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VIADUCTS BY PUSHING: INCREMENTALLY LAUNCHED BRIDGES

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ABSTRACT

Despite its widespread use around the world, constructing bridges using the incremental launch method (ILM) hasn't been popular in Turkey. With very few examples, the knowledge and application on this topic is limited. However, Turkish engineers and construction companies are developing their knowledge and gaining experience on this topic in neighboring countries.

The method requires setting up a casting yard on one side or both banks, casting of each span in segments, and pushing each successive span over piers after hardening of concrete. A steel nose, installed in front of the first span, reduces the concrete deck cantilever length prior to reaching the next pier. Guiding devices are placed at three locations, and temporary sliding bearings are installed at each pier. Optimal span length ranges from 40-60m without the need of temporary supports. Advantages of this method include increased quality of fabrication and manpower efficiency due to casting at prefabrication yard, limited investment on scaffolding and on special equipment. Bridges longer than 1.2km are known to be launched using this technique (Miryang, Korea).

Using this method, bridge support bearing arrangement may create further economy in design. The deck can be left free to move in longitudinal direction at pier heads and fixed at abutments with energy dissipating devices, transferring little horizontal force to piers. Hence, the stiffness requirement in tall piers greatly reduces, generating an economical design.

Two recent examples using this method are presented: the BTZ Bridge in Algeria, and the Liakhvi Viaduct in Georgia. Quantity and cost comparison between the ILM and simply-supported precast isostatic girder bridges will be presented.

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Viaducts by Pushing: Incrementally Launched Bridges

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ABSTRACT

Despite its widespread use around the world, constructing bridges using the incremental launch method (ILM) hasn't been popular in Turkey. With very few examples, the knowledge and application on this topic is limited. However, Turkish engineers and construction companies are developing their knowledge and gaining experience on this topic in neighboring countries.

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Introduction

Despite its widespread use around the world and its advantages, constructing bridges using the incremental launch method (ILM) hasn't been popular in Turkey. Except a few examples, the knowledge and application on this method is limited. However, Turkish engineers and construction companies are developing their knowledge and gaining experience on this topic especially in neighboring countries. This paper presents a brief description of the incremental launching technique, and provides a cost comparison between ILM and precast girder system. Two examples using this method: the BTZ Bridge in Algeria and Liakhvi Viaduct in Georgia are presented.

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Incremental Launching Technique

The concept of incremental launching was first implemented on the Rio Caroni Bridge in Venezuela in 1962 to avoid the required scaffolding to support the formwork. By doing so, the deck was pushed over the piers creating a continuous bridge with 48m side spans and four 96m interior ones, with the help of a 17m launching nose and temporary piers in each span. The temporary supports reduced the launching span to 48m [1]. The deck structure was assembled from precast elements and was prestressed by concentric tendons. Since then, many new materials and techniques have been developed, giving shape to today's ILM method. As is done in Miryang Bridge (Korea), 1.2km long deck has been launched using this technique.

The method requires setting up a casting yard placed behind the abutments on one side or both sides. Since there is only one formwork on either side, the deck is cast in segments, continuously. However, the next segment cannot be cast until the previous segment leaves the formwork. So, after sufficient concrete strength is reached, the whole deck is pushed over piers giving the access to the formwork to build the next segment. Launching operation is realized by deck sliding on temporary bearings placed on top of abutment and on each pier. Launching steps of the segments is shown in Figure 1.

