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Choice of structural form for Bhulta flyover

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ABSTRACT: The proposed four lane Bhulta flyover is on Dhaka Sylhet highway. Simply supported post tensioned pre-stressed standard I-section was used in the proposed design. In the original design quite a good number of PC-I girder in transverse direction was required for superstructure. It increases the cantilever length of Y shaped pier. Simply supported span requires more uncomfortable expansion joints. To overcome those problems seven span continuous RCC twin cell box girder is introduced in the revised design. The paper gives an overview of the project and how the design development process starts. How the new superstructure reduces cost, saves quantity of material, enhance riding quality and introduce aesthetic view are the salient feature of this paper.

1 INTRODUCTION

The Flyover is located at Rupgonj, Narayangong. The site location is shown in Figure 1. The proposed Flyover is an approximately 1.2 km long elevated concrete structure. The superstructure of the Bhulta Flyover is reinforced concrete box supported section continuous over the piers of approximately ±215.00m.

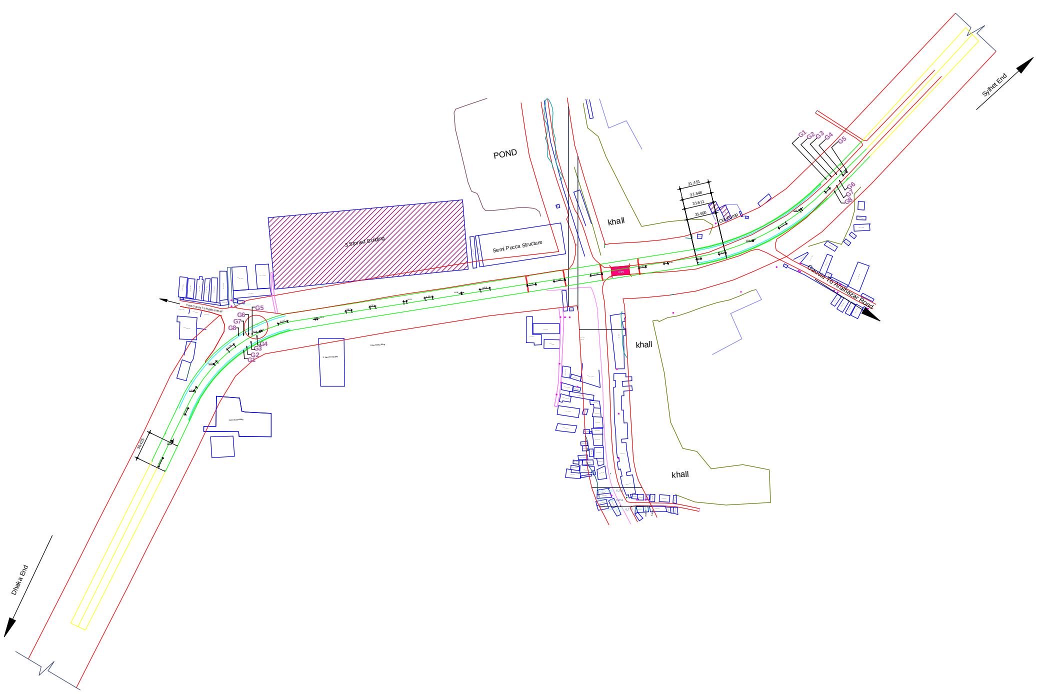

Figure 1. Layout of the Bhulta Flyover

The bridge construction practice in Bangladesh is based on some simple procedure. Other than few long bridges funded by foreign aids, most of the bridges are simply supported beam-slab bridge with individual span generally varies from 20.0 m to 45.0 m. Main problem associate with this type of bridges are (i) Riding discomfort – individual spans are separated by poorly made expansion joints which always cause bumping of the vehicle while crossing over it; (ii) Risk factor– construction practice of such bridges are to construct an individual girder on scaffold and shift it laterally on position. During side shifting falling down of girder has become a common accident; (iii) Expensive solution – such type of bridges demand more material and construction time.

Why different structural forms are not tried? There are few definite reasons for this (i) The decision makers do not want a change; (ii) The contractors are trained for a particular type of construction with limited resources; and (iii) The design team do not want to put more time for learning. Simple change of anything in bridge form and material beyond the tradition is quite difficult. Design and Construction of Bhulta flyover tries to accommodate something new from the tradition. This paper is not a technical innovation or anything like that. It describes the process of transformation of bridge form from simply supported I-girder to continuous Box girder.

