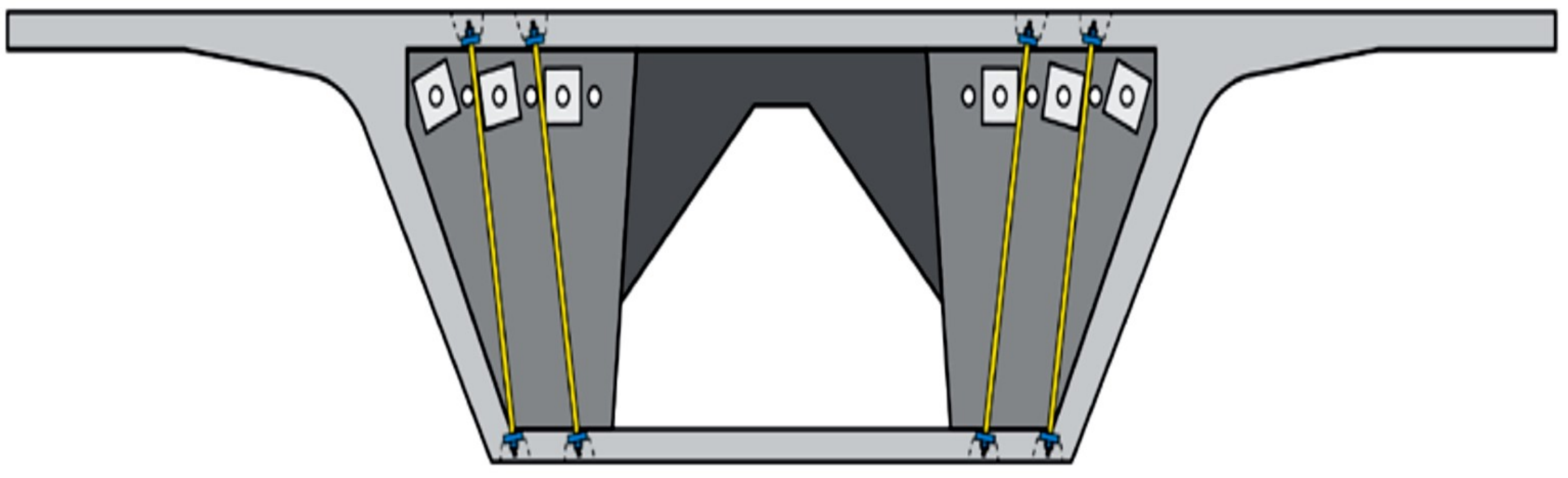
Transverse Post-Tensioning in the Top Slab of Box Girder

6.2 Transverse Top Slab Post-Tensioning



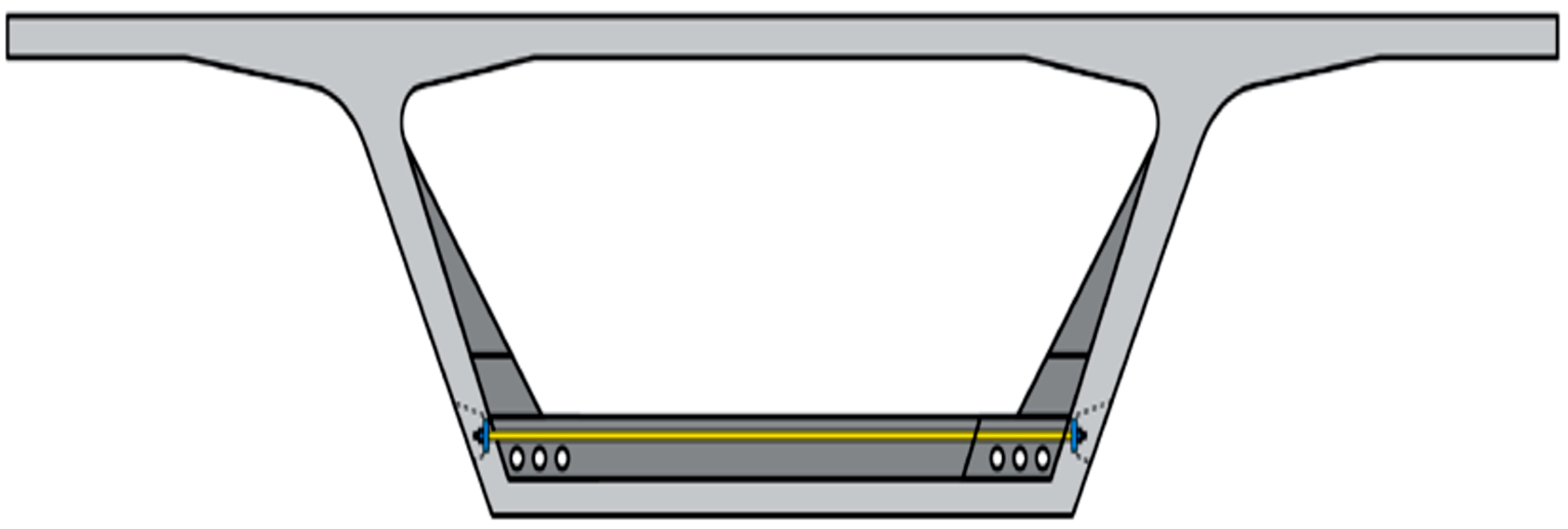
Transverse Post-Tensioning in Diaphragms