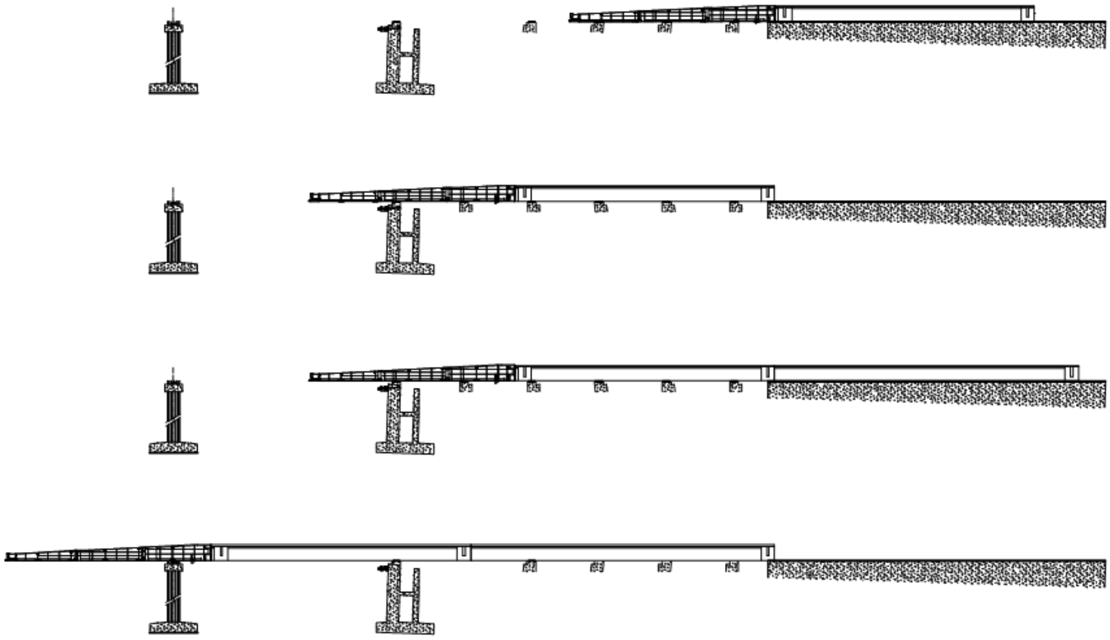

Figure 1. Construction steps of ILM.

The construction sequence can be summarized in four main steps. First, the concrete section is cast in the formwork. Then, after the concrete attains adequate strength, the tendons are post-tensioned, giving way for launching. Next, the whole bridge is pushed over the supports. Usually, a work cycle of one week is required to cast and launch a segment, regardless of its length.

The operations are scheduled such that the concrete would reach sufficient strength over a week-end, so the launching can be performed. Steam curing and other methods can easily be applied at this stationary set-up. Hydraulic jacks are used to push the segments forward.

Guiding devices and Teflon coated bearings (providing minimal friction) on the piers make it possible to slide the whole deck forward. The piers and the abutments have to be checked considering the effects during launching; since some friction force will be transmitted as horizontal force.

When the casting yard is established, it is stationary until the end of the project. A sheltered environment is provided, which increases the quality of fabrication and provides better quality control. Since, single formwork is required for casting, limited initial investment is required for equipment. Moreover, working in a stationary casting yard is simpler and safer, rather than working on a false work.

The most suitable cross-sections for launching are the single–cell box sections. Double T-sections and solid–section decks for short spans have also been used. Box–sections better tolerate the secondary forces developed during launching because of its high torsional stiffness compared to ribbed slabs (double–T sections). If pier caps are provided, higher torsional stiffness reduces the pier cap dimensions. [1].

Bridge alignment of ILM may be either straight or curved with constant radius. This requirement of constant rate of curvature applies to both horizontal and vertical curve. Bridge decks with different curvatures can be launched from both abutments and connected at their intersection. Longer total span lengths can be constructed when launching is performed from both sides.

When the bridge is launched, the deck starts to move over the piers. As it moves forward, the section forces created due to its self–weight changes. This is shown in Figure 2. Deck cross–section along the span must be sized to resist these constantly changing internal forces. Maximum bending moment is created when the first segment cantilevers of the pier, right before reaching the next pier. Sizing the section for this maximum bending moment would yield uneconomical sections. So, to reduce the moment coming from cantilever action, a steel beam (called “nose”) is installed in front of the first segment.

