Fast Track Aesthetic Design of Segmental Elevated Road Bridge

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ABSTRACT

Barapulla Elevated Corridor was envisaged as a dedicated signal-free access to transport participants from the Games Village to the Main Venue (Jawahar Lal Nehru Stadium) for the Commonwealth Games (CWG 2010). The project was taken up and commissioned by PWD Government of Delhi, India. The corridor is located along and above the existing Barapulla drain. The 4.5 km long viaduct consists of 2 separate structures of 10m width each for the up and down traffic.

The innovative design concept was geared for high speed construction (time available: 20 months) using precast prestressed segmental techniques (no. of segments 3000) including many large obligatory spans (upto 85.0 m). Standardization was the key to cost-optimization .Decreasing the expansion joints in the deck by providing integral constructions led to increased riding comfort. Flexibility in design for accommodating modifications in alignment, span arrangement and foundation configuration contributed greatly in avoiding relocation of underground and overhead utilities.

Delhi, capital city of India, is a city of archeological monuments and a highly sensitive approach is required to be taken for their preservation. Each of the major crossings presented difficult challenges. For instance, the block-time for the Railway tracks was limited to a mere 2 hours on alternate days, while for the other obligatory crossing the deck level had to be raised to 20m to provide an uninterrupted view of the existing monument. Alignment had sharp curvatures and skew crossings to avoid crossings above the ancient Barapulla Bridge as well as to preserve the visual sanctity and safety of the heritage structures along the alignment. It was ensured that the construction of elevated corridor did not require slowing or shutting down the traffic below.

Keywords: Aesthetics and Finishes, Creative/Innovative Solutions and Structures, Segmental Bridges, Commonwealth Games 2010, Delhi, Fast Track

INTRODUCTION

Barapulla Elevated Corridor (Fig. 1) was envisaged as a dedicated signal-free access to transport participants from the Games Village to the Main Venue (Jawahar Lal Nehru Stadium) for the Commonwealth Games (CWG 2010). The project was taken up and commissioned by PWD, Government of Delhi, India. , The corridor is located along the existing Barapulla drain. The 4.5 km long viaduct consists of 2 separate structures of 10m width each for the up and down traffic. This vital corridor now serves as a major arterial road for the east-south traffic axis of the city (Fig. 2). Barapulla elevated road constitutes a most unusual bridge in that it runs parallel to and above the stream instead of crossing it.

Fig.1: Completed view of Elevated Road over Barapulla Drain

Fig.2: Alignment of Elevated Viaduct of Barapulla Nallah (Drain) (Google Map)

ENVIRONS & ALIGNMENT

Delhi, capital copy of India, is a city of archeological monuments and a highly sensitive approach is required to be taken for their preservation. Physical protection of the monuments in the vicinity of corridor and retaining of as existing view of these monuments even after construction of corridor were the most important consideration for the selection of alignment from many alternatives before the project could get approval of bodies such as Delhi Urban Arts Commission, Archeological Survey of India and various Technical Committees and Expert Groups set up by the Government. The process of selection of alignment from various alternatives took considerable time and compressed the available time for construction

CHALLENGES

The construction period available was only 20 months for the 9 km long elevated corridor along extremely harsh and disagreeable terrain of an open drain subject to flooding and sewage flow.

All the foundations were to be provided in the drain bed.

The alignment had to cross over major hurdles like railway tracks, arterial roads, existing bridges and unchartered underground and overhead utilities.

The site has various utilities and services like overhead power distribution lines, gas pipe line at ~1.0 m depth from drain bed level and sewer lines. Many of these utilities could not be relocated and hence alignment had to be tailored to avoid interference with these obstructions. Foundation locations were finalized after probing at the proposed location to determine whether any underground utility was fouling with it.

The Barapulla drain is some 700 year old and is in close proximity to many heritage structures, prominent among them being the Khan-e-Khana (1556AD-1627AD) Tomb (Figs. 3, 4) and the 400 years old masonry multi-arch bridge (Fig. 5). Avoiding damage or obstruction to view of heritage structures resulted in complex geometrics of the alignment. The deck level had to be raised to 20m above the drain bed at some locations while alignment had sharp curvatures at many locations to meet the objectives.

The biggest challenge came by way of completing this vital link before the start of the Commonwealth Games 2010, despite all the hurdles to meet these objectives.