Precast Concrete Construction
Permanent Post-Tensioned Applications
6. Transverse Post-Tensioning of Superstructures
6.3 Vertical Post-Tensioning in Diaphragms



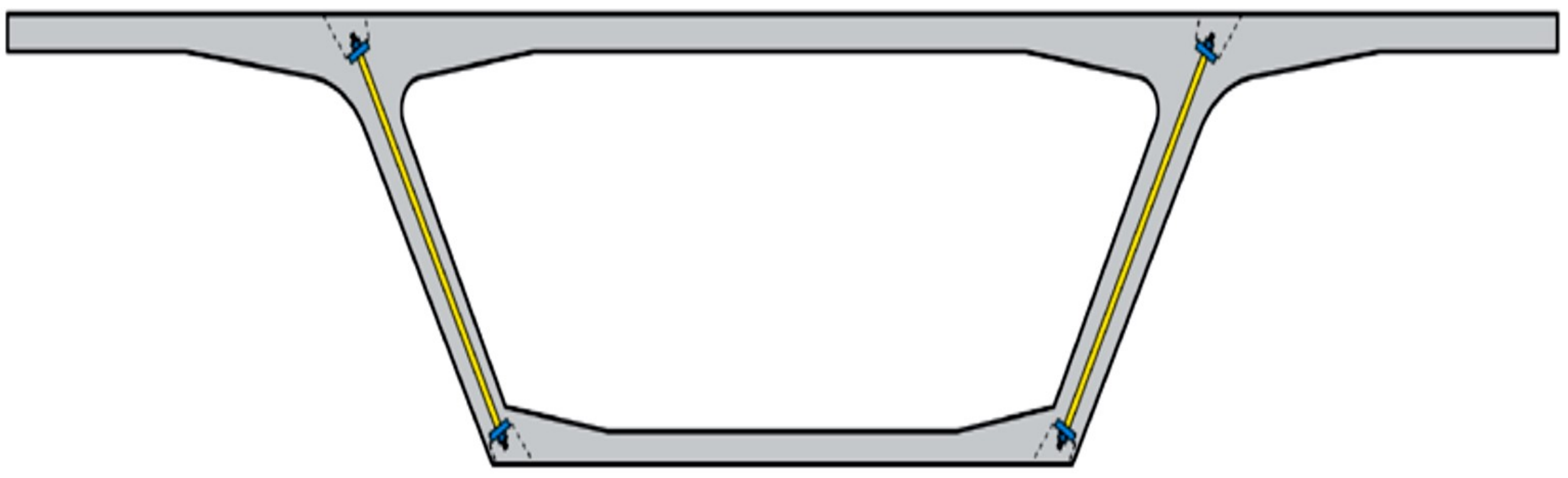
Transverse Post-Tensioning in Diaphragms