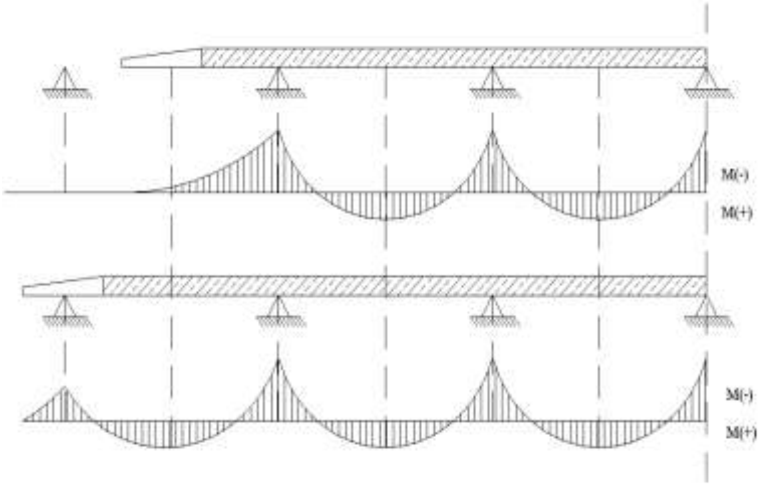

Figure 2. Change in bending moment during launching.

In general, launching nose consists of two twin steel girders braced horizontally and transversely. The lower part of the nose should be set parallel to the bottom edge of the deck, acting as an extension of the deck. For an economical sizing of the nose and the deck section, the approximate length of the launching nose would be in the range of 60% of the longest span. The nose weight should approximately not exceed 10% of the span weight, and the stiffness of the nose should be in the range of 15% of the deck. Figure 3 shows a typical launching nose.

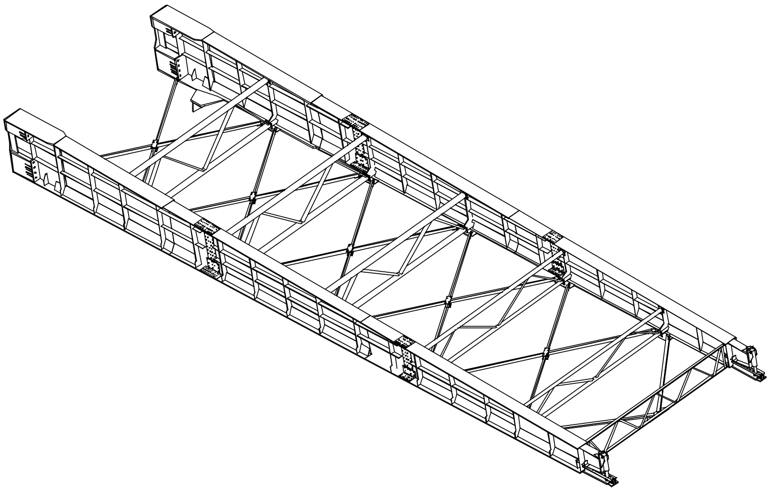

Figure 3. Typical Launching Nose.

A concentric post-tensioning on the deck section is provided during the construction stage, which creates constant compressive stresses on the section. Since all sections experience positive and negative bending moments during its movement, the deck section and tendons are selected so that the section limits are not exceeded. When the launching operation is completed, the continuity tendons are installed according to the bending moments under dead and live loads. Continuity tendons supplement the concentric prestressing in the section.

Using this technique, bridge support bearing arrangements may create further economy in design. During launching operation, the deck transfers forces to the piers in three components: (i) support reaction of the continuous deck in vertical direction, (ii) force due to friction plus force due to slope of the deck (if sloped) in longitudinal direction, and (iii) forces created by guiding devices in the transverse direction [1]. The deck can be left free to move in longitudinal direction at pier heads and fixed at abutments with energy dissipating devices, transferring little horizontal force to piers. Hence, by fixing the deck only at abutments in the longitudinal direction, the stiffness requirement in tall piers greatly reduces, generating an economical design.

Numerical Example

To demonstrate method, quantity and cost comparison between the ILM and simply supported pre–tension precast girder bridge is presented, keeping the span length unchanged. In simply–supported girders, the total static moment is carried by the midspan section. In continuous members, the moment actions are carried both by the midspan and support sections. ILM creates continuity over supports, generating an efficient design.

The Melet Viaduct in Ordu, which is currently under construction, is selected for comparison. The pre-tensioned precast girder option is chosen by contractor. The total length of this bridge is 1,198m, two decks built side by side. The width of the deck is 13.5m.