Innovative concepts had to be evolved which could surmount all the difficulties and yet retain the elegance and aesthetics of an urban structure prominently in public view. Good riding characteristics for the fast moving traffic on the elevated road was another important consideration.

Indian Roads Congress Codes[1,2,3,4] for loading and design and Special Publication[5] relating to segmental construction were adopted for the project

Fig. 3: Tomb of Abdul Rahim Khan-e-Khana (1556AD- 1627AD) :
View from Mathura Road – Before Construction

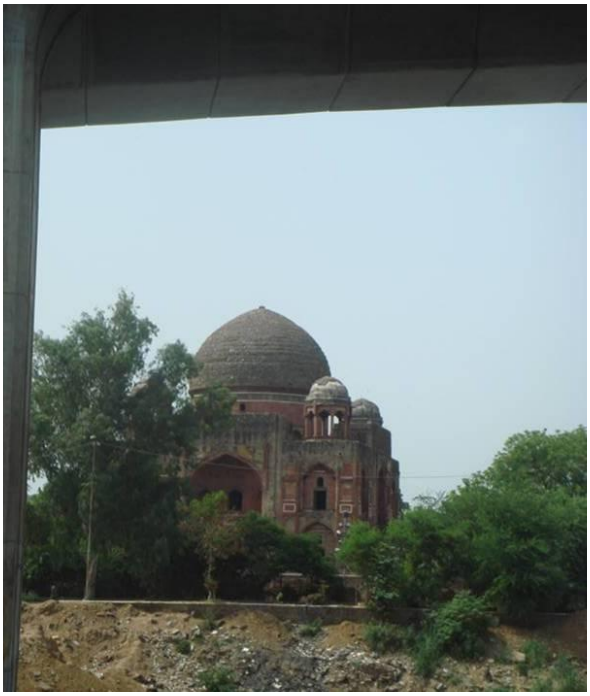

Fig. 4: Tomb of Abdul Rahim Khan-e-Khana (1556AD- 1627AD) :
View from Mathura Road – After Construction

Fig.5: Heritage Bridge over Barapulla Drain

CONSTRUCTION TECHNIQUE

The complete elevated corridor can be divided in two type depending on span lengths as below:

(a) Standard Spans with maximum span as 37 m
(b) Special Spans at obligatory crossings where arterial roads or railway tracks were to be crossed (spans over crossings were 74 m to 84.5 m)

Precast segmental construction using match-casting was selected as the appropriate method of construction for both the standard spans as well as the obligatory crossings. The motivation behind selecting this technique can be summarized as follows:-

a. Construction of superstructure segments could be taken up in parallel with foundation and pier casting at site. This led to speeding up of construction cycle as the superstructure span could be erected within 3 to 5 days after pier concrete had gained adequate strength after concreting. It would not have been possible to meet the extremely tight schedule if cast-in-situ construction of superstructure was adopted for the project.
b. As the segments were cast in factory like conditions with round the clock supervision, superior quality and finish of superstructure was obtained. Further, at site, the superstructure level was as high as 20 m from drain bed level. Providing shuttering & formwork for casting of superstructure at that level would not be feasible.
c. Due to reduced construction cycle per span with fewer works to be taken up at site and totally avoiding shuttering and formwork for superstructure, the construction related risks were minimal.
d. As there was minimal amount of cast-in-situ concrete and fewer works are to be taken up at site, the disturbance to environment and surrounding was

minimized. The time cycle was also reduced which limits the time to which a location was exposed to construction activity.

e. Designs were tailor-made to have flexibility during construction. Standard spans were designed for spans from 37 m to 25 m. In the 37 m span, there were 13 segments while in 25 m spans, there were 9 segments the moulds of the segments were identical. This was required to have flexibility of change in spans on encountering of any uncharted utility/site constraint.

The 3000 odd segments of 3.0m length each were match cast in a central facility (Fig. 6, 7) before being transported to site on low bedded trailers, Fig. 8, 9.

Fig.6: Stripping of End Shutter: Note formation of Shear Keys

Fig.7: Stacking Yard

Fig.8: Transportation of standard segments


Fig.9: Transportation of heavy segments

STANDARD SPANS

The standard span lengths were selected as 34.0m each (Max. 37 m, Min. 25 m) which were erected by launching girders span-by-span, Fig. 10. The peak speed of erection was 1.5 days/ span. Flexibility in span lengths were a part of the design concept should an unchartered underground utility be encountered. For the same reason simply supported spans with continuity in deck slab was the selected concept which ensured good riding quality with expansion joints spaced at 102m center-to-center Fig. 17 shows the cross section of the structure.