Precast Concrete Construction
Permanent Post-Tensioned Applications
6. Transverse Post-Tensioning of Superstructures
6.4 Transverse Post-Tensioning in Deviator Ribs of Precast Segments



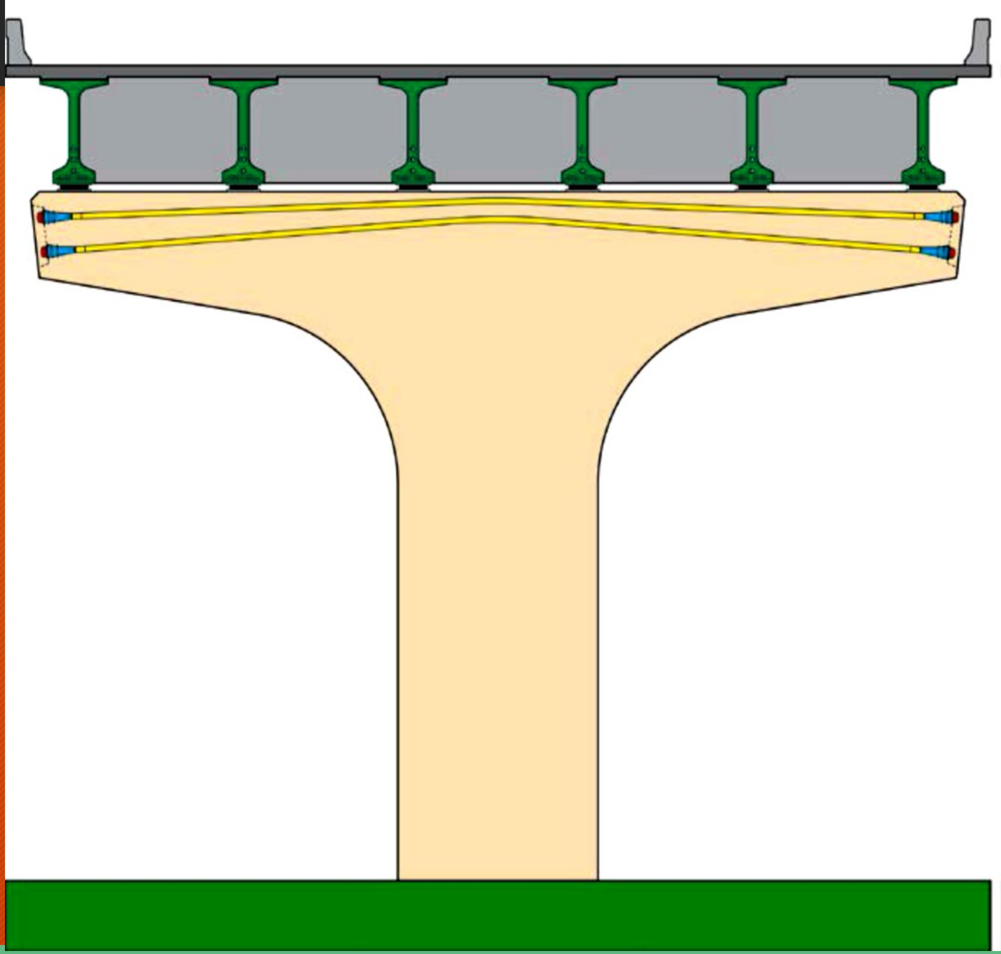
Transverse Post-Tensioning in Deviation Ribs

