Extradosed Bridge-Span Construction: Case Study of 3rd Narmada Bridge, Bharuch

Viranjkumar Patel¹, Dr. Devanshu Pandit², Ajay Kumar Kamani³
¹Pre final year, CEPT University, ²Associate Professor, CEPT University, ³Planning Manager-Civil Special Bridges, L&T-ECC

Abstract: Resolving obstacles in transportation involving any water body, requires the concern of bridge engineering. In current scenario, many structural configuration options are available for bridge structure. Bridge decks supported with cables are aesthetically pleasant and in some cases proved cost efficient too. As a result of advancement in the construction technology, construction field is speculating merger of structural configuration to achieve desirable results. Extradosed bridges are perfect example for combination in structural configuration of, stay cable bridges for aesthetics and girder bridges for their durability, strength and ease of construction. Merger of both bridge configuration leads to economical bridge construction in terms of design and construction costs savings.

The 3rd Narmada bridge is taken as a case study in this paper to describe components and functioning of an extradosed structure. This paper addresses the design characteristics and construction methodology for bridge decking in extradosed bridge structure.

Narmada bridge design and construction comprises of bored cast in situ pile foundation, pier-cap, Y-shaped pylons, and extradosed cable deck which consist of 3-4 m varying length segments having three-cell precast segmental box girder cast with short line method and erection with balance-cantilever under-slug method by Bridge Builder. Stay-cables and post tensioning systems are provided to have structurally sound deking system.

Keywords: Extradosed Bridge, Segmental box girder, Balance Cantilever System, Stay-cables

Introduction

National Highway (NH)-8-India, connects two major cities Delhi and Mumbai via many other important cities in its alignment including Surat, Vadodara, Ahmedabad, Udaipur, and Jaipur. Route considered as one of the busiest national highway across the country.

In 2012-13, heavy traffic conjunction issues are being encountered on this NH-8 due to distress of existing Sardar Bridge on Narmada River at Bharuch. Prior to that, the two well-functioning bridges, old Sardar Bridge and 2nd Narmada constructed by L&T earlier are serving the traffic.

NHAI [National Highway Authority of India] has taken responsibility to assure smooth transportation on this highway. As per requirement, NHAI has initiated another 4-lane bridge over river Narmada. For this bridge, L&T proposed extradosed bridge design keeping the aesthetics and economy as a priority and won the contract from NHAI.

Some of the salient features of the project are as under:

Name of the Project: Six Laning of Km 192.00 to Km 198.00 Between Vadodara to Surat Section of NH-8 Including Construction of a new four lane Extradosed Bridge across river Narmada in state of Gujarat on EPC mode

Type of Project Road and bridge Infrastructure project

Location: On Narmada River, Nr. Zadeshwar crossroads, Bharuch, Gujarat, India.
Client: National Highway Authority of India (NHAI)
Contractor: L&T Construction Heavy civil infrastructure (HCIC)
Start of the Project: 3rd March 2014
Duration of Project: 30 months
Type of Contact: E.P.C. (Engineering Procurement and Construction)
Type of Structural: Extradosed type Bridge structure
Specific Technology: Stay cable extradosed system-Dyna-Link Anchor box stay cable system, Post-tensioning bar stressing.

Bridge structural configuration

This bridge has segmental precast girders erected in balance cantilever manner on both side of pylons supported eventually on pile foundation. Concept is more or less module based design, where ninenumbers of pylons having balance cantilever extradosed design along with two abutments makes the bridge. Module geometry is illustrated in Figure 1.

Figure 1: Structural component details
Alignment and Geometry of Bridge

The extra-dosed bridge has straight alignment between abutments A1 and A2.4 pylons are located in river, rest are situated on land mode. The length of main bridge is 1344m with two end spans of 96.0m and nine internal spans of 144.0m. The superstructure consists of 20.8m wide precast segmental concrete box girder, with a carriageway to accommodate four lanes of traffic. Superstructure also has a single 3.0m wide footpath. Stay cables are anchored at the edges of box girders to support them which are later deviated in short pylons. The precast segments are erected by balanced cantilever construction method using a beam and winch erection system. Transverses slope of 2.5 % is provided at single end for drainage purpose.

Expansion joints are located at mid-span of every other span. For vertical displacement between two adjacent cantilevers, a shear key is provided at the expansion joint. The bridge substructure is Y-shaped cast-in-situ concrete pylons supported on pile foundations.

Foundations

Bored cast-in-situ piles of 1.5 m diameter have been provided with over 2 m thick pile-cap. Top of pile cap is at low water level. Vertical pile capacity is duly modified for scour condition by considering overburden pressure from scour level.

Pylon

The typical pylon for the main bridge substructure is chosen to have a Y-shaped with rounded corners to improve aesthetics and to reduce wind and water current loads. To cast this kind of shape, special steel formwork with adequate scaffolding and false-work system was designed and provided to have control over geometry of structure.