Pre-tensioned Precast Girder Option

The pre-tensioned precast girder option has 37m long simply-supported spans with 31 piers along the length. The depth of the cast-in-place topping deck concrete is 25cm. Pre-tensioned precast girders are 150cm deep placed side by side, as shown in Figure 4. With the deck concrete, total depth of the viaduct becomes 175cm at midspan. The concrete volume, rebar and tendon amounts are summarized in Table 1.

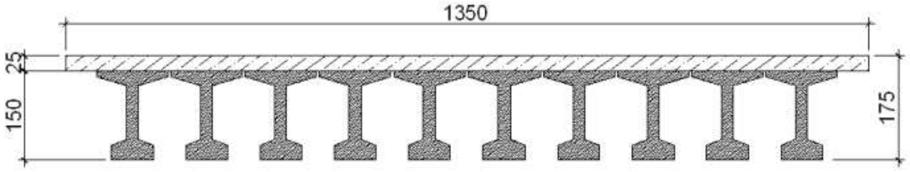

Figure 4. Simply-supported precast girder option.

ILM Post-tensioned Box–section Option

For ILM option, the span length is increased to 50m, with 24 piers. For 50m continuous spans, a constant depth box – section width 2.7m height is selected, as shown in Figure 5. The slenderness ratio of the section results to L/19, whereas for the first option it results to L/21. The total concrete volume, rebar and tendon amounts are summarized in Table 1.

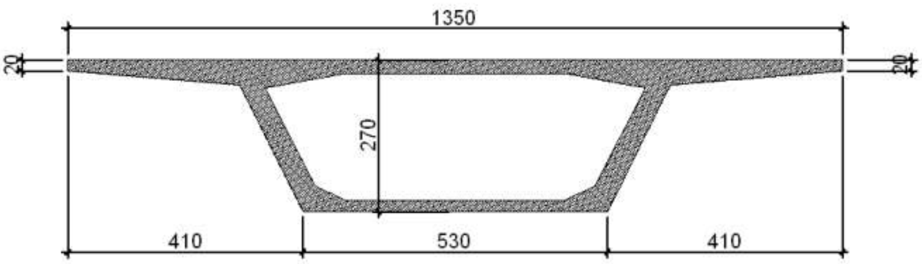

Figure 5. ILM continuous post-tensioned deck option.

Table 1. Comparison between Precast and ILM alternatives.

		Precast	ILM	Difference	
				Quantity	%
Pier + Pier Cap	Concrete (m3) Rebar (tons)	10,369 2,567	3,265 736	-7,104 -1,831	-69% -71%
Deck	Concrete (m3) Rebar (tons) Tendon (tons)	28,720 4,949 832	21,468 3,256 1,002	-7,252 -1,693 170	-25% -34% 20%
Total	**Concrete (m3)** **Rebar (tons)** **Tendon (tons)**	**39,089** **7,516** **832**	**24,733** **3,992** **1,002**	**-14,356** **-3,524** **170**	**-37%** **-47%** **20%**

As this numerical example demonstrates, compared to the pre-tensioned precast girder option, the post-tensioned continuous deck option using ILM creates 37% reduction in concrete and 47% reduction in steel material quantities, with increased span length. Reduction in material quantities results in direct cost savings. Detailed analysis of highway bridges has shown that the required tendon quantity for precast beam solution and ILM are more or less the same. Moreover, due to the continuity of the deck, few number of expansion joints are needed, which reduces the initial cost, and long term maintenance costs of the bridge. It is estimated that each typical segment can be launched in a 7-day cycle.

In addition to the savings in construction cost and time, the resulting structure is aesthetically pleasing with its slender deck, and provides a comfortable drive with no joints.

Recent Examples to ILM Technique

In this section information about two recent application of ILM technique: BTZ Bridge in Algeria and Liakhvi Viaduct in Georgia are presented.

The BTZ Bridge Project

The project is part of the double track railway system, connecting the cities of Birtouta and Zeralda in Algeria, composed of 4 concrete deck viaducts with single–cell box sections. The owner is ANESRIF (National Agency for the Conception and Follow-up of Railway Investments), the main contractor is Yapı Merkezi AŞ, and Freysaş-Freyssinet is in charge of Incremental Launching, supply and installation of post-tensioning, expansion joints and seismic bearings. The project is commenced in January 2014 and estimated to be completed in May 2015.