6.5 Vertical Post-Tensioning in Webs



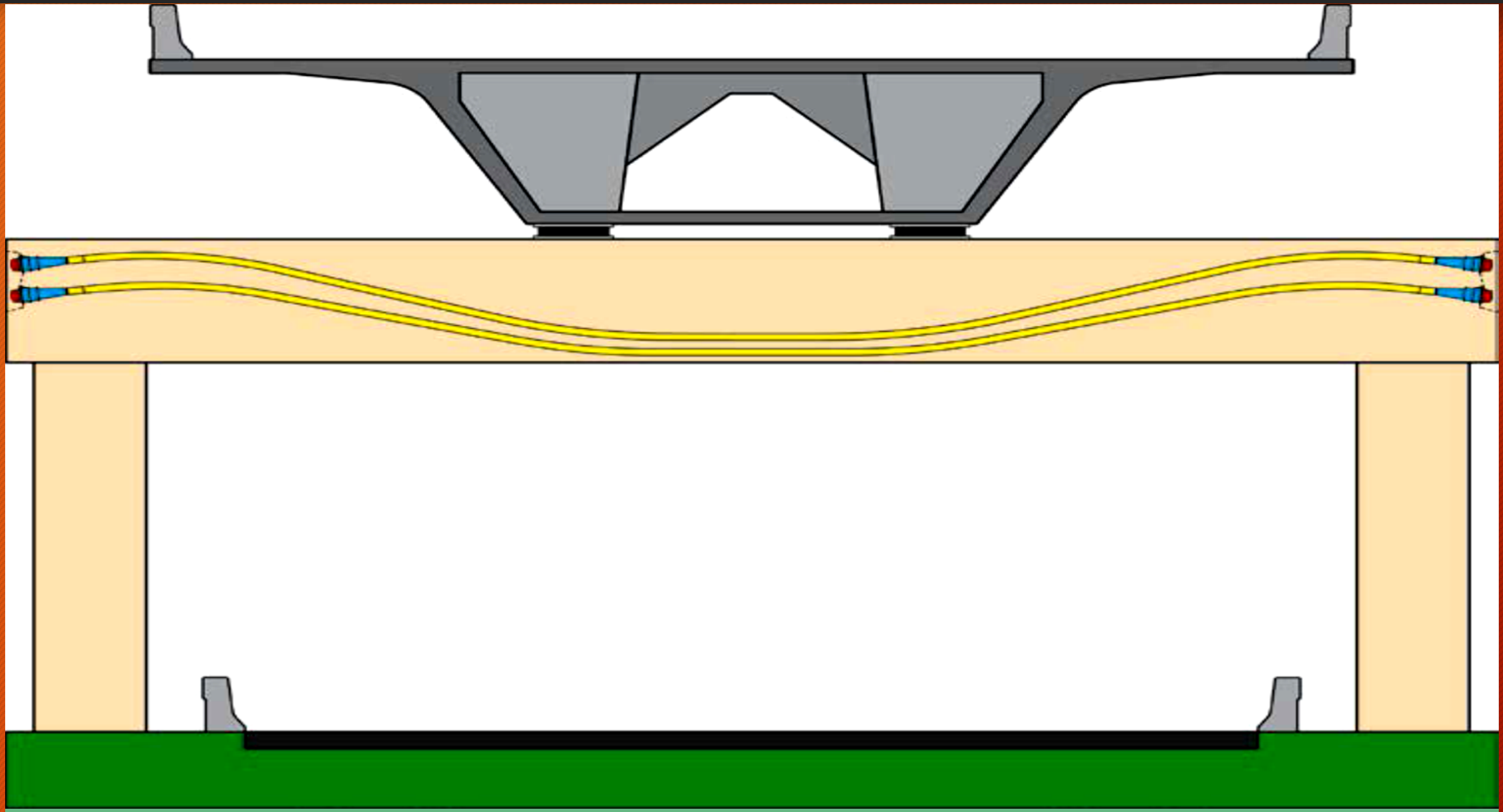
Vertical Post-Tensioning in Webs

Precast Concrete Construction
Permanent Post-Tensioned Applications
7. Post-Tensioning of Substructures
7.1 Hammerhead Piers