As already mentioned the standard spans were designed for spans from 37 m to 25 m. In 37 m span, there were 13 segments while in 25 m spans, there were 9 segments. This was required to have flexibility of change in spans on encountering of any uncharted utility/site constraint. Prestressing cables were so profiled that they draped up only in the end four segments and were horizontal in remaining segments. Hence, same shuttering moulds at casting yard were used to cast segments for all spans.

Overhead launching girder was used to lift and aligning the segments. Launching girder was supported over pier of spans to be cast as well as the span previously cast. These segments were then prestressed. Segments were brought from casting yard to site using low bedded trailor and then lifted from crab hoist mounted on launching girder.

Fig.10: Erection technique for standard spans

SPECIAL (OBLIGATORY) CROSSINGS

There were seven crossings which required spans in excess of 37 m because of obligatory crossings (7 nos.). These Crossings (7 nos.) were required at the following locations (Figs. 2, 11).

a. Ring Road: 1 no. (For left carriageway)
b. Heritage Bridge & Railway Tracks: 2 nos. (One for left carriageway, one for right carriageway)
c. Mathura Road: 2 nos. (One for left carriageway, one for right carriageway)
d. Lala Lajpat Rai Marg: 2 nos. (One for left carriageway, one for right carriageway)
e. Cantilever segmental construction was the basic erection methodology for the obligatory spans

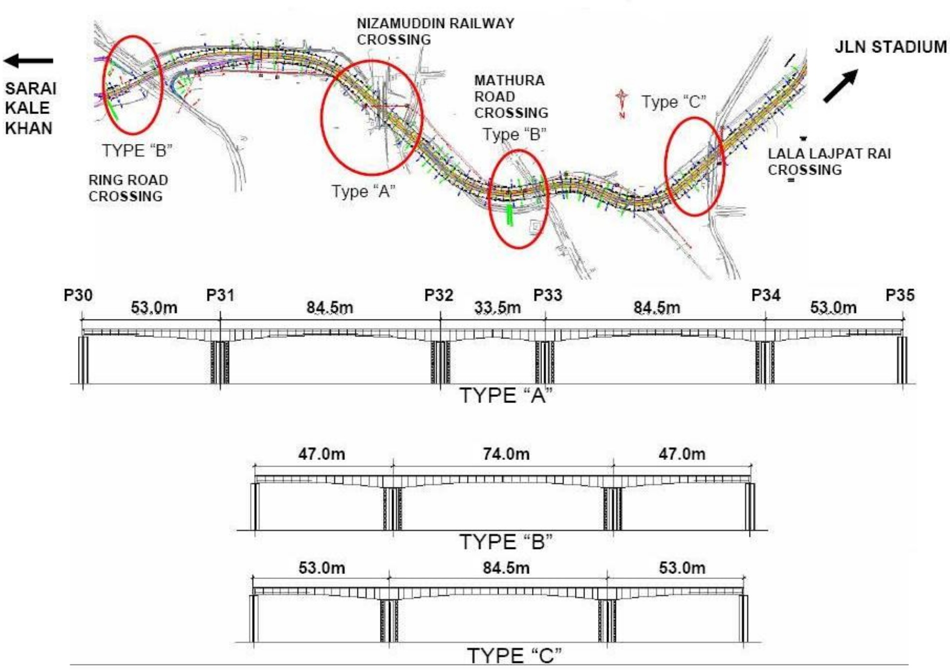

Fig.11: Special Structures

Here too standardization was the key in the structural concept so that economy could be achieved by formwork repetition. Fig. 17 shows typical cross section of the structure. Segment dimensioning and prestressing profile was so selected that for all the special crossings, same casting bed and same moulds could be used, as was done in the case of the standard spans

The construction methodology adopted for segment erection was by utilizing ' segment lifters', Fig. 12. Cantilever construction sequence was adopted with central cast-in-situ closure pour, Fig. 13. Special lifters were procured for the purpose. These lifters could lift the segment from ground, rotate and move the segment to its intended location. At many locations, segment lifting was possible from one end only. At these locations, segments were moved by lifter from one end to other. The segments were secured to previously cast segments through temporary prestressing. After erection of the twin segment on the other cantilever, permanent cantilevering cables were threaded and tensioned.

