The First Extradosed Bridge in Turkey: Design of the Antalya Çallı Bridge

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Abstract Cast-in place (CIP) continuous post-tensioned bridge construction method is a fast and efficient way of constructing urban bridges. In this method, the hyperstatic property of the continuous deck is utilized to efficiently place material at where it's needed. For some urban projects, higher ratio of span-to-depth arrangement, beyond the capacity of internal post-tensioning is required. In order to achieve this requirement, higher eccentricity/load balancing is needed from the post-tensioning tendons, which is usually created by increasing the section depth. However, given a fixed section depth, higher eccentricity from the tendons can be achieved by placing them above the deck level–outside the concrete–at support locations. The resulting structure is a hybrid between internal and external post-tensioning, resembling a stay cable bridge. Quite aesthetic in view with shallow pylons, this type of bridge is named extradosed bridge in literature.

Çallı Bridge, in Antalya city center, will be the first extradosed bridge designed and constructed in Turkey. The 180m long bridge has an 80m main span with 50m side spans, 30m wide pi section deck with 2.5m constant depth. In addition to internal longitudinal and transverse post-tensioning, 2 x 4sets of 4 extradosed cables are provided above the deck at 7m pylons. The 30m x 180m deck piece is supported on lead-rubber bearings to increase effective period as well as damping ratio to reduce seismic force effects.

The owner of the project is the General Directorate of Highways (KGM). The main contractor is Antalya İnşaat (Makyol-HGG JV). The preliminary design calculations and sizing of the bridge is performed by Freysaş. The Designer of the project is Mega Mühendislik. Freysaş is responsible for all post-tension works, seismic bearings, expansion joints, and extradosed cables including saddle systems. The project is under construction and is planned to be opened to traffic for Expo 2016. This paper presents key information about the design and construction of the bridge.

1 Introduction

Extradosed bridges, which combine the prestressed girder bridge concept with the cable-stayed bridge concept have become an attractive bridge type around the world in recent years. While the external appearance of the extradosed bridges resembles the cable-stayed bridge with short pylons, the behavior of the bridge is structurally similar to the prestressed concrete girder bridge with external prestressing tendons. Its shallow pylons and aesthetic view enables the extradosed bridge to be a viable alternative in urban areas.

There have been two methods of cable installation in extradosed bridges. One of them is the Christian Menn's application for the Ganter Bridge in Switzerland (1980) with a main span of 174 m. Superstructure of the bridge is a combination of prestressed box girder with the extradosed cables encased in concrete walls.

On the contrary another proposal was arisen with the Arret Darre viaduct in France. Its concept is based on replacing the internal tendons with the external cables, providing connection between upper side of the deck and the short pylons. This concept is the basis of the Extradosed Bridge concept adopted in recent years by the majority of the engineers.

The concept of the Ganter Bridge is quite different from the Arret Darre viaduct (Figure 1): the extradosed cables of the Ganter Bridge are not easily replaceable and the Ganter Bridge is much stiffer than the Arret Darre Viaduct.

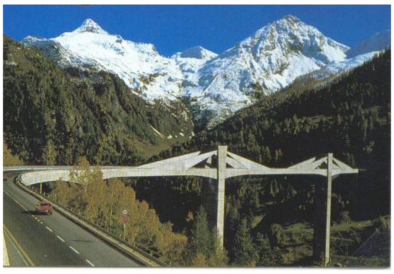


Figure 1-a. Ganter Bridge [1]

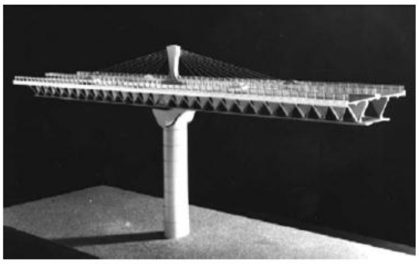


Figure 1-b. Proposed Viaduct for Arret Darre [2]

Since 1990's, there has been many examples of the modern extradosed bridge concept built around the world. The Odawara Port Bridge in Japan (1994), which was constructed based on the concept of the Arret Darre viaduct is one of the first extradosed prestressed concrete bridges built in the world. Its main span is 122m with a total length of 270m. With its 275m main span, Kiso Gawa Bridge in Japan (2001), has the longest main span in the world.

Despite the many examples of post-tensioned and a few cable-stayed bridges, an example of an extradosed bridge has not been constructed yet in Turkey. Çallı Bridge, in Antalya city center will be the first extradosed bridge designed and constructed in Turkey.