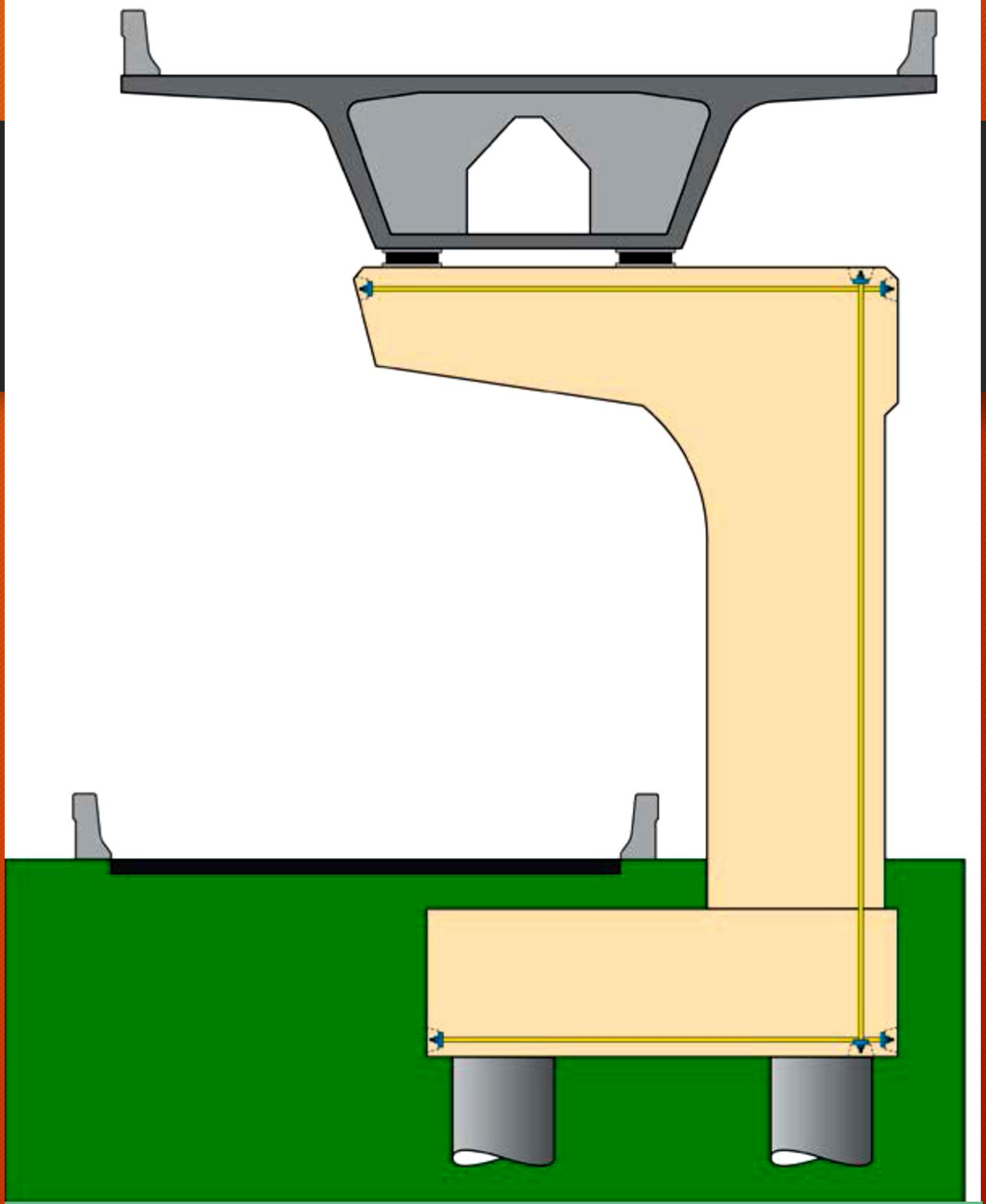
Post-Tensioning in Hammerhead Piers

Precast Concrete Construction
Permanent Post-Tensioned Applications
7. Post-Tensioning of Substructures
7.2 Straddle Bents