2 INITIAL DESIGN OF BHULTA FLYOVER

Bhulta Flyover (in true sense – a grade separator) was designed by RHD Design Unit. It is almost 1.2 km long structure which crosses two curved intersections. The solution was done by introducing traditional simply supported I-girder for both straight and curved portion. There were 26 nos. of expansion joints along the length and too many bearings beneath the girders. It may be noted that bearing and expansion joints are maintainable parts of the bridge and maintenance practice in Bangladesh is very poor. The cross-section of Flyover deck is shown in Fig. 2.

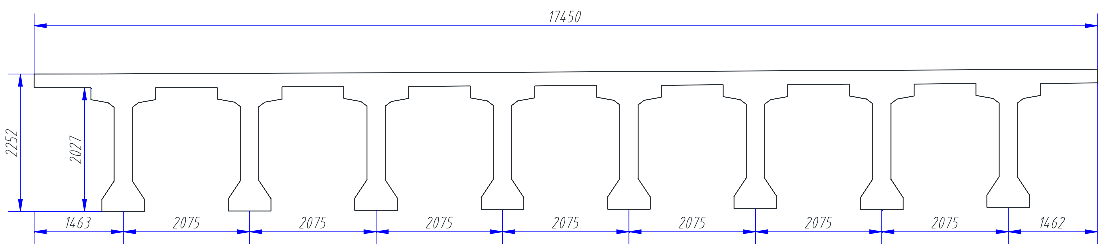

Figure 2. Cross deck section of traditional section

2.1 *Bhulta Fly-Over Design Development Process*

Learning from recently build Banani Overpass, it was decided to make the Bhulta Flyover continuous of some extent. Banani over pass is a multi span bridge with too many expansion joints. Riding discomfort and noise is being experienced while crossing this overpass.

To make some change from the tradition, it was first decided to make the deck slab continuous over the precast I-girders. This is a standard design process detailed in the AASHTO and a very common construction practice in other parts of the world. As there were two curved portion along the Flyover, a box section was introduced as superstructure (see Fig. 3). It has the advantages of i. better torsional stiffness - so, the curved portion can be managed easily; ii. Utilise cantilever action of the box section – so it reduce the length of pier cap – creates more space below (see Fig.4); and iii. Consume less material – thus make it an economic solution; iv. easy to construct - the structure is on the dry land with pier height ±8.0m, there is available land underneath the Flyover for full scaffolding; and v. above all it is aesthetically pleasant to look at.