2 Extradosed Bridge Concept

Concept of extradosed bridge is based on a combination of post-tensioned girder bridge and stay cable bridges. In some situations, bridges with higher ratios of span-to-depth arrangement, beyond the capacity of internal post-tensioning, is required. In order to achieve this requirement, higher eccentricity/load balancing is needed from the post-tensioning tendons, which is usually created by increasing the section depth. Figure 2 summarizes the all three concepts.

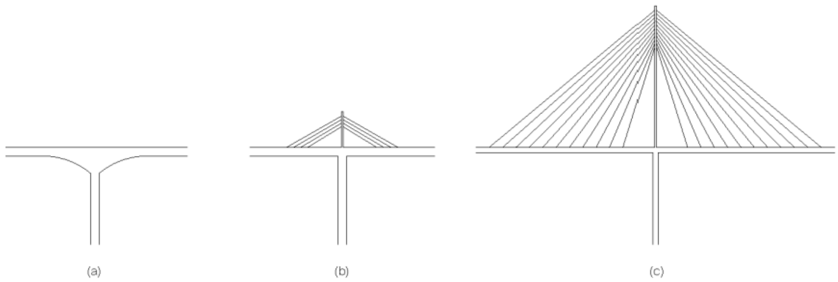


Figure 2. Typical view of (a) girder, (b) extradosed and (c) stay-cable bridges

With fix section depth, higher eccentricity from the tendons can be achieved by placing them above the deck level–outside the concrete–at support locations. The resulting structure is a hybrid between internal and external post-tensioning, resembling a stay cable bridge. The general appearance of a typical extradosed bridge appears like a stay cable bridge, however the structural system behavior is more of an externally prestressed girder bridge due to the deck stiffness (as compared to a stay cable bridge, which has a much less stiff deck).

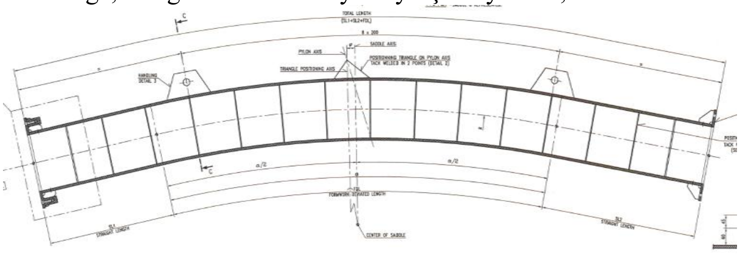
In extradosed bridge concept, the cables coming from the lower pylons reach to the deck with small angles. The down side of the cable connection with a small angle is that the horizontal component of the cable force compresses the deck section. Consequently, the cables act as prestressing cables for the concrete deck. Locating prestressing cables above the deck to increase the eccentricity and utilize the capacity of the deck slab in compression have been an inspiration to the development of the extradosed bridges.

Extradosed bridges are preferable in urban areas, where shallower decks as compared to conventional post-tensioned bridges are required. As compared to stay cable bridges, due to its shallow pylons and relatively shorter and horizontal cables, stress variation and fatigue effect under live loads are limited on the extradosed cables. Consequently, maximum 60% of GUTS in service is allowed in the extradosed cables, whereas the limit is 45% of GUTS in cable-stayed bridges [3].

One of the important elements of the extradosed bridges is the saddle system. Saddles provide the deviation of the stay cables through compact pylons. Saddle system is an alternative to the anchorage system. Saddles should be designed to resist the forces coming from both sides of the pylons: if one span is loaded only, force should be transferred to the connecting cable on the mirror span through the saddles. In the anchorage systems, force must be transferred to the mirror side cables via posttensioned connection, or overlapped cables through the pylon. In the saddle system, the differential forces in the same cable are resisted by friction, bonding or mechanical means through the saddle surface. For The Çallı Bridge, deviation saddle system was preferred. The deviation saddle of the bridge continues through the pylon. The Freyssinet saddle system consists of a multi-tube saddle based on the use of the Cohestrand strand in order to take up the asymmetric frictional loads through the strand sheath to the pylon. Each strand is deviated individually in a specific tube, giving the following advantages:

- complete continuity of corrosion protection (HDPE sheath, waxed and galvanized wires in Cohestrand)
- possibility of individual replacement of strands (not possible if the force transfer relies on the bonding of the stripped wires to the saddle; then the whole saddle needs to be replaced along with the cables)
- fatigue resistance identical to a standard stay cable anchor.

The Freyssinet system uses Cohestrand technology, which is a sheathed strand with seven galvanized steel wires, covered by a system capable of resisting corrosion in very corrosive environments and also taking axial loads through the sheath when required, to the deviation saddles. The Cohestrand strands used in Çallı Bridge has 1,860MPa ultimate tensile strength capacity. In Figure 3, saddles of the Çallı Bridge, designed and built by Freysaş-Freyssinet, is shown.