Post-Tensioning in Straddle Bents

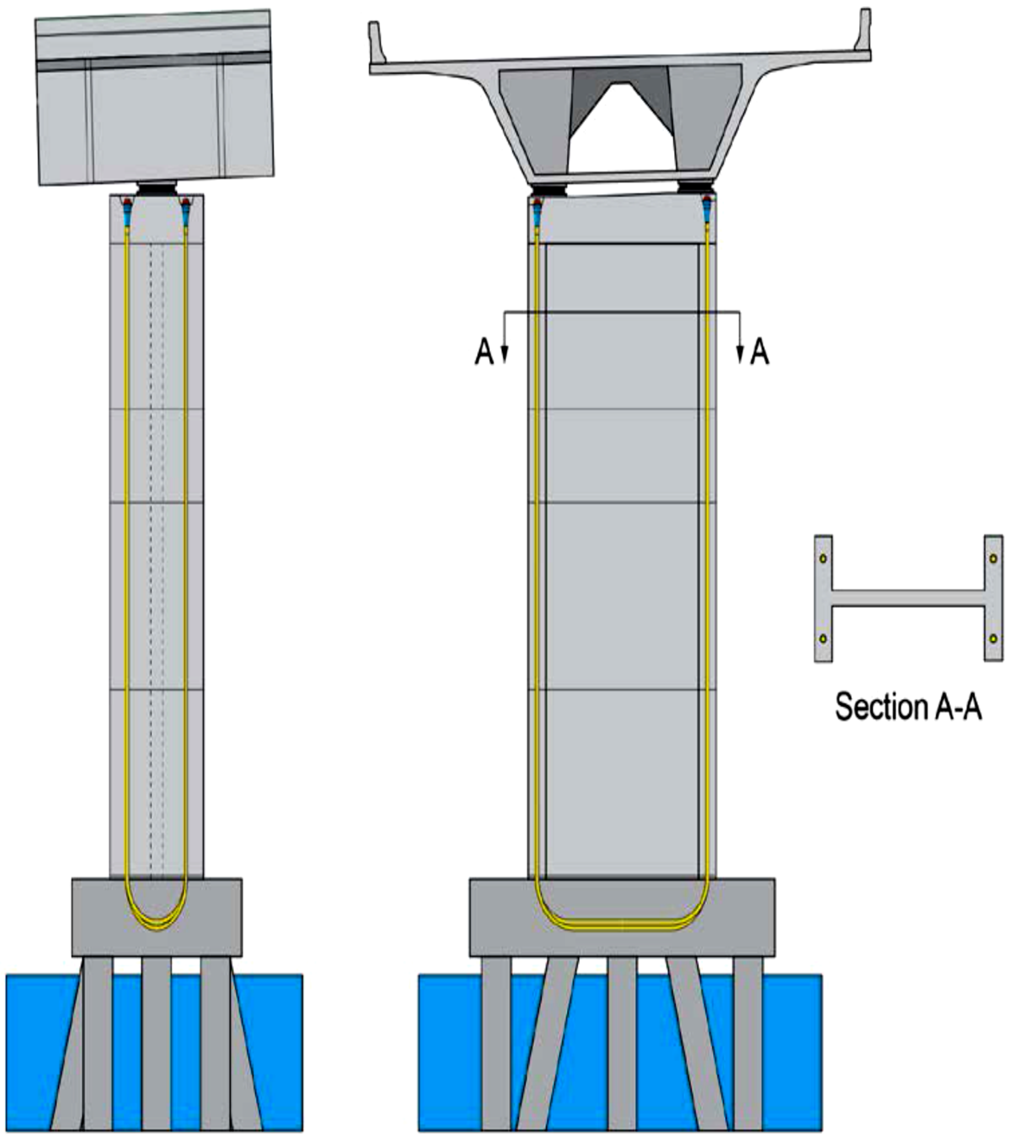
7.3 Cantilever Piers



Post-Tensioning in Cantilever Piers

Precast Concrete Construction
Permanent Post-Tensioned Applications
7. Post-Tensioning of Substructures
7.4 Precast Piers

