International Journal of Research and Review
www.ijrrjournal.com E-ISSN: 2349-9788; P-ISSN: 2454-2237

Review Paper

Prestressed Bridge Construction: Systems And Methods

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ABSTRACT

The prestressed bridge is one of long span bridges using cable system as the main support. Being known in the 1800s it has undergone several innovations in both the system and the construction methods. This paper is the result of library research and aimed at describing the bridge's innovations and variations in its construction systems and methods.

Keywords: System, Method, Bridge, Prestressed, Construction

INTRODUCTION

The prestressed bridge becomes one of the long span bridges in which its main support uses cable system. Its concept began in 1872 when Jackson patented a prestressed system using a tie rod on a single beam or arc. Since then it had rapid development in its systems, technologies, and construction methods and fifty percent of long-spanned bridges employs prestressed systems.

PRESTRESSED BRIDGE CLASSIFICATIONS

Prestressed bridges can be classified into structural and beam systems, places or locations of beams or segments, cable tensioning systems, tendon positions, and unbounded or bonded tendons. The place of mold, or blocks or segments casting, can be divided into *cast-in place* (CIP), in which a block, or a segment that is casted is in the final position of the segment placement, and *precast* (PC), in which the block is printed in the project site or elsewhere. The manufacturer's precast beams have various shapes and precision sizes because they are easily controlled.

Based on the tendon tensioning system, the prestressed system is divided into pretensioned and post-tensioned. In pretensioned, the tendon tensioning is carried out before the beam or segment is casted or placed in post-tensioned, cable tensioning is performed after the concrete has become hard. In precast systems, the tendon tensioning can be undertaken by both pretensioned or post-tensioned, whereas in cast-in placed, usually only post-tensioned is used. Pretensioned or post-tensioned cables can be bounded/grouted or unboded. The Fig. 1 shows the classification scheme of prestressed system.

TENDONS

Types and materials of tendons

Tendons used in prestressed concrete can be single wire, strands and bar. The types, shapes and properties of tendons which are commonly are shown in Fig. 2 and Table 1.