The span arrangement for each of the four viaducts is as follows:
V1: 30 +15 x 40+30 = 660 m
V2: 30 + 8 x 40+30 = 380 m
V3: 30 +12 x 40+30 = 540 m
V4: 27 +7 x 40+27 = 334 m

The cross-section of the deck was designed to house two train tracks. Figure 6 shows the typical cross section of the box-section. The box-section is a single cell trapezoidal box girder with a depth of 2.6 m, corresponding to a span to depth ratio of 15.4. Continuity over supports is provided by post-tensioning and continuous casting. Span lengths vary between 27 to 40 meters.

The box-section was designed to handle widths varying from 10.60 meters to 11.00 meters. The top slab is transversely reinforced. The section has a constant geometry except for the web thickness which varies from 500 mm at midspan to 700 mm near the piers. The running rail track is supported by a ballasted track on top of the box-section.

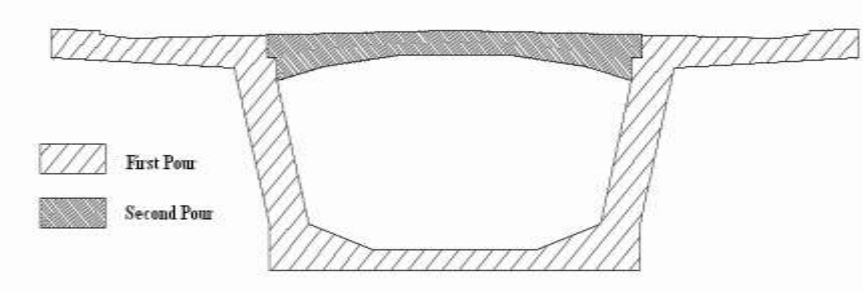

Figure 6. BTZ Bridge Typical Cross-Section.

The launching internal post-tensioning is straight in top and bottom slabs. The service load post-tensioning is undulating in the web from high point at pier to low point at midspan. An additional service continuity post-tensioning is running in the bottom slab and anchored on blisters, at 8m on each side from the mid-span.

Figure 7. BTZ Bridge in movement.

The Liakhvi Viaduct in Georgia

This project is part of an existing highway upgrading activity along the Tblisi–Leselidze Highway. The owner is The Road Department of the Ministry of Economic Development of Georgia, the contractor is the Akkord Corporation and Freysaş-Freyssinet was in charge of Incremental Launching, supply and installation of post-tensioning, expansion joints and seismic bearings. Two viaducts side-by-side are constructed, using the incremental launch method. The chosen deck for the bridge is a double–T section (Figure 8). The project was completed in about 9 months in 2012.

The overall width of a single deck is 14m. The height of the section is 2.4m. The viaduct was designed as multi-span continuous longitudinally post tensioned deck. The total length of the viaduct is 877m spanning 19 piers. Maximum span length is 48m and longitudinal slope is constant at % 3, with no curves. The span arrangement of the viaduct is as follows: 36+7x45+40+6x45+2x48+45+42+33=877m. Pictures during launching operation are given in Figures 9 and 10.

Figure 8. Liakhvi Viaduct Typical Cross-Section.

Figure 9. Liakhvi Viaduct during launching.

Figure 10. Liakhvi Viaduct close to completion.

Conclusions

The incremental launching method is one of the highly mechanized erection methods used in bridge construction. Since its first application in 1960's, many bridges have been constructed using the ILM technique worldwide. However, the application of this method in Turkey is quite scarce. Two recent examples to this method executed by Freysaş-Freyssinet are provided.

As demonstrated in the numerical example, compared to the pre-tensioned precast girder option, the post-tensioned continuous deck option using ILM creates 37% reduction in concrete and 47% reduction in steel material quantities, with increased span length. Due to the continuity of the deck, few number of expansion joints are needed, which reduces the initial cost, and long term maintenance costs of the bridge. It is estimated that each typical segment can be launched in a 7-day cycle. The ILM technique has proven that it is an economical alternative that can be constructed in less time, which yields aesthetic slender sections.

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