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Outline of the New Construction Project over the Kelani River

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Abstract: This project is to construct part of urban expressway in the most congested area in Colombo, Sri Lanka. It is featured by a long-span prestressed concrete extradosed bridge and elevated steel box girders supported by steel portal frame piers. This paper presents outline of the project by focusing on the advancement of technologies employed in this design, construction method and long-term durability.

Keywords: High performance steel, epoxy coated and filled strand, extradosed bridge, accelerated construction, gravel compaction, urban elevated steel bridge

1. Introduction

With the opening of Colombo-Katunayake Expressway (CKE) connecting the Sri Lankan capital to Bandaranaike International Airport in October 2013, there is a considerable increase in the traffic entering the Colombo city and the capacity of existing New Kelani Bridge will not be sufficient to cater to such heavy traffic volume. The daily traffic volume of both roads is 86,000 vehicles on Baseline Road and 27,000 vehicles on Port Access Road.

Major developments in Colombo city and Colombo Port will further increase the traffic in this area. Therefore, Road Development Authority has decided to implement a project to construct a new bridge adjoining the existing bridge with six lanes together with related elevated approach bridges and interchanges.

This Project is the largest bridge construction project in Sri Lanka. As a symbol of Greater Colombo region, it has a long-span extradosed bridge and advanced technical features. The construction will commence in early 2017 and is scheduled to complete by end of 2019. This paper describes the outline of the detailed design and involved technical features.

2. Scope of the Project

The Project is located about 5km north of Colombo Center (Figure 1). The route starting at CKE end point, diverges from the CKE and runs parallel to the existing road, then at the Kelanitissa Junction, 4-lane elevated bridge runs south over Baseline Road 4-lane diverge to west on Port Access Road through the Junction. Those elevated steel box girder bridges will be built over the existing roads supported by steel portal frame piers.

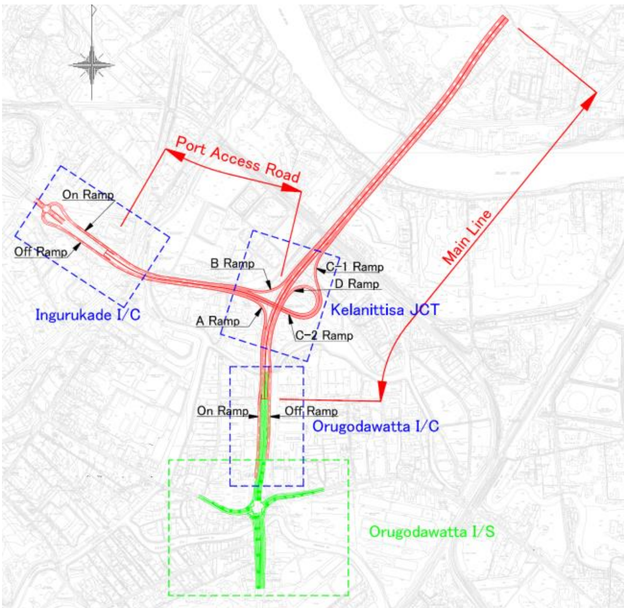

Figure 1: Project Outline

The design life is 120 years. The applied bridge design codes are Bridge Design Manual, Road Development Authority, Sri Lanka, and BS5400, and Bridge Design Standard for Highway Bridges in Japan.

Live load is in accordance with BS5400-2 (1978), including HA loading and 45 units of HB loading. Basic wind speed is 33.5m/sec.

3. Extradosed and PC Box Girder Bridge

3.1 Extradosed Bridge

The extradosed bridge crossing the Kelani River accommodates 6-lane traffic with 380m length having 180-m main span and two 100m side spans. The pylons are reinforced concrete and main girders are three cell prestressed concrete box girder. The girders are supported by pod bearings, longitudinally fixed at one pylon and the others free. The pylon foundations are with 2 m diameter bored piles. The piles are basically end bearing type and the ends socketed into rock.