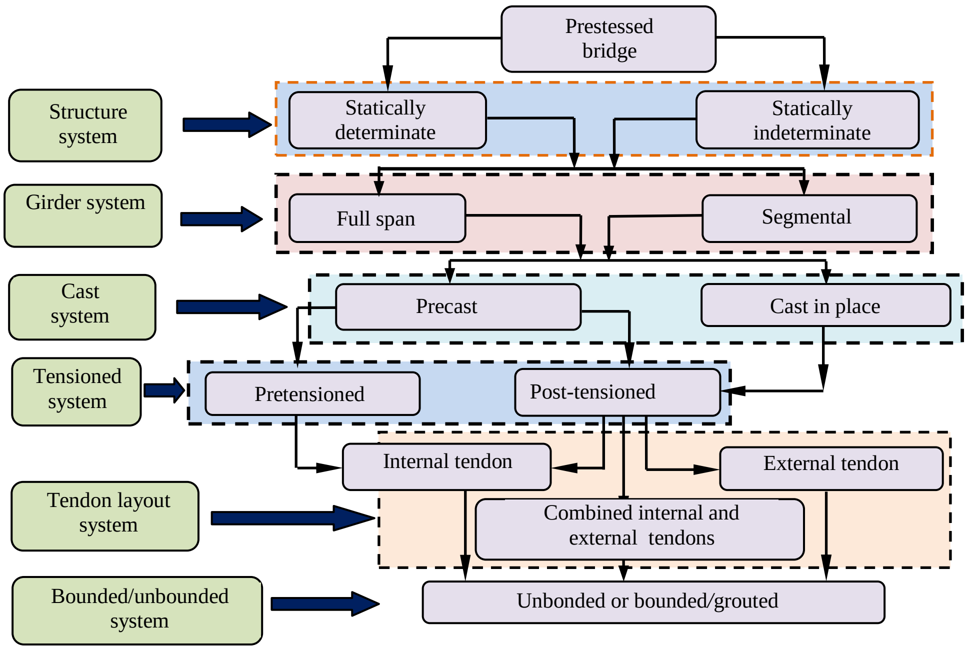

Figure 1. System schemes and prestressed bridge classifications

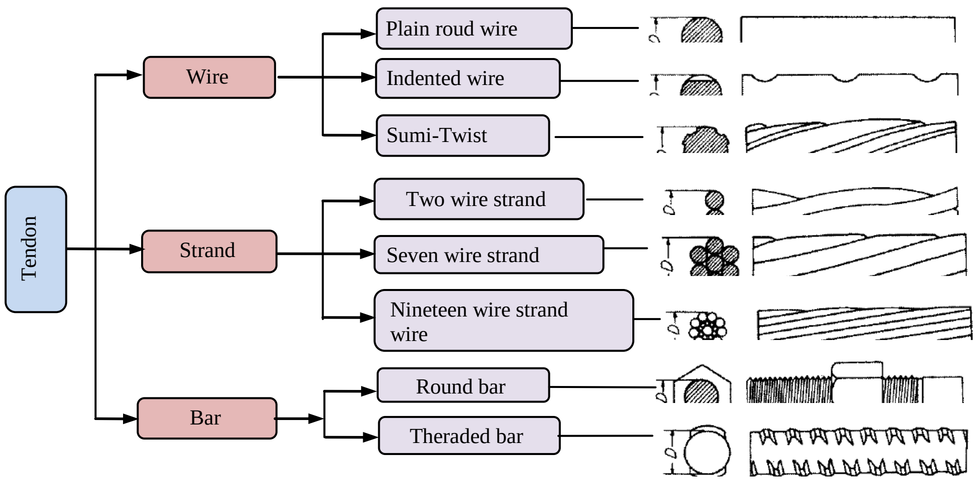

Figure 2. Classification and shapes of prestressed tendons

Table 1. Tendon properties

Materials	Type and Grade	Diameter (mm)	Tensile strength f_{pu} (MPa)	Yield strength f_{py} (MPa)	Elas. modulus E_p (MPa).10^3
Wire	BA* /WA*	4,88 – 7,01	1622-1725	85%f_{pu}	185 - 200
Strand	1725 (250) 1860 (270)	6,35 – 15,24 10,53 – 15,24	1725 1860	85% f_{pu} 90% f_{pu} for lr*	186 - 197
Bar	Ulir	15 - 36	1035 - 1104	80% f_{pu}	193 - 207

Note: BA*= button anchorage; WA*= wedge anchorage; lr*= low relaxation

Locations of tendons

1. Internal tendons

The early development of prestress used internal tendons; nowadays, prestressed tendons can be placed inside the section, outside or inside, and outside the section.

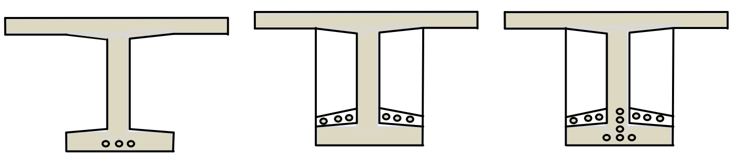

Figure 3. Tendon layout on the girder section

2. External tendons
External tendons can strengthen elements or beams as well as reduce the dimensions of the beam’s appearance. On the box section, the external tendons can be placed outside or inside the sections and they are used on the post-tensioned system in both the pre-cast and cast-in placed systems. They also have several advantages, such as, for inspection and maintenance, and the replacement and installation of tendons can be easily carried out with less friction; prestressing force can be modified after construction.
The prestressing force on the external tendons is transferred to the structure through the anchor system in the diagraphm and deviator. External tendons in the cross section can be bounded or unbonded at the deviator points in which deviators usually consist of three types, for instance, diagraphm, rib or stiffener and saddle or block (see Fig. 4).