Fig.12: Segmental Lifters used for special crossing

Fig.13: Preparation for cast-in-situ closure pour for special crossings

The special crossings were configured as a 3-span arrangement Fig. 11 (Type 'B' & 'C'). However, a single structure had to be devised for the special crossing mentioned at 'A' to cater to the heritage bridge as well as the bridging across the railway tracks at the sharply skewed alignment. The five span arrangement for the railway crossing was 53.0m+84.5m+33.5m+84.5m+53.0m = 308.5m. The central 33.5m span was made cast-in-situ. Reference may be made to Fig.16 for details.

The peak speed of erection for these special spans could easily reach 6.0m/day.

Fig.14: Balance cantilever construction with integral pier

To ensure against accidents during the tight construction schedule of the special crossings, the integral design concept was adopted. The piers were made monolithic with the deck, Fig. 14, 15. All special crossing were provided with 'twin leaf' piers which increased safety during the cantilever constructions without using any temporary props. The flexibility of the twin leaf piers (Fig. 16 & 17) ensured that the strains due to temperature, shrinkage and creep could still be accommodated even in the 308.5m long module despite the fairly short height of the piers.

Fig.15: Cantilevering at Railway Crossing

The erection of the spans over the railway tracks, Fig. 15, presented special difficulties as all activities above them had to be restricted to alternate days for two hours only starting at mid-night, when the ‘block-time’ could be made available. The design was specifically made to ensure that one end stressing of tendons was possible with the live end located on side spans. i.e., away from the railway tracks. Also the threading of prestressing tendons over long lengths and tensioning them was not an easy task at site.