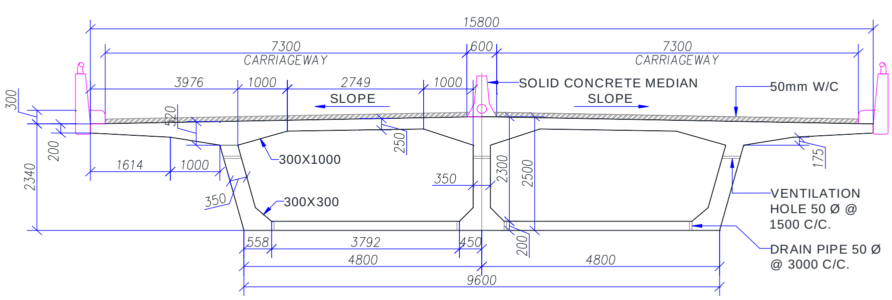

Figure 3. Revised RCC twin box section

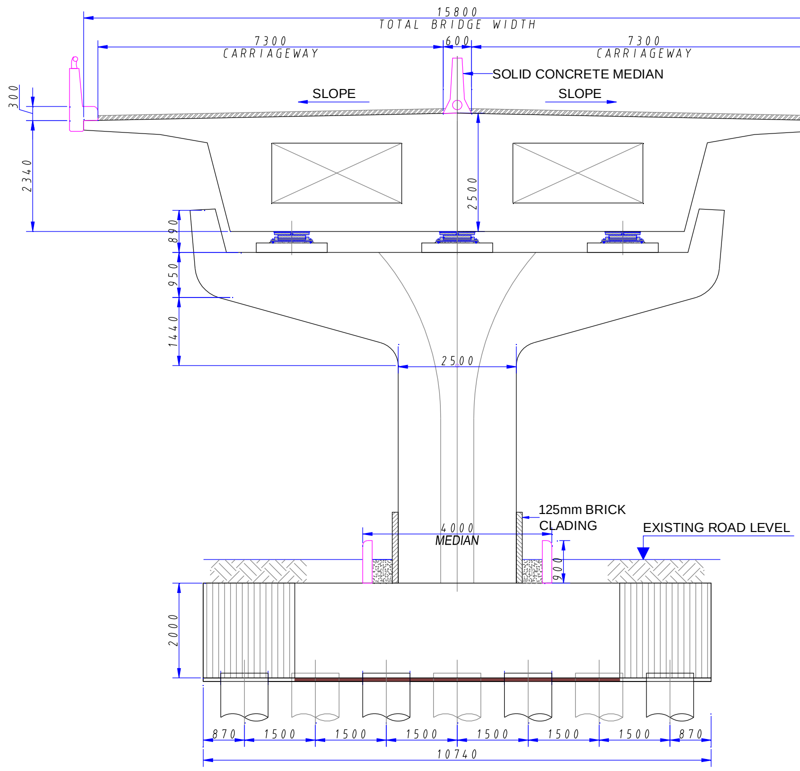

Figure 4. Revised pier section

2.2 *Design Consideration*

Individual span of the flyover was ± 31.0m. There was no demand for longer span along the length. Minimum depth of the box was 2.5m. Further reduction of the box depth was mathematically possible but for proper working facility in cast-in-situ construction, depth reduction was not practical. In such situation, Reinforced Cement Concrete (RCC) was proposed.

Seven span module of length ± 215.0m was considered continuous. Continuous length was fixed based on relatively moderate opening of expansion joint. Optimization of span arrangement was possible by reducing exterior span length (see Figure *5*). But to keep harmony of the pier spacing, span was kept same but additional reinforcement was provided for exterior spans moments and first interior support moments.

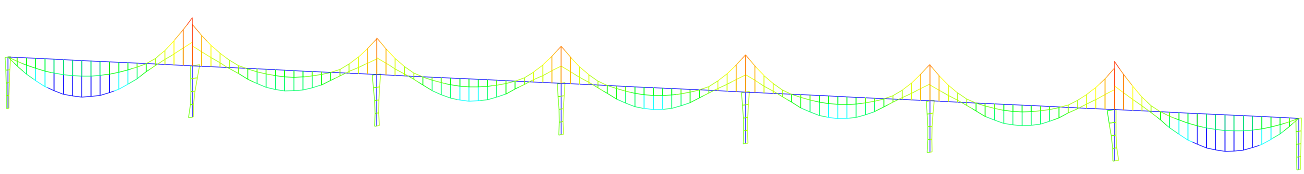

Figure 5. Moment envelope of a continuous module

At the same time longer span would cause more load to the foundation. So, the structural form was agreed to continuous reinforced concrete box girder supported through bearing on cast-in-place reinforced single Pier. The Pier was assumed to be rigidly connected with the Pile cap as shown in Fig.4.

Key points considered in the reinforcement detailing are:

i. More confined reinforcement are provided in Pier. This is to ensure additional protection against brittle failure of concrete and also to enhance concrete strength for confinement;
ii. Lesser diameter bars with closer spacing are used for concrete box section to prevent cracking of from secondary forces;

iii. Top of the Piles and bottom of the Piers have been considered as part of Earthquake Resisting System (ERS) and detailing as appropriate for plastic hinging are done in these places.

2.3 *Seismic Behaviour and Articulation Arrangement*

Bangladesh National Building Code (draft 2015) includes a Seismic Hazard Map of Bangladesh. The hazard map provides a zoning of the country with peak ground acceleration (PGA) which has a 2% probability of exceedance in 50 years. This represents a 2,475 years seismic hazard and technically termed as Maximum Credible Earthquake (MCE). As per code, the Design Basis Earthquake (DBE) has been suggested as 2/3rd of the MCE. [*BNBC provides limited data for seismic design of bridge that follows the AASHTO. It may be noted that both the AASHTO Guide Specifications for LRFD Seismic Bridge Design AASHTO/2009 and the AASHTO Bridge Design Specifications have adopted the new 1000-year seismic hazard for bridge design.*]

The Response Spectrum Curve generated from the available data is represented in Figure 6. Seismic demand for the site is not much. The site has been classified as Seismic Design Categories - SDC B.