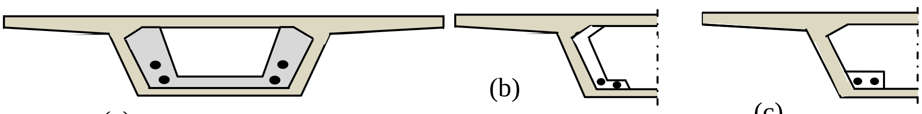

Figure 4. Deviator types: (a) diagraphm, (b) stiffener, (c) saddle

Tendon layout is shown in Fig. 5 and tilted tendons can be made in indeterminate static structures and the straight tendon has no vertical force components, so it is not effective to resist shear forces.

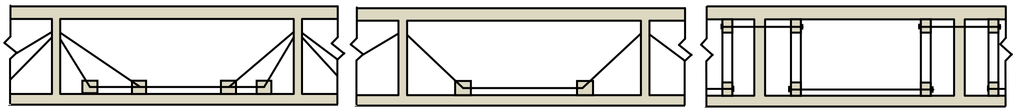

Figure 5. External tendon layout

3. Continuity prestress (static uncertainty)
Compared to a simple support beam, the continuity beam has several advantages: the its maximum moment is less, it saves anchor and energy, its tendon waves can withstand from positive and negative moments, it saves initial and maintenance costs for joints due to environmental influences, and it increases resistance to temporary and environmental burdens.

4. Tendon profile
The tendon profile of the continuity beam is chosen to maximize the prestressed effects. The shape of the prestressed profile is influenced by the ease in the construction method used and the shape of the tendon profile that is usually used in a continuity prestressed bridge is shown in Fig. 6.

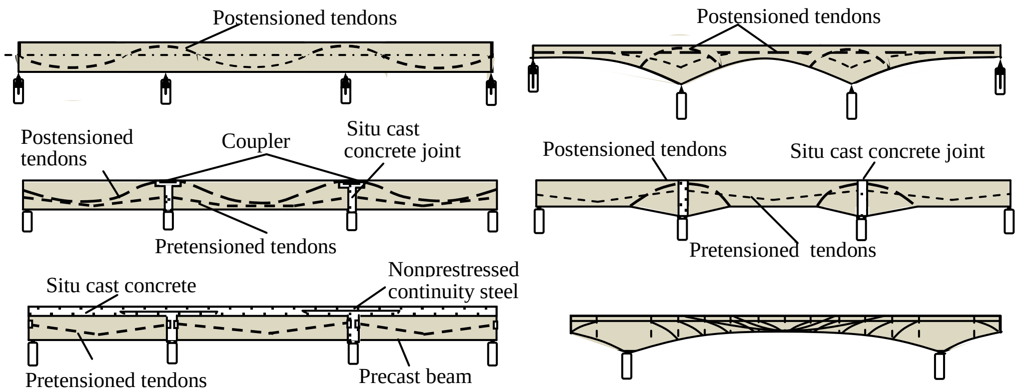

Figure 6. Tendon layout of continuous beam

5. Cable systems and segments of prestressed cantilever bridge

In cantilever systems, tendons are needed to support segments during the installation and the post-construction in which the cantilever, continuity and closed tendons are used. Cantilever tendons can at least support the segment during construction and are anchored in the upfront or in the blister/deviator or a combination of both. The continuity tendons are placed in the area of positive moment (lower fiber) and of negative moment leading to one pedestal to others (upper fiber). The continuity tendons of lower fiber are anchored in the upper blester. The closed tendons become the tip tendons of the lower tendons from the lower and upper fibers. The cantilever tendons and poles can be either external tendons or a combination of internal and external tendons.

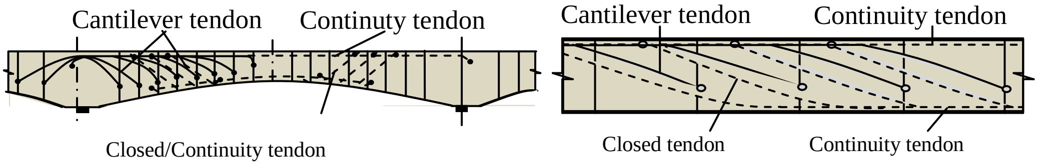

Figure 7. Tendon layout of cantilever system

CONSTRUCTION METHODS

The implementation methods or construction of prestressed bridges can be classified in several systems, for example, the scaffolding or falsework, the launching, the phased segment, and the cantilever methods.