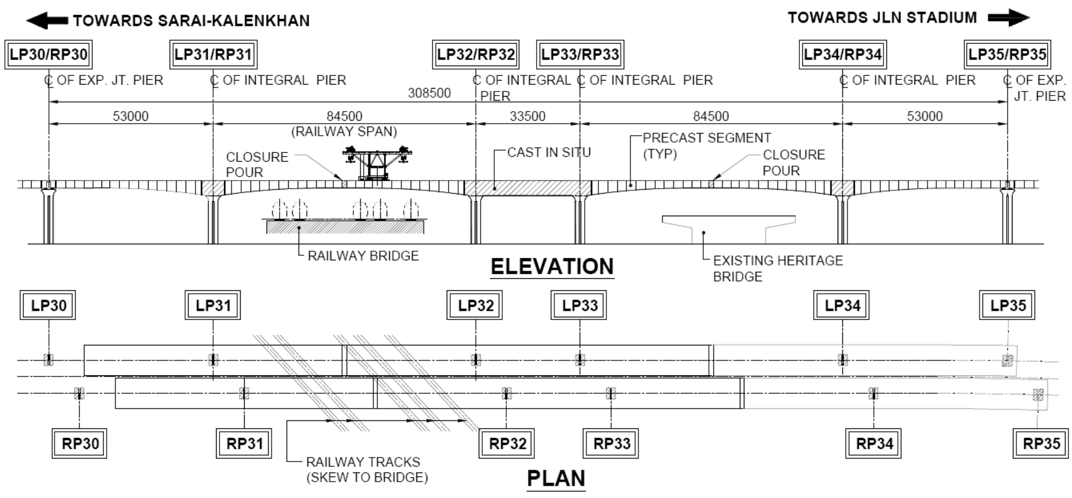

Fig. 16: Special Skew Crossing over Railway Tracks and Heritage Bridge

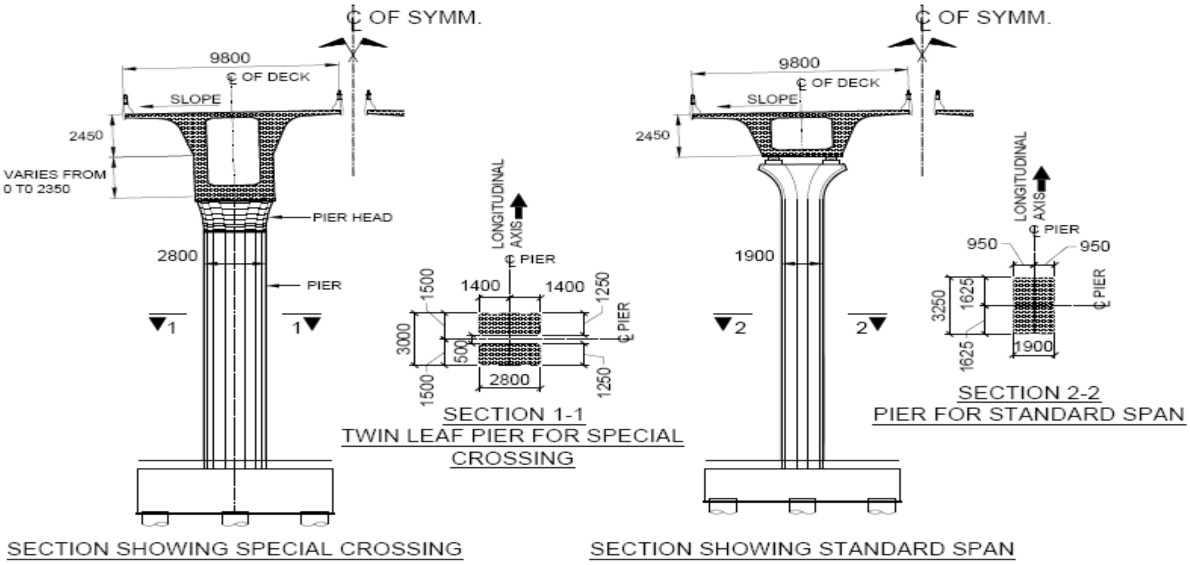

Fig. 17: Typical Sections

OTHER IMPORTANT ASPECTS OF PROJECT

Delhi is located in a fairly high seismic zone, i.e., zone 4, whereas zone 5 is the highest in the country. Response spectrum analysis in accordance with the Indian Roads Congress code was carried out. Ductile detailing was done to ensure enhanced resistance during severe ground shaking.

Elastomeric bearings were adopted for the standard spans, with longitudinal restraint at one support. Transverse restraint was provided at all supports.

POT-PTFE bearings were adopted for the end piers of the special crossings, with no bearings being necessary for all the other piers where the deck was made integral to the 'twin leaf' piers. The design concepts were such that the expansion joints were minimized. These measures ensured that during the service life, inspection & maintenance requirements would be reduced to a minimum.

Bored cast-in-situ piles of 1.2m dia using hydraulic rotary rigs were adopted as foundations. Working with heavy equipments in the drain bed given the unfavourable environment was quite precarious, made more so with the unseasonal incessant rains.

Anti-carbonation coating was recommended for the structure due its location in severe conditions of exposure. This is in addition to other measures taken for durability, such as increased reinforcement cover, higher concrete grade and reduced water-cement ratio.

The East end of the elevated road becomes a viaduct passing near the Jawaharlal Nehru Stadium and a school. It was decided to position foot bridges at these locations to facilitate crossing of pedestrians. With spans of 80m and 90m, the footbridges (Fig.18) are visible from long distances and were painted to give the impression of a rainbow. Special Studies were required concerning excitation due to wind as well as that due to pedestrian foot falls to ensure that various natural frequencies are outside the range that could cause resonance.

Fig. 18: 90m Arch FOB-Delhi

CONCLUDING REMARKS

The Barapulla Elevated Road structure is a pre-eminent example of precast segmental construction. Its highlights can be summarized as follows:

i. Compressed contract period of 20 months for constructing 9km bridge length.
ii. Physical protection and visual facilitation of the archeological monuments in the vicinity of the alignment.
iii. Alignment along extremely harsh and disagreeable terrain of open drain subjected to flooding and sewage flow.
iv. Major crossovers including railway tracks, existing bridges, arterial roads, unchartered underground and overhead utilities.
v. Completing the vital road link before the start of the Commonwealth Games 2010.

AWARDS RECEIVED BY PROJECT

1. *Indian Building Congress Award for Excellence in Built Environment, 2011*
2. *Indian Concrete Institute Award for Prestressed Concrete Structure in the Country, 2011*
3. *Construction Industry Development Council Vishwakarma Award 2011 Under the Category 'Best Project'*

REFERENCES

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