The stay cables, 12 stays per plane with 37 strands maximum are continuous at pylon and supported by saddles embedded into pylon and the stay cable sockets are fixed to the main girder. The stay cables are composed of epoxy coated and filled 7-wire strands which exterior is coated with polyethylene, and then entire strands are covered by polyethylene pipe, thus giving three layers of corrosion protection system.

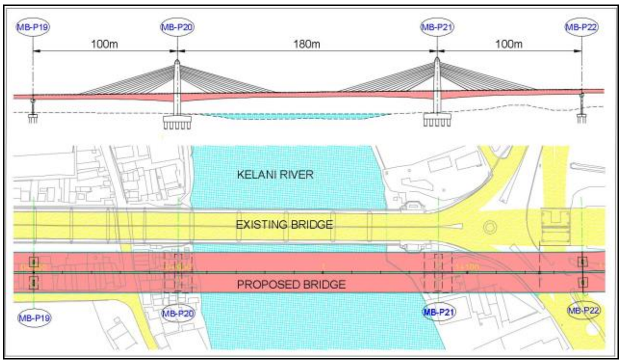

Figure 2: Extradosed Bridge

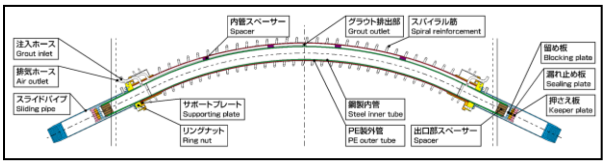

Figure 3: Stay Cable and Saddle

The main girders' three cells have a depth of 5.6m at the pylon and 3.3m at the mid span. The girders are supported by stay cables at 4.5m spacing, considering the construction duration. The girders are longitudinally prestressed and the deck has transverse prestressing for durability.

The pylon extends 23.4m above the deck level, which is L/9 where L is main span length. The pylon is slanted outward and the tip is curved for aesthetical consideration.

The cube strength of concrete for pylons and main girders is 50MPa.

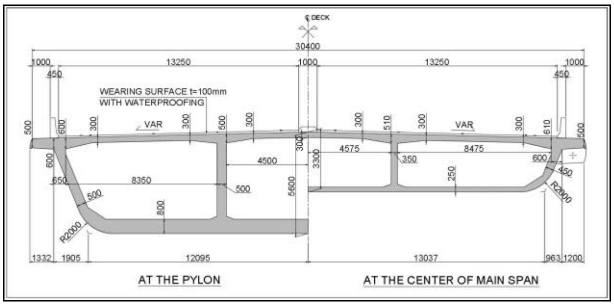

Figure 4: Cross Section at Pylon

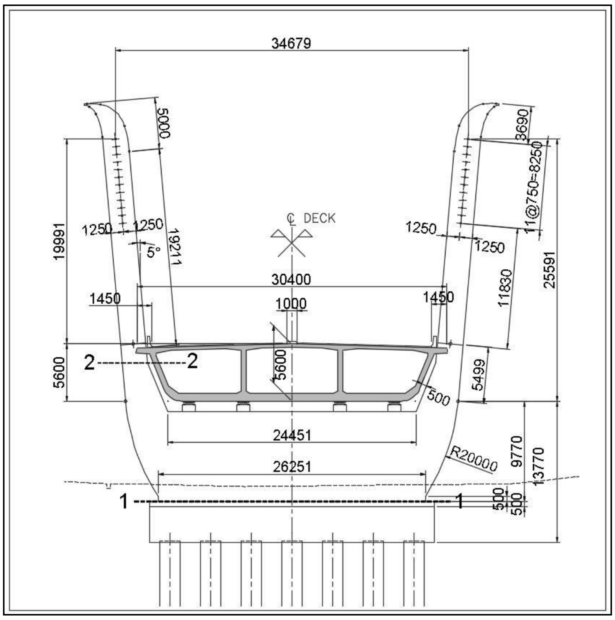

Figure 5: Cross Section at Pylon

3.2 PC Box Girder Bridge

Two PC box girder bridges are located in the northern end in this project. The one connecting with CKE is a 6-span continuous bridge with 40m to 45m spans. It has a double cell girder of 20.5m width. The other end which connects with the extradosed bridge and steel girder and ramp is a 4 and 5-span continuous box girders having variable width with spans varying from 40m to 45m. Those bridge girders are monolithic with the piers. The section is single section for narrow box and double cell section for wide section.