Precast Hollow Segmental Piers, Foothills Bridge No. 2

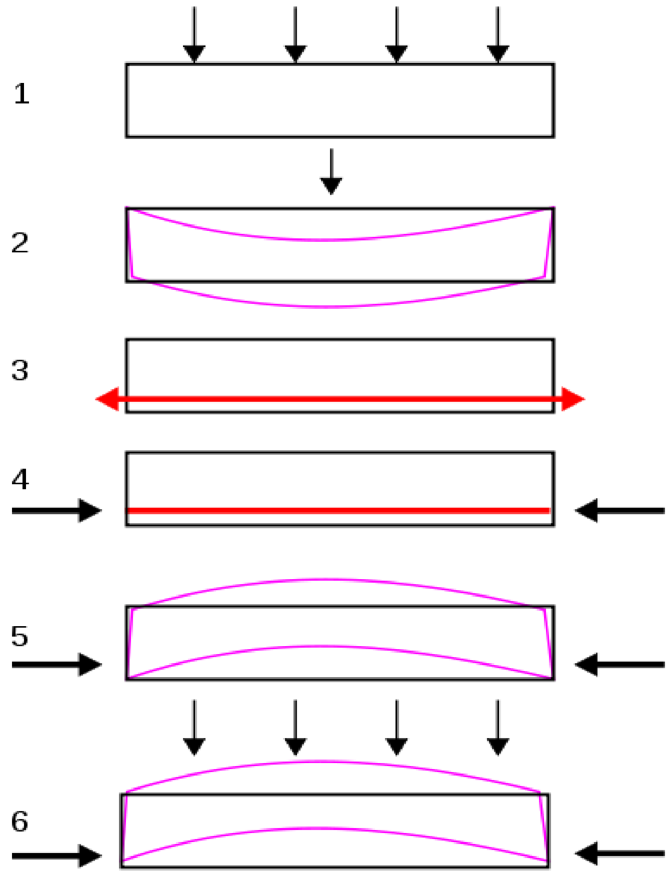


Precast I-Piers

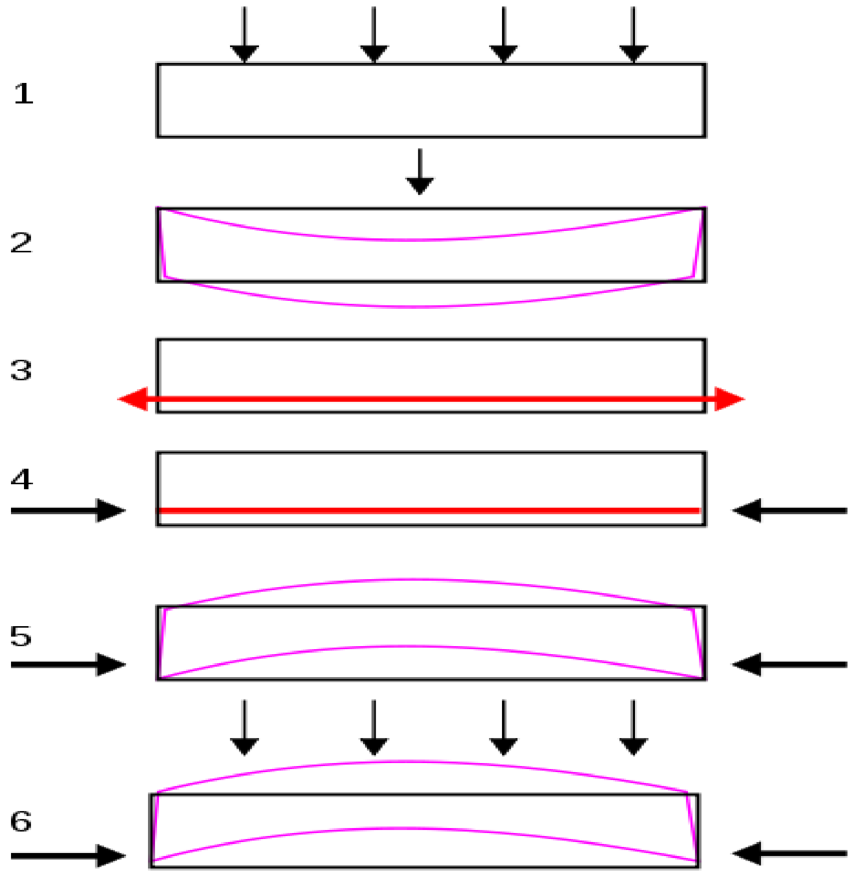
Precast Concrete Construction
Permanent Post-Tensioned Applications
7. Post-Tensioning of Substructures
7.5 Precast Segmental Box Section Arches