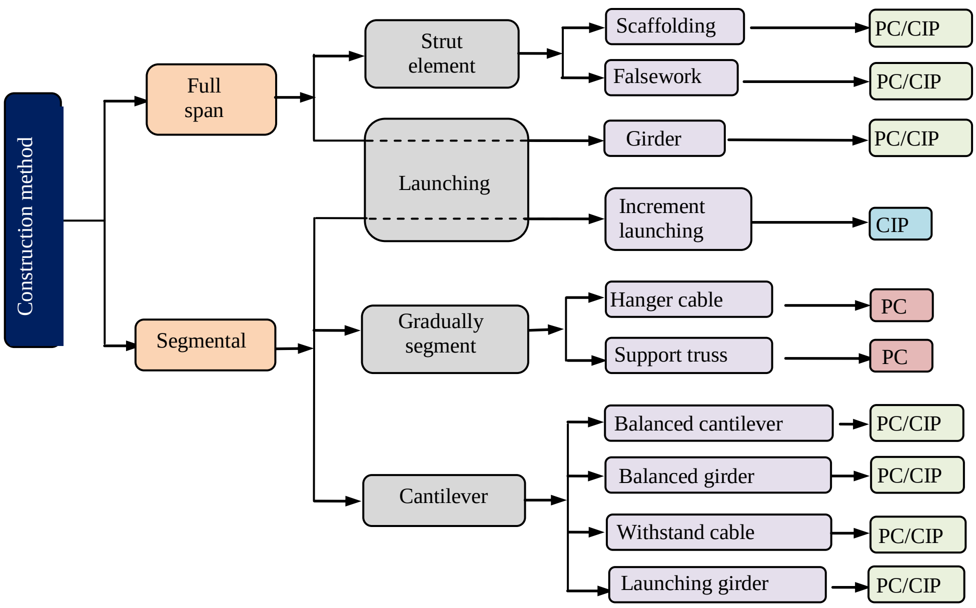

Figure 8. Scheme of construction method

1. Scaffolding method

Scaffolding systems are divided into scaffolding and falsework; the first consists of straight and angled stems (bracing) which are arranged and assembled from the bottom surface to the level of the bridge stand. The second refers to a frame supported by two or more feet in which the feet can be made fixed or move (movable scaffolding system). Scaffolding is usually made of wood or steel but falsework is commonly made of steel or concrete. Steel scaffolding and falsework can be formed manually or in special shapes made in factories.

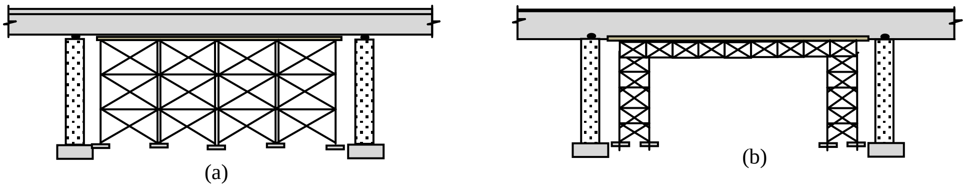

Figure 9. Scaffolding construction methods: (a) scaffolding, (b) falsework

2. Launching method
In this system the girder is casted on one side of the land bridge and after being hardened the girder is launched by pulling or pushing until it reaches the planned position. The method can be carried out either by girder launch or incremental launching. The girder launch method is applied only for a single span and is only done by using a gantry or two cranes that work at the same time.