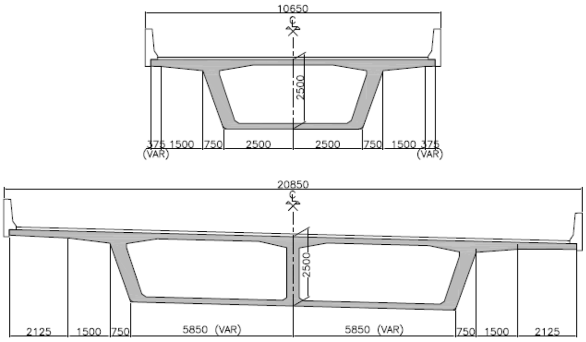

Figure 6: PC Box Girder Sections
(Double-cell section)

4. Steel Bridges

The application of steel box girders and steel piers is to facilitate accelerated construction over the most congested roads in Colombo. Also the junction and interchange bridges are made of steel box girders. Merging and diverging ramps to the main line makes the overall widths of the girders varying.

Although the expansion and contraction due to temperature changes (24 to 40 deg C.) and live loads is small, steel finger-type expansion joints are adopted for long-term durability.

4.1 Steel Box Girders

The span lengths are varying from 42.5m to 78m maximum. This variance is due to the designing of the structure to avoid interference with underground utilities and surrounding important buildings and structures. Those long-spans are not usual for elevated bridges built on land which require 3m deep box girders.

The mainline bridges are consisted of 4 to 5 number of 2m wide box girders. Each box girder is supported by one set of pot bearing at each pier location. However, for ramp bridges, curved with maximum of 50m radius, two bearings support the girder at each pier. The girder for ramp is a single trapezoidal box girder with 6m wide top flange.

The box girder depth is 2m for the main line but the long spans including ramp has 3m depth. The steel grade for the long spans is Bridge High Performance Steel, SHBS500 which has yield strength of 500MPa. This TMCP (Thermo-Mechanically Control Process) steel has been developed as 15% higher than ordinary high strength steel of this grade and has higher ductility and low pre-heat requirements, thus ease of fabrication.

For corrosion protection, the exterior surface of steel will be coated with fluorescent resin paint, with a total film thickness of 250 micro meters, which has said to be 40-60 years effective life.

The deck is a steel-concrete composite deck, which is made of prefabricated steel panels which serves as a form for casting concrete as shown in Figure 9 for example. The bottom plate is 8mm thick and concrete slab is composite with this bottom steel. The deck depth varies 260mm to 300mm.

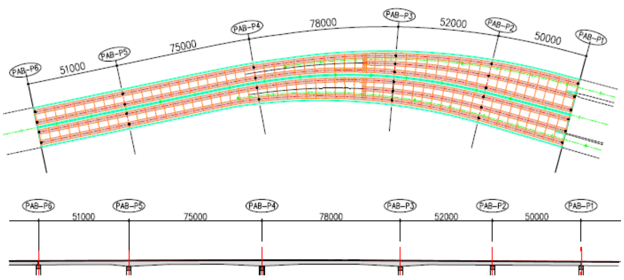

Figure 7: Port Access Bridge

Figure 8: Junction Bridge

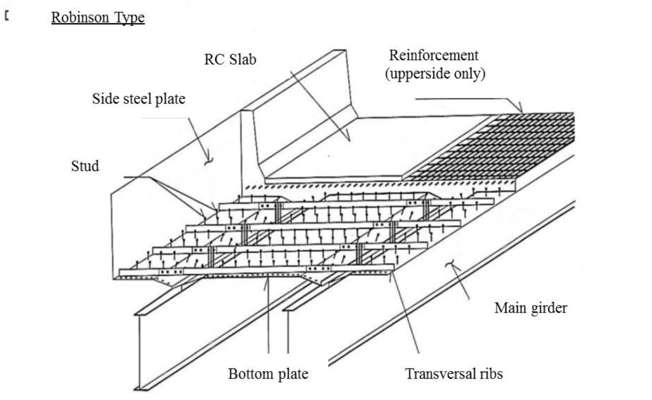

Figure 9: Steel-concrete Composite Deck (typical)

4.2 Steel Portal Frame Piers

The location of pier footing was determined to avoid interference with underground utilities.