Natchez Trace Parkway Arches, Tennessee

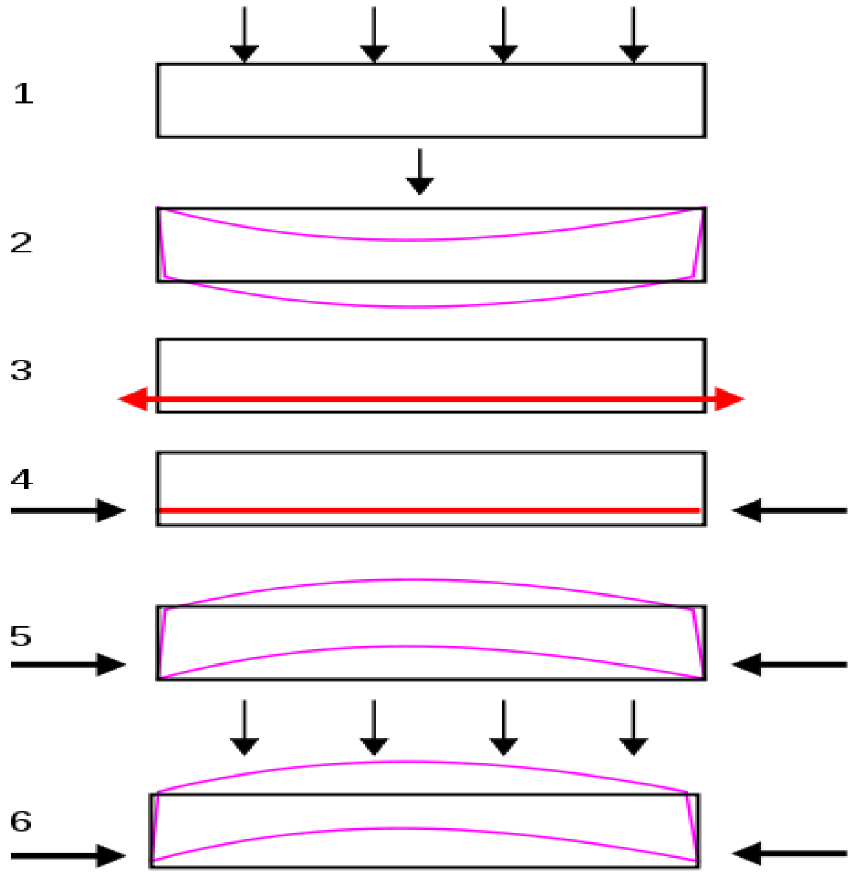
Precast Concrete Construction
Prestressed Girder Making



Precast Concrete Construction
Prestressed Girder Making



Precast Concrete Construction
Prestressed Girder Making



Precast Concrete Construction
Prestressed Girder Making

Precast Concrete Construction
Prestressed Girder Making

Precast Concrete Construction
Prestressed Girder Making

Precast Concrete Construction
Prestressed Girder Making

Precast Concrete Construction
Care To Take

- During designing all the loads are to considered and losses are also to be considered as per codes for pre-stressed concrete.
- Casting and curing is to be done properly for quality concrete. Suitable method of post tensioning is to be adopted.
- Casted elements are to be stoked care fully, details should be given by designer for storing members.
- Transportation is to be done carefully to avoid damage to the precast elements.
- Erection process is to be well decided and planed based on type of bridge and site condition.




Precast Concrete Construction
Case Study: Hangzhou Bay Bridge

- Longest trans-oceanic highway bridge in the world, with a cable-stayed portion across Hangzhou bay in the eastern coastal region of China (6-lanes)
- Total length of bridge is 35.67m.
- Construction of the bridge was completed on June 14, 2007.
- The bridge shortened the highway travel distance between Ningbo and Shanghai from 400 km to 280 km and reduced travel time from 4 to 2.5 hours.
- 40 piers with large number of girders
- Girder is of 70m length and 16.5m wide in plan
- 830 cubic meter of concrete for one girder and took 8 hours to cast one girder
- Barge crane was used for erection of girders for 25 km. and for other portion special machine was built

Precast Concrete Construction
Case Study: Hangzhou Bay Bridge

Precast Concrete Construction
Case Study: Hangzhou Bay Bridge

Thank-you for Listening!

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(Shad)