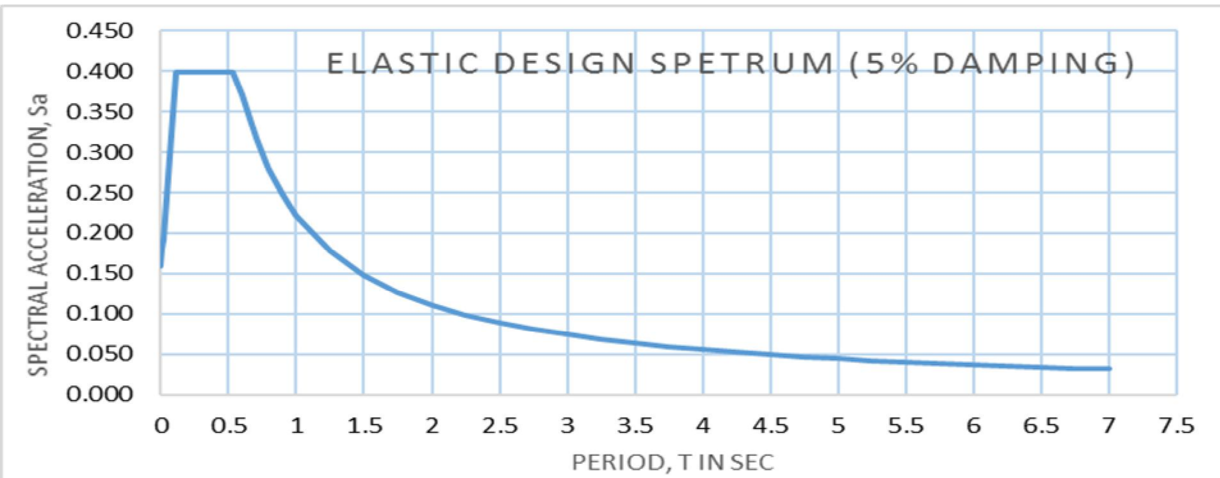

Figure 6. Design Elastic Response Spectrum

It is to be noted that data provided in the BNBC is limited for seismic design of bridges as per AASHTO provision. It is required to develop new data for bridge design.

The bridge deck is continuous between expansion joints giving a total expansion length of ±215.0m. At each pier there are 3 nos. vertical bearings which transmit the deck loads through the substructure directly into each pile. Horizontal fixity in both longitudinal and transverse directions is provided at middle Pier (alternately at Pier 4 and Pier 5 in the subsequent modules) and horizontal transverse fixity only is provided at other piers thus allowing the deck to move relative to the fixed pier. The location of bearing and shear keys are shown in Figure 7.

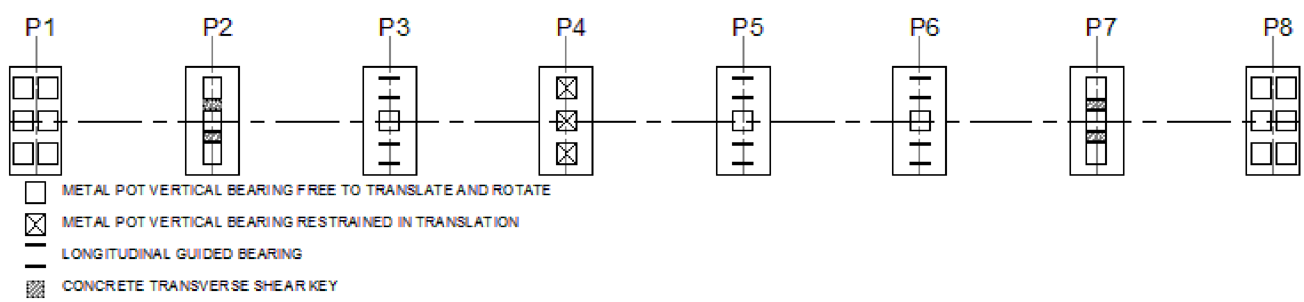

Figure 7. Location of bearing for a continuous span

3 COMPARISON

Considerations for Bhulta Flyover redesign was basically arise from riding comfort attributed by expansion joints. Most of the cases strength is the prime consideration to the bridge design engineers. Serviceability given the least importance. Continuous deck as proposed for Bhulta Flyover is a change from the long continued tradition being followed here. As a by-product of this change, considerable savings are anticipated. For example – (i) basic section of the deck was like as shown in Figure 2. Total 8 number of I-girder were placed at 2.075 m centre to centre and a solid deck slab of 225mm thickness was placed over it. Gross concrete area of the section was 11.37 m^2/meter of length. Gross concrete area of the box section is 9.21 m^2/meter of length. The new section saves concrete of 2.16 m^2/meter length. As a result it reduces foundation load 5.3 ton/meter of length. For a 31.0m span, total foundation load reduces to 165.0 ton; (ii) Number of maintainable parts like bearing and expansion joints are reduced to a minimum; (iii) Eliminates the health hazard of PC girder construction and shifting.

4 CONCLUSIONS

Redesign of Bhulta flyover is not something very technical or innovative. This redesigning process aims to shift the paradigm of practicing bridge engineers. Providing or increasing strength is not only the solution for bridge design. One should take a holistic approach for an aesthetic, comfortable and durable solution for a bridge. Improving visibility while riding, reducing sound and discomfort, removing maintainable parts (where there is no practice of maintenance), improving aesthetic and thinking beyond the tradition may result a more satisfactory structure. We are looking forward to the completion of the Bhulta flyover to see its impact.

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