Therefore, their portal frame transverse beam had to be widened up to 47m maximum at some locations. The depth of the beam is 2m and 2.5m.

The corner plate thickness of the rigid frame is thickened up to 60mm due to shear lag effect. This also necessitated the use of high strength steel, 500MPa Bridge High Performance Steel, same as for the long-span girders. This high performance steel reduces steel weight at the rigid frame corners.

The column ends connected by 100mm to 140mm diameter anchor bolts which are embedded into footing. Inside of column bottom is filled with concrete.

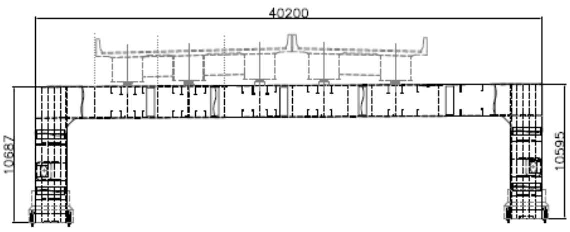

Figure 10: Portal Frame Pier

4.3 Foundations

Bored piles are adopted for the foundation for piers and abutments. Those along the Port Access Road are single laid piles by which the transverse width was reduced because of underground high voltage power cables. Also some foundations needed to adopt eccentric foundations to reduce the transverse dimension of the footing. The diameters of piles are 2.0m, 1.5m and 1.2m.

Pile tip is penetrated into rock designated as Grades IV and III, highly to moderately weathered gneisses rock. Figure 11 shows boring logs for extradosed bridge piers. Allowable end bearing pressure is 3000 to 5000 kPa. Also skin friction is considered for medium to dense soil layers.

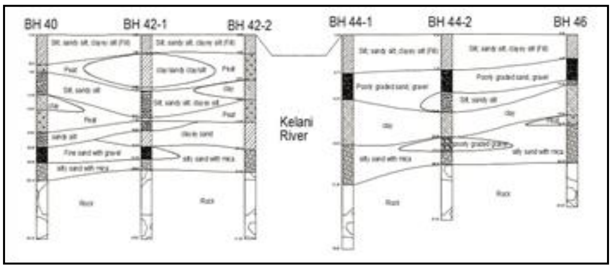

Figure 11: Soil Profile

The abutment located at the CKE end lies in soft soil treated area, and it is considered in design that soft ground is treated before the construction of abutment.

4.4 Transportation and Erection

It is a challenge to build such huge steel structure over the heavy traffic roads. Steel segments transported offshore will be landed at the Colombo Port and transported by low-bed trailers to the site.

The 11m-long box girder segments will be pre-assembled for a span or two on temporary bents, and then transversely moves on rollers on the transfer beams on the portal frame beams. The first box girder span is moved laterally for 3m. Then the second box girder span is assembled and connected with the first one by lateral beams. Then those two box girders are moved laterally, and this operation continues until the fourth box girder spans. For the curved sections, the lateral transfer will have to be done several times, and set on the next transfer beam, when the spanning piers are not parallel. Joining is made by 22mm diameter high-tension bolts (S10T).

