Innovative design and construction of pier head for Nivedita Setu

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1. Introduction

Nivedita Setu is the fourth Hooghly river crossing for bridging the twin cities of Kolkata and Howrah. Built with extradosed cable- stayed technology, the bridge boasts of its technological marvel in the application of advanced bridge engineering in Indian scenario. The rich location of the bridge site, with the historical temple at Dakshineswar and the unique Vivekananda bridge situated 50m upstream of Nivedita Setu, demanded both excellence in state-of-the-art bridge structure and its harmonious blend with the existing surroundings. To that end, innovation in both the bridge form and method of construction were adopted to overcome the challenges of balancing high-end technology with cost, and thereby complete the construction within a tight 36 months.

One of the areas of innovation was the pier head that posed challenge to bridge engineers. This paper discusses the constraints to construction of this critical component of the balanced cantilever method, and the innovative solution to successful completion of the landmark extradosed cable stayed bridge.

Keywords*: pier head, pier table, precast segment shell, hybrid structure*

2. Design Challenges

The challenges posed to the design of Nivedita Setu was to build an iconic bridge structure commensurate with the surroundings and yet not to cast shadow upon the famous temple and old landmark bridge. The temple spire was constraint to the vertical height of the bridge, while the span of old Vivekananda bridge was governing the span length and the navigable waterway. The above parameters and bounded also by stringent control of the project cost and time, necessitated the development of an extradosed cable stayed concept.

The 7x110m main spans and 2x55m end spans suited to the bridge location and also restricted the height of pylon to 14m above the deck and thereby not exceed the height of the temple. Precast concrete segmental superstructure was adopted to expedite the construction of bridge foundation and superstructure.

The 880m long Nivedita Setu was designed using 29m wide, single cell, precast concrete segments for six lane carriageway width and supported by single central pylon pier and a central plane of stay cables. A single plane of cable stays and the sloping webs of segmental box girder deck embelished the uniqueness of the bridge. Moreover, bearings at pier supports were eliminated to facilitate balanced cantilever construction and also reduce maintenance costs, thus providing a monilithic connection between the pier shaft, pier head and the upper pylon.The bridge was designed as two span continuous with mid-span expansion joints at every 220m. The main spans were analysed into 4 nos frames of 220m, comprising of two pylon piers and expansion joints at the ends. During construction, individual pylon piers were built with alternate midspan expsnsion joint and midspan continuity closure joint. The pier table construction was the critical component for balanced cantilever construction of the span segments and thus cost and timely completion of the bridge was largely dependent on the completion of the pier head.

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The massive dimensions and huge weight of the pier table was challenging in terms of transportation and erection. Precasting and cast-in-situ pier table alternatives were examined against the economy and time of construction and a hybrid concrete-steel form of pier table was finally adopted.

3. Construction Challenges

The hybrid pier table comprised of two precast concrete segment shells connected by steel frame. This concept was acceptable for the following reasons-

i) Handling weight of the individual precast concrete shells was within the capacity of lifting tackles,

ii) Individual precast concrete shells were erected on top of the pier and connected by steel frame for stability, thereby reducing the temporary supporting systems,

iii) Cast-in-situ base and diaphragm, was easy to construct inside the segment shells without having to design costly form traveller,

iv) Integration of pylon and pier shaft with the superstructure deck was simplified to speed up the construction. The design intent of a monolithic connection of pylon pier was adhered.

Fig 1: Erection of precast segment shell

The individual precast concrete segment shells were lifted to a height of 15m above the water level and erected on top of the pier with the help of a barge mounted gantry crane with strand jack lifting system [Fig1]. As the gantry was supported on two barges, a differential movement of 150mm between them due to tidal effect was considered in the design. The concrete segment shells were precast in a special mould and prestressed before removal of forms. Individual precast concrete shells were supported on steel stability brackets and erected on the pier. Each precast segment shell was surveyed and the levels were adjusted by using flat jacks before connecting the stability frames of the two segment shells. Next, reinforcement and second stage prestressing ducts was installed within the segment shells. In-situ concrete of M60 grade was then placed to complete the monolithic structure, followed by transverse and longitudinal prestressing.

All the pylon piers repeated the same sequence of stages prior to erection of 2x 100t erection tackles for balanced cantilever construction.

A precise geometry control system was adopted during precasting of segments and also for erection by balanced cantilever method and for span continuity. However, the geometry control of pier table was critical and challenging in terms of controlling the bridge alignment and to achieve deck erection close to theoretical profile during construction as well as in the long-term. After-cast observations to elevation, horizontal and twist error was independently deternined by two observers to an agreement of +/- 0.3mm tolerance on control points.

4. Conclusion

Technological innovation was the cornerstone of success of Nivedita Setu. The adoption of innovative hybrid design and construction approach to pier table simplified the construction manyfolds in terms of both budgeted cost and completion time of 36 months. No wonder this bridge won an Award of Excellence from American Segmental Bridge Institute (ASBI), in 2007, for an exemplary showcase of technological marvel in the history of Indian bridge engineering.