(a)

(b)

(c)

Figure 3. Saddles used in Çallı Bridge

3 Çallı Bridge

General Directorate of Highways (KGM) is the responsible government entity for the planning, construction and operation of vehicular bridges in Turkey. For Çallı junction in Antalya, KGM evaluated different bridge options and decided to build an extradosed bridge, reviewing its advantages and appearance. Çallı Bridge, the first extradosed bridge designed and constructed in Turkey, is under construction and is planned to be opened to traffic for Expo 2016, in Antalya.

Table 1. Çallı Bridge –General Data

Owner	KGM
Designer	Mega Mühendislik
Span Arrangement	50m+80m+50m, in total 180m
Superstructure Width	15m x 2 = 30m
Traffic lanes	3 x 2 = 6 lanes
Main Contractor	Antalya İnşaat (Makyol-HGG JV)
Posttension/Staycable Bearing and Joint Supplier	Freysaş – Freyssinet

The preliminary design calculations and sizing of the bridge is performed by Freysaş. Optimum deck cross sections and amount of tendons required are determined.

Çallı Extradosed Bridge is straight in plan with three spans: 50m+80m+50m totaling to 180m. Over each pier section, three pylons with 7m height are built. 2x4sets of 4 extradosed cables (32 cables) are provided above the deck. The cables are designed nearly parallel (harp design) to one another. Side view of the bridge is shown in Figure 4.

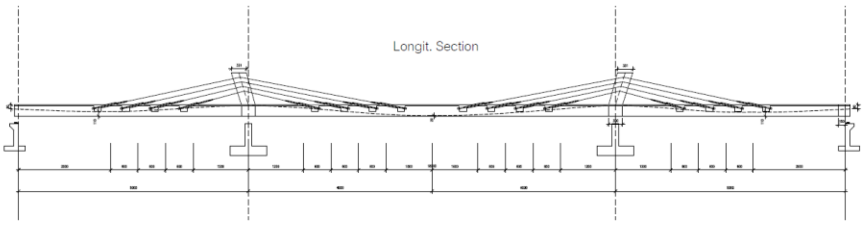


Figure 4. Elevation view of Çallı Bridge

Typical deck cross-sections is given in Figure 5. The bridge has 2 x 15m wide typical twin pi-decks separated 50cm, to minimize torsional and unbalanced load effects. The deck height is 2.5m constant throughout the span. At pier locations, a solid pier diaphragm section connects the two pi-sections to provide torsional rigidity. At extradosed cable anchorage locations, shallower mid-diaphragms provide rigidity and distribute the force coming from stay cables. The middiaphragm do not connect the two pi-sections. To reduce top slab thickness, transversal posttensioning tendons are provided in the top slab.

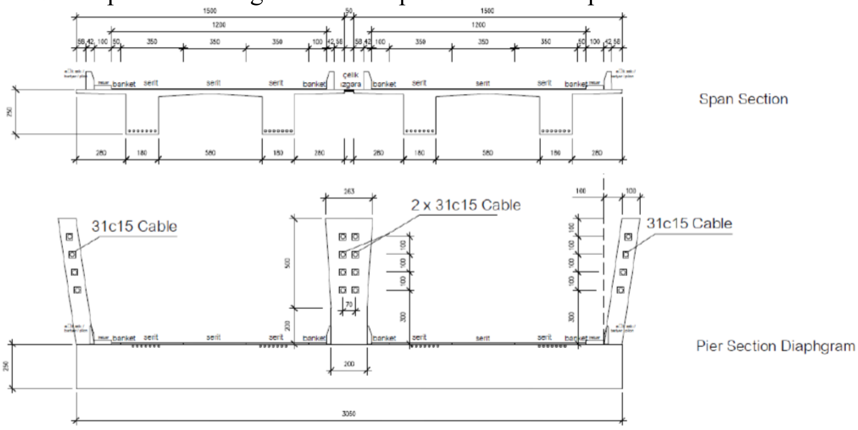


Figure 5. Typical cross-sections of Çallı Bridge

In the longitudinal direction, apart from extradosed cables, each rib of the pi-section contains 7x31C15 internal posttensioning tendons (28x31C15 tendon in total). The deck is cast in two segments, and intermediate stressing of tendons is performed at the construction joint to reduce the friction losses in the tendon. Tendon continuity is provided by mechanical 31C15 Freyssinet couplers.

Antalya is located in seismic Hazard Zone 2 according to the Turkish Seismic Hazard Scale. To avoid large seismic forces, lead rubber bearings (LRB) are placed over piers and abutments. Lead rubber bearings provide higher rigidity and damping ratios, as compare to elastomeric or high damping rubber bearings (HDRB). In Çallı Bridge, on each pier 6 LRBs and on each abutment 3LRBs, in total 18 LRBs with ϕ1000mm in diameter are used. Bearing configuration is given Figure 6.