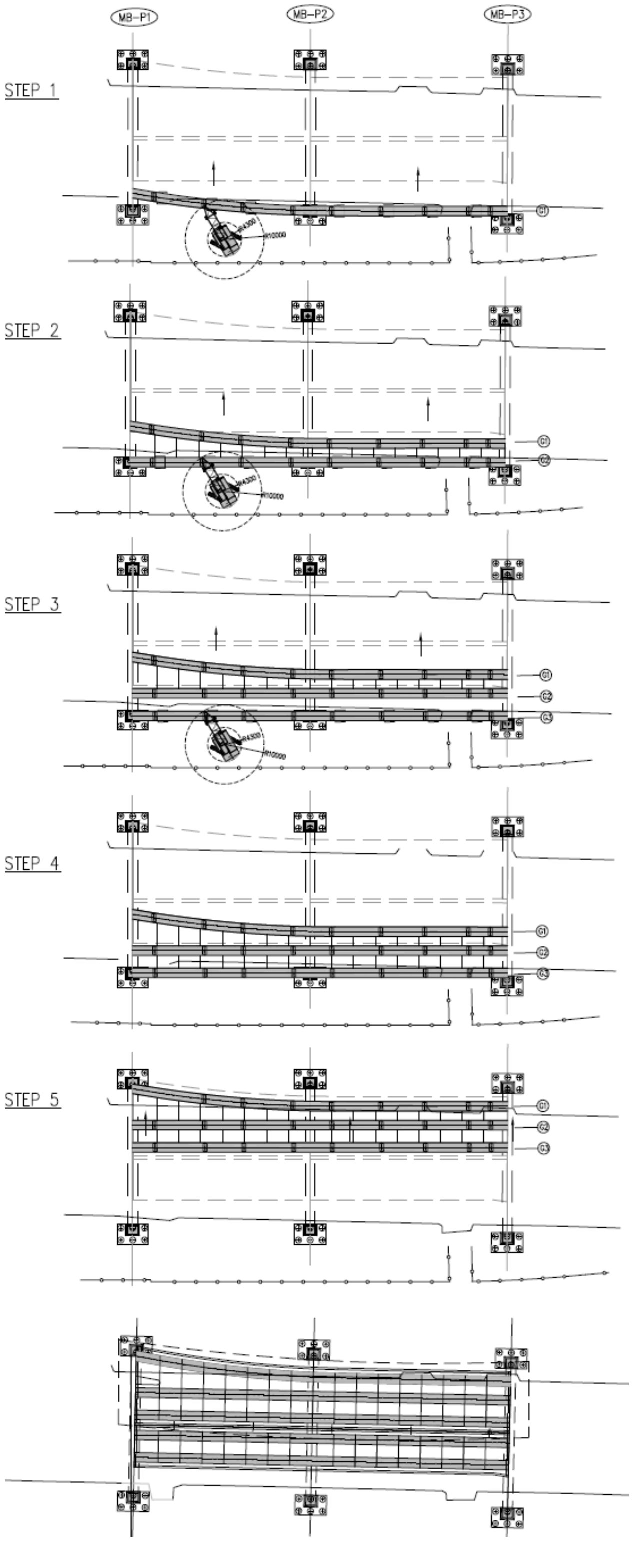

Figure 12: Lateral Transfer of Box Girders

A large lifting crane with a capacity of 160 ton-m will be used to lift up the large segments for assemblage. For the erection of transverse beams of portal frame piers and lateral transfer of box girders, it is necessary to use night time when the traffic is reduced.

Pier columns will be erected by crane installed inside the Right of Way, however, approximately half length of the transverse beam (pre-assembled) will be erected on the temporary bent on the median from the carriageway.

Figure 12 shows construction sequences of box girder erection using lateral transfer.

After erection of girders, panels of steel-concrete composite deck is laid out between the box girders, and connection with main girders is made, followed by casting expansive concrete to complete the deck. Then asphalt pavement with a total thickness of 100mm is laid.

The construction period is scheduled as 3 years, in which approximately 1 year for foundation and 2 years for piers and superstructure.

5. Soft Soil Treatment

The new road merges and connects with CKE end point with an embankment. About 100m section in this region is with around 7.5m deep organic clay underlying requiring soft soil treatment. The new road merges to the existing CKE with embankment with the maximum of 4.5m depth. The CKE embankment was previously improved by use of 0.5m diameter sand compaction pile on 1.5m triangular grid. General plan and subsurface condition is shown in Figure 13.