Pylon consist of four major components

1. Lower pylon (cast-in-situ in 3 lifts specially design steel-forms of approximately 5m height)
2. Pier Table (cast-in-situ consist of segment shape to have uniform connection between segments and pylon)
3. Upper pylon (cast-in-situ in three lifts specially design steel-forms of approximately 5m height)
4. Anchor-box with support system (embedded in second and third lift of upper-pylon, during construction system is supported by frame)

For stay cable, DYNA Link system is provided by Dywidag System International. The firm is works as a subcontractor for extradosed stay cable work by L&T.

Superstructure

In the super-structure of the main bridge, three-cell of precast segmental box girder with depth of 4.0m. Sloping outer webs connects the top slab and the inner vertical webs to stabilize the top slab in transverse direction and also to transfer stayforce to the bottom of inner/vertical webs. Soffit corners are rounded due to presence of transverse tendons in outer sloping webs and also to reduce drag coefficients under wind loadings. The length of typical segment is limited to 3.550m to limit the weight of the segments during handling. Segments are to be match-cast. Integral connection at the pylon location of substructure and the superstructure is provided by pier tables. Anchor saddle boxes are provided at upper pylon which provides individual support for each strand and avoid lateral pressures due to grouping of strands.

Balanced cantilever construction method is used to erect the box girders with epoxy joints between segments. For service and ultimate load condition adequate internal post-tensioning is provided.

The draped hybrid (part external, part internal) tendons are provided for shear relief. The box girder is transversely post-tensioned against live load effects to eliminate cracking in the top slab and to provide increased durability. Transverse post-tensioning provides further reduction in the slab thickness compared to reinforced concrete slabs and facilitates reduction in segment weights for handling.

Bridge Span construction

Bridge span-construction is a complex activity involving different phases shown schematically in Figure 3.

Segment casting process

Total three number of cell pre-cast RCC box (Having of PT tendons, in both longitudinal as well as transverse direction) is 20.8 m wide segment casting work is going on for the river as well as land portion. The Main bridge length is 1344 m, which is divided into 10 spans with extradosed arrangement. The span consists of 8 nos. - 144 m and 2 nos. of 96 m typical shape and stay segments are as shown in below sketch.

<table>
<thead>
<tr>
<th>Segment (Typ.)</th>
<th>Total segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stay segment</td>
<td>104 nos.</td>
</tr>
<tr>
<td>Expansion joints</td>
<td>4 nos.</td>
</tr>
<tr>
<td>Total segments</td>
<td>342 nos.</td>
</tr>
</tbody>
</table>

Table 1 Segment Count

The typical short-line method with match cast type of pre-casting the segments has been adopted for this Project cast segments are being erected by “under slung” method with the help of erection tackles. In addition to the transverse PT, Longitudinal PT is proposed for holding the erected segments.

Segment casting yard

Casting yard is situated 5 km. away from the bridge siteto...
provide adequate space for casting and stacking of segments. Short-line segment casting arrangements and stacking yard are provided. This layout is currently in modification phase due to increase in the number of segment casting mounds. Gantry cranes are provided in the arrangements. To lift 1 segment (105-115T) minimum 2 nos. of cranes are required for handling/stacking/loading work. Figure 4 shows segment views and Figure 5 shows casting yard.

There is a provision for road and survey towers in this arrangement. For loading/unloading purpose loading space is provided for puller tractor to move for better access.

Figure 4: Segment Classification

Figure 5: Casting moulds with stacking Yard for Segment

Typical segment casting cycle consist of alignment work, rebar and post tensioned work, shuttering work, inspection and concreting, deshuttering work. Cumulatively it results in three days of typical segment casting cycle. Stay segment takes five days due to complex reinforcement and other guide-pipe arrangement in blisters.

Segment handling

Segment stacking yard is planned adjacent to segment production area. Two 100MT capacity gantries for handling of segments are erected on track beam supported on RCC raft. (refer Figure-6).

Considering balance cantilever method of erection preliminary step of handling and transportation work is to identify the segment. Erection of segment on any pylon will start from expansion side segment. After the erection of one segment on expansion side, next segment will be erected on continuous joint side.

After that, lifting beam is attached to that particular segment. Lifting holes are provided in design and left during casting of segments, and with help of both of lifting cranes slings and de-shackles segment is lifted and moved to loading bay.

Figure 6: Segment Loading Process on Puller Tractor

There are two different transportation modes available during erection work (Figure 7 & 8).

1) Land-front Erection

In this mode loaded Puller tractor is just aligned to the orientation of bridge segment. For erection work

2) Water-front Erection

In this mode loaded Puller tractor moves to Load out jetty structure as shown in Figure 8 and then via lifting gentry crane it is being loaded on floating barge. Then barge is being aligned to the orientation of bridge segment.