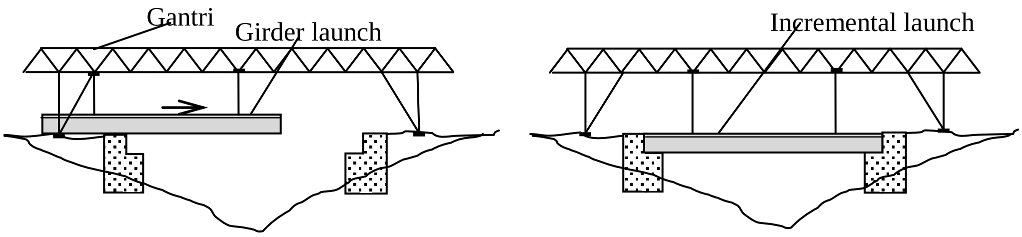

Figure 10. Construction method by girder launch

The incremental launching method is used for more than one spans and it requires a steel launching nose mounted on the front of the first segment to reduce negative moments due to cantilever. The launching nose is about 60% of the longest span and the unity is about 10% of the weight of the beam. This method has two requirements, such as, the girder section must be prismatic and if the bridge alignment is horizontal or vertical, the radius must be the same.

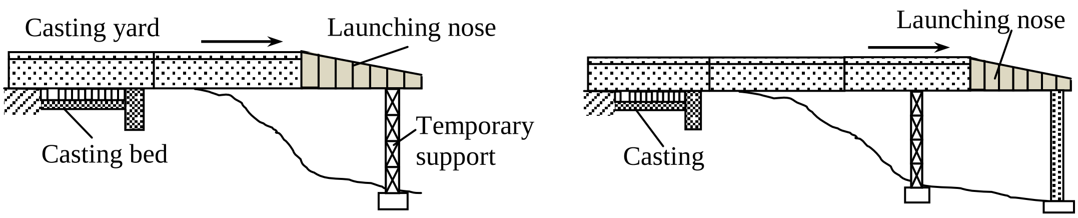

Figure 11. Construction methods with stepwise segments: (a) methods with cable hanger; (b) support truss

3. The stepwise segment method
This method (see Fig. 12) is applied in segment-by-segment stages and the segment installation can be by hanger cables and by truss supports. In systems of hanger cables, the precast segments are installed and supported by cables that hang on the gantry. In systems of truss supports, the segments are supported by truss that span from pillar to pillar. The position of the truss can be under the segment or segments placed in the box-shaped truss. Lifting the segment may use gantry or crane.

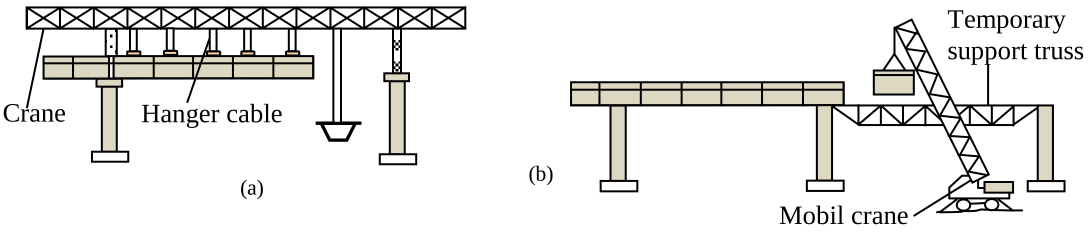

Figure 12. Construction methods with stepwise segments, (a) methods with cable hanger; (b) support truss

4. Cantilever method

In this method, the segments are installed and resemble cantilever on both sides of the span or on one side of the span. Cantilever segments are supported by a special prestressed cable while the permanent load is retained by a separate prestress. This method may have four techniques or forms, such as, two-sided cantilever, cantilever with balancing beam, cantilever with retaining cable, and cantilever with launching girder.

A. Two-sided cantilever method

The two-sided cantilever is a classic method in which one side functions as a balance for the other sides and the method is carried out simultaneously. In concrete with precast systems, its segment removal and travelling is carried out using gantries, cranes or frames. In insitu cast concrete, the installation of segments is done by using traveling form. The final points of sided cantilever or inner span can be filled with small segments as closed segments.