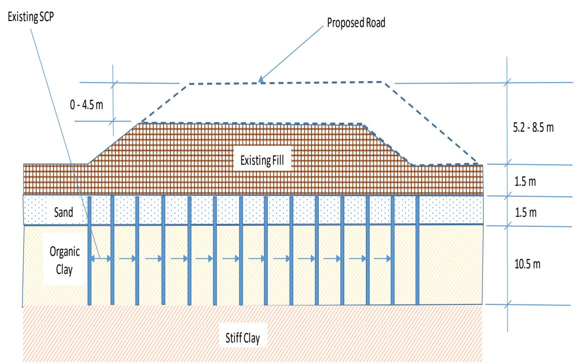

Figure 13: Soft Soil Treatment

The design criteria used for the soft soil improvement is such that the duration for preloading is not more than 18 months, safety factor for short and long term stability is 1.2 and 1.25 respectively, safety factor for bearing is 2.0, residual settlement is less than 150mm after 3 years in service.

The analysis consists of slope stability of embankment, strength evaluation of existing sand piles, and long-term settlement. For settlement analysis, 2D Plaxis software was used. The soil data used for the analysis are tabulated in Table 1.

Table 1: Soil Parameters

Depth (m)	7.5
Soil Layer	clay
Unit Weight (kN/m^3)	14.0
Compression Index, C_c	0.729
Recompression Index, C_r	0.073
Secondary Compression, C_a	0.044
Void Ration, e_0	3.772
Coeff. of Vertical Consolidation, C_v (m^2/yr)	1
Coeff. of Horizontal Consolidation, C_h (m^2/yr)	2

Due to the soft nature of existing soil, ground improvement is necessary to reduce post construction settlement and to improve ground stability. The ground improvement work will consist of embankment preloading and installation of granular compaction piles (GCP). GCP are constructed by compacted sand or gravel, which is inserted into the soft clay by displacement method and thus create a composite ground (Figure 14).

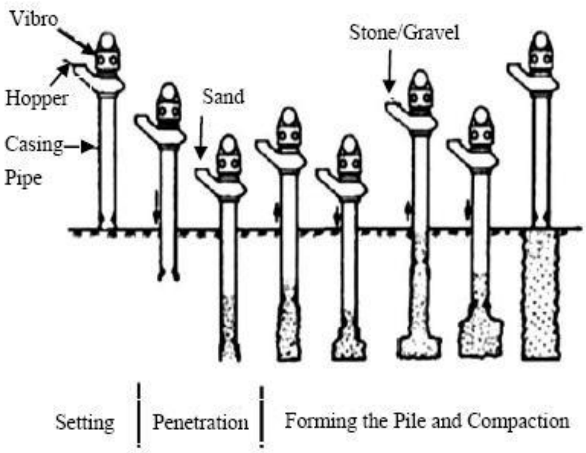

Figure 14: Installation of GCP

Using preloading with GCP, the following are achievable:

- Improved stiffness of the subsoil to decrease settlement.
- Improved shear strength for better stability and increased bearing capacity.
- Rapid consolidation of the subsoil.

Estimated settlements are shown in the Table 2. During the construction, embankment settlement, displacement and pore water pressure will be monitored and checked with the design.

Table 2: Soft Soil Analysis Results

Fill Height (m)	Consolidation Settlement (m)		Residual Settlement after Preloading (m)
	Untreated	With GCP	
8.5	1.295	0.906	0.010
7.6	1.228	0.845	0.007
6.5	1.135	0.761	0.061
5.8	1.068	0.702	0.059

6. Conclusions

The summary of outstanding features of this project is summarized as below:

(1) The first long-span wide deck PC extradosed bridge to be built in Sri Lanka
(2) The first urban elevated long-span steel box girder bridges to be built on wide span steel portal frame piers
(3) Accelerated erection of elevated bridges over heavy traffic roads
(4) Use of bridge high performance steel (500MPa yield stress) for long-span box girders and wide portal frame piers
(5) Soft soil treatment for organic clay with 0.7m diameter gravel compaction piles with consideration of differential settlement between the existing overlay embankment and new embankment
(6) Consideration of long-term durability for stay cables, steel coating specifications and concrete deck

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