Figure 7: Alignment of Puller Tractor for Land-Front Erection

Figure 8: Load-out jetty arrangement

BridgeBuilder

The Bridge builder is used for free cantilever construction of post-tensioned box girder/Segments - and cable-stayed concrete bridges.

Figure 9: BridgeBuilder arrangement on Pylon-span

Precast segmental BridgeBuilder

The precast Segmental BridgeBuilder (Figure 9) is designed for a maximum precast segment length of approx. 3 - 5 m and load capacities between 100 and 300 tons. It is equipped with two hoists for lifting the precast segments as well as for adjusting the cross-fall. A manipulator permits adjustment of the longitudinal fall and hydraulic cylinders launch the device forward. The Precast Segmental BridgeBuilder is designed and adopted for balance cantilever precast segment erection.

The bridge builders on both end of the spans initially erected on pier-table only. Then one by one precast segments are lifted simultaneously and fixed as motioned in erection section involving prestressing and stay cable system.

Erection work methodology

The erection procedure includes 4-cyclic activities, which
BRIDGE ENGINEERING: CASE STUDY

are listed below. Erection method is precast-segmental balance cantilever erection system. So, erection process will be for both arms of pylon.

The erection of segments involves the following activities.

Lifting of segment

Initially lift & tilt arrangement is lowered using strand jacks, mounted over the BridgeBuilder frame. Segment top beam is fixed to the segment with the help of lifting pins. Then segment is being lifted from trailer/puller with the help of lift & tilt system. Segment is lifted to the required level with lift & tilt system.

Gluing on segment

After alignment glue application is carried out to have proper bonding between two segments. Epoxy glue is mixed with a mechanical mixer. Application of glue on the face of the erected segment as well as new segment is carried out by experienced construction workers. Backward movement of new segment is performed to match with erected segment. Temporary stressing is applied to segment to squeeze the excess glue out.

Post Tensioning

Following are the types of stressing being adopted at site for the segments:
- Temporary Stressing, - Permanent Stressing

Temporary stressing

This stressing is carried out to squeeze the glue and get adequate rigid bonding between two segments. To achieve that P.T Bars with the coupler is being connected in the previous segment. These bars are connected throughout five segments and then stressed by placing hex-nut and tightening it up to desired pressure.

Permanent stressing

As its name suggests, the stressing which is going to remain permanently are classified in this stressing, which is a combination of partially stressing PT Bars and majorly PT Tendons. PT bars are stressed in the same manner but this time with higher forces and locking nut is also being installed to remain that stress.

Post-tensioning tendons are major stressing component in the bridge. This tendons acts as vanes distributed through pier-table. Providing rigid joinery and additional bearing capacity to bridge span. As in described in geometry, transverse as well as longitudinal tendons are there for post tensioning purpose.

Transverse tendons are provided and stressed during segment casting only. But longitudinal tendons are provided during erection, here it is noticeable that the tendons are provided starting for one end to another end every time in erection. Means some of the tendons can travel up to half-span length or more.

In order to do stressing strands are High-Tensile stands are inserted according to design and sequence and then stressed with the help of jack one or both end. And then grouted after suitable duration.

Stay cable work

Stay cable work consists of main sub-activities involving material procurement work, cable installation work, and stage-wise stressing activity.

Material and system selection is depends upon requirement of structure, Environmental conditions and client’s requirements. Material includes coated strands HDPE duct-pipes and anchorage system. For anchorage, in particular segment blister is provided to counter stressing/busting forces and live anchor from where stressing is conducted with help of stressing jack. Dead anchor boxes are already embedded during pylon casting. So, there is an simple installation procedure for cables and then stage wise stressing is provided to have control over geometry. Average 2 days erection cycle is achieved in normal site conditions.

Conclusion

Case study on the NarmadaBridge is excellent example for multi-span extradosed bridge type. Construction methodology adopted reduces the construction duration and economizes the overall cost. However, construction still has to face constraints such as tidal conditions and weather will, but bridge progress till date substantiates the importance of sound efforts in planning, design, and management.

Bridge case study demonstrates the ease in precast segmental construction. Ease in construction can be determined by the ongoing process, which is at segment casting yard- with six moulds and 3 to 5 days of casting time cycle for segment, average 30-40 segments casting is observed. On erection front, 35-40 segments per months are achieved with help of 3 sets of BridgeBuilder.

Acknowledgement

The authors would like to acknowledge entire the Narmada Bridge project team, L&T – (Heavy civil Infrastructure) for their data support and guidance.

References*
- The 3rd Narmada Bridge – L&T – (Heavy civil Infrastructure) project Documentation, 2016

*References: A complete list can be viewed at: www.masterbuilder.co.in