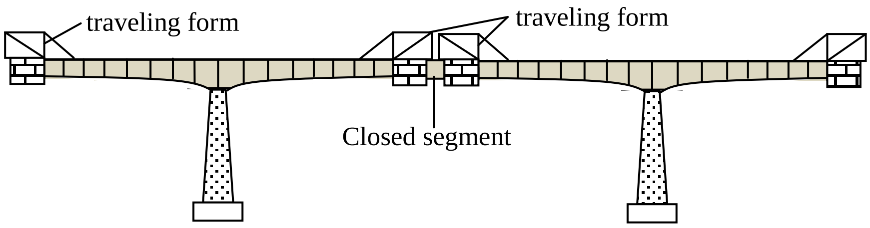

Figure 13. Construction method with double-sided balanced cantilever

B. Cantilever method with balance blocks

This method is applied with a balancing beam located on the mainland side. The counter beam can be a precast or cast insitu system that is refuted using scaffolding. It usually consists of three spans in which the middle span is installed segment-by-segment and the installation of cantilever segments is similar to the installation of double-sided segments.

C. Cantilever method with supporting cable

This method may be applied by using temporary cables to refute and hold the fixed segment in its position. Cantilever segments may be in the form of precast or in situ concrete. The installation of the precast segment uses gantry, crane or frame and the installation of the in situ cast segment may involve traveling form.

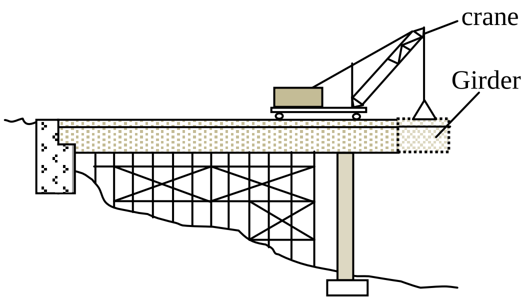

Figure 14. Construction method with balance blocks

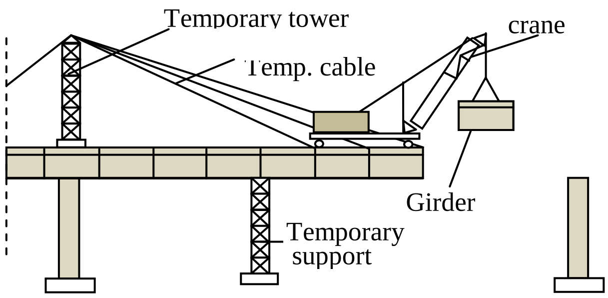

Figure 15. Construction method with supporting cables

D. Cantilever method with launching girder

This method uses gantry to lift, travel and install cantilever segments and can also lift precast girders that are on the pontoon, on the truck or on the bridge itself. Segment lifting can be carried out for two sides at the same time.

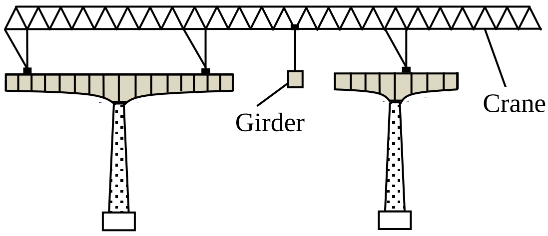

Figure 16. Construction method with cantilever launching girder

CONSIDERATION ON THE APPLICATION OF PRESTRESSED BRIDGE CONSTRUCTION METHODS

Considerations for the use of the prestressed bridge construction method are described in Table 2.

Table 2. Consideration on the application of prestressed bridge construction methods

No	Criteria	Strut element	Launching girder	Gradual segment	Cantilever
1	Traffic under the bridge cannot be disturbed and diverted				
2	Free space under the bridge	low	low-medium	medium	tall
3	Riverbed or valley	shallow	shallow-medium	medium	deep
4	Swift bay or river currents	No	No	Yes or No	Yes
5	Main spans	25 - 125	25 - 80	30-150	30 - 300
6	Wide land behind the abutment				

CONCLUSIONS

1. The implementation of prestressed bridge structure is influenced by system and span length and by ease of implementation.
2. The choice of construction method is affected by natural conditions of the location, by landscape and by construction costs.

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How to cite this article: Kadir A. Prestressed bridge construction: systems and methods. International Journal of Research and Review. 2019; 6(9):287-293.

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