Extradosed Bridges for Major River on Vadodara Mumbai Expressway

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SYNOPSIS

National Highways Authority of India (NHAI) proposes to construct about 400 km long Mumbai-Vadodara (VM) Expressway to be implemented under Public Private Partnership. This is part of 1000 kms. of expressway being developed under National Highways Development Program (NHDP) Phase-IV. NHAI have commissioned the services of M/s. Intercontinental Consultants and Technocrats Private Limited (ICT) for carrying out consultancy services for "Preparation of Feasibility cum Preliminary Design Report for the Expressway.

For the particular sites of **Ulhas River (near Mumbai) and Tapi River (near Surat)** under proposed Vadodara-Mumbai Expressway Project, there is a navigational requirement of minimum 100m horizontal clearance and 10m vertical clearance above HFL / HTL through the bridges. Ulhas river crossing is close to the Arabian sea, while Tapi river crossing is in the open. Ulhas is close to Mumbai and Tapi close to industrial city of Surat. From aesthetic considerations and from navigational requirement, extradosed bridges have been planned and designed as a part of Detailed Project Preparation for the Expressway.

This paper brings out justification for adopting extradosed type superstructure for the two river bridges on proposed Expressway. Main bridge on these river crossings is proposed as an extradosed 5-span module of 75m+120m+120m+120m+75m to be constructed with transversely pre-stressed single cell 21m wide precast box segments of uniform depth of 3.5 m, along with simply supported viaduct spans of 45m on either side of main bridge.

Till today more than 120 nos. of extradosed bridges have been built or are under construction in India and Abroad.

For selection of type of superstructure, cable stayed type extradosed bridges, PSC segmental girder and tied arch superstructure were considered for bridges across Ulhas and Tapi rivers.

The choice between a tied arch and an extradosed structure might be guided by the span configuration. If only one long span is needed, then tied arch is a good choice. For multiple spans, cable supported structures are good choice due to potential of cantilevered construction and having relatively low impact on the terrain. The extradosed bridge superstructure fully utilizes compressive capacity of concrete, while maintaining conventional girder cross section and common construction methods.

In the design of five span continuous extradosed bridges, the main span has been kept as 120m and the shore span is 75m, which is almost 0.6 times the main span. Structures have been designed as per provision of AASHTO and Indian Roads Congress Code of Practice. Loading on superstructure includes dead load and superimposed dead load along with vehicle loads as specified by Indian Roads Congress Standards for four lane or five lane live loading. Depth of the box girder deck has been kept as 3.5 m, suggesting a slenderness ratio of 34.28. Depth of deck has been kept constant since such a deck structure shall be most sensitive to live load. Allowable stresses are as per Indian

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Roads Congress code of practice and manufacturer's specification for pre-stressed concrete construction. Allowable stress in prestressing steel has been kept at 0.6 $f_{pu.}$ (where f_{pu} is ultimate tensile strength) tension has not been allowed at any section of the deck girder. Superimposed Dead Load and Live Load are to be resisted by extradosed cables which are 60% of the total loads. Design methodology has been adopted considering an adequately stiff deck i.e. PSC box girder with cables anchored in the deck in such a way that tension variation on cables due to live load is within $0.6f_{pu}$. Analysis has been carried out using ADAPT-ABI software which takes care of effects of pre-stressing on superstructure during construction and service stages. The effects of continuous segmental construction have been considered through inputs generated by carrying out calculations on spread sheets. Design of superstructure has been carried out by using limit state design approach both for ULS and SLS case.

Durability measures like 100 years design life, use of high strength concrete, higher concrete cover, proper stitches, use of HDPE sheathing, adopting anti-carbonation measures, water proofing with acrylic membrane, provision for external prestressing and protecting strands of stay cables by galvanizing and encasing in a sheath filled with grease or wax or epoxy coating have been incorporated in design.

The cost of superstructure of extradosed bridge works out almost equal to that of girder bridges. Accordingly the extradosed bridge superstructure were proposed for Ulhas river near Mumbai and Tapi river near Surat due to their elegance, sleekness, aesthetic look and mainly being close to main town and the population. The cost comparison for these two alternative options are given below. It may however be mentioned that in case the cost of substructure and foundation is also taken into account, the cost of extradosed bridge will be somewhat less than the girder bridges, as the superstructure of extradosed bridge is lighter.

Sr. No.	**Type of Superstructure**	**5 Span Continuous Unit (m)**	**Cost of Superstructure per sqm. of Deck Area**
1	Extradosed PSC segmental box girder	2 x 75 + 3 x 120	Rs. 39,703/-
2.	PSC segmental box girder by balanced cantilever	2 x 75 + 3 x 120	Rs. 42,412/-

Extradosed bridges provide very cost effective solution for bridges having span lengths in the range of 100 to 200 m. From considerations of material utilization and ease in execution, extradosed bridges are advantageous, besides being aesthetically pleasing.

An extradosed bridge is still a relatively new concept compared to cable stayed bridge and girder bridge. One of the major challenges of using this concept is the lack of specifications for bridge design and construction. However the acceptance of this type of bridge is increasing every day and has high potential in future for span ranging 100m to 200m.