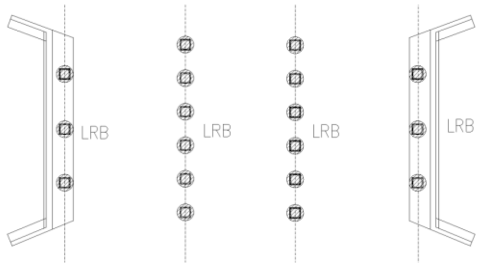


Figure 6. Bearing layout of Çallı Bridge

In preparing the construction schedule, it is decided to support the deck on formwork until the bridge is completed. The two twin-pi decks are cast and internal post-tensioning is applied first. Then, the pylons are constructed and stay cables are installed symmetrically in each horizontal row (Figure 7). After the stay cable installation, formwork will be removed and asphalt and other superimposed dead loads will be applied on the deck.

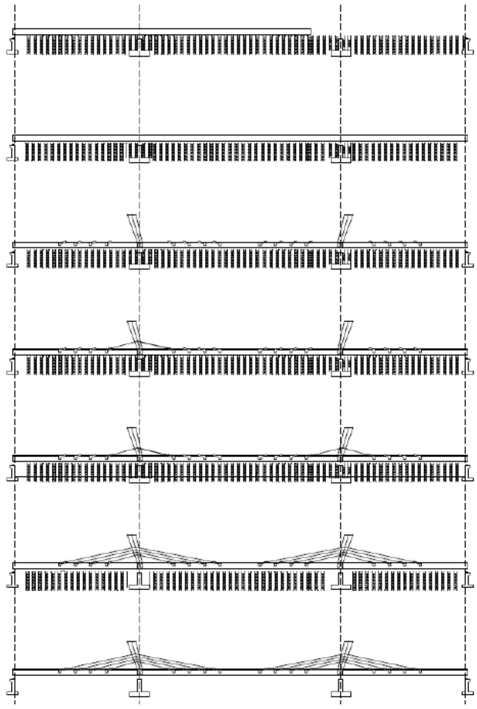


Figure 7. Construction Stage Analysis

Bridge is modelled and analyzed using Csibridge software [4]. Construction stages are defined to consider staged construction steps and time dependent material effects. Analyses is performed for construction, service and ultimate limit states including seismic effects. Csibridge 3d model view is shown in Figure 8.

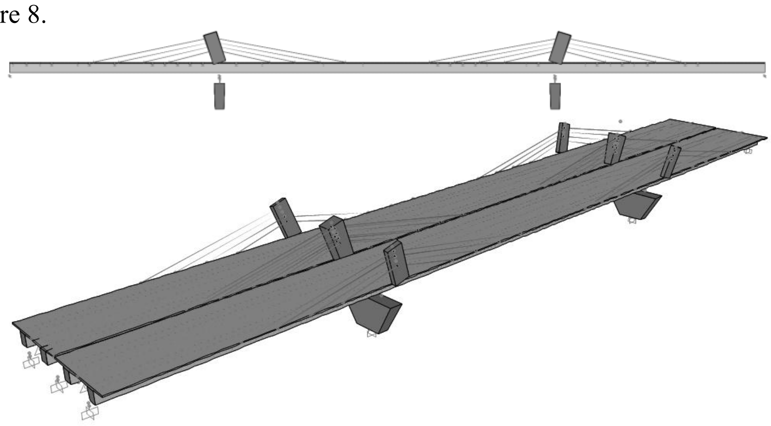


Figure 8. Çallı 3d computer model view.

4 Conclusions

This paper presents the concept of extradosed bridges in general, and gives detailed information about the Turkey's first extradosed bridge in Antalya: The Çallı Bridge.

With their shallow pylons and aesthetic view, extradosed bridges are feasible alternatives in urban areas, where the deck height is limited by various constraints.

The main contractor for the project is Antalya İnşaat (Makyol-HGG JV). The Designer of the Çallı Bridge is Mega Mühendislik. Freysaş is responsible for all post-tension works, seismic bearings, expansion joints, and extradosed cables including saddle systems. The project is under construction and is planned to be opened to traffic for Expo 2016.

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References

1. Janberg N. (2009), Ganter Bridge. [Photograph] Available at: http://en.structurae.de/photos/index.cfm?JS=153412
2. Virlogeux M. (1999), Recent evolution of cable-stayed bridges. Engineering Structures
3. Cable Stays, Recommendations of French inter-ministerial commission on Prestressing, Setra, June 2002.
4. Computer and Structures, Inc., Csibridge Software Version 18.1.1