RESEARCH ARTICLE OPEN ACCESS

Comparative Study of Wide Deck Bridge Superstructure Systems and Their Suitability: A Review Paper

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Abstract:

Increasing urban population, traffic flow and restricted available width to spread horizontally in cities,prestressed concrete wide-deck box girders have been increasingly usedespecially spine and wing arrangement either withbox girder with transverse ribs or box girder with struts, for constructing new bridges and flyovers. A ribbed cantilever slab or cantileverwith supportingstruts can increase the cantilever length and transverse stiffness while reducing the dead weight of the deck. Present trend is to provide only a single median pier to cover the wide deck, so that both surface level space underneath elevated corridor as well as at the elevated level space can be fully utilized for the traffic movement.Bridge aesthetics are also very important as bridges are located in cities, prime locations, tourist's spots.

A literature study revealed that the prestressed concrete box girders with transverse ribs are already used in to meet the requirements of wide bridge decks of single-cell concrete box girders. However, little research has been conducted.

The objective of this study is to understand the behavior of different types of wide deck bridge superstructure systems and their suitability with respect to various aspects such as analysis and design along with their construction, site constraints, handling, segment erecting schemes for choosing best suitable option for a particular project.

Keywords **—wide-deck, box girders,spine and wing,ribbed cantilever slab, struts,single-cell.**

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I. INTRODUCTION

India's transport sector is large and diverse. Roads are the dominant mode of transportation in India today. One of the impediments in the fast progress of road infrastructure is acquisition of land & related regulatory hurdles. Completion of many projects are delayed on account of such factors. There is a restriction of the available width and to spread the road horizontally. Therefore, present trend in urban areas is to go for elevated grade separators, wherein both surface level as well as elevated road can be fully utilized for traffic movement. By avoiding costly land acquisition, it results in reduction in cost of the project and certainly segregate local and fastmoving traffic, thereby further increasing speed of movement. Design and Construction of such elevated corridors however poses many challenges to structural engineers. Restricted workspace during construction adds to the challenge and brings out many innovative solutions to the problems.

Past practice of constructing elevated flyovers used to be with the concept of covering the space underside of the flyover for landscaping or for shops. Therefore, the superstructure used to be supported on twin/multiple piers, covering a major part of at-grade space underneath. The surface level road was kept outside the flyover width. Present trend is to provide only a single median pier to cover the 4 to 6 lane wide deck, so that both surface level space underneath elevated corridor as well as at the elevated level space can be fully utilized for the traffic movement.

II. LITERATURE REVIEW

[1] This paper introduces the strutted box widening method (SBWM), a system that allows a segmental bridge to be designed andconstructed so that it can be easily widened to accommodate more lanes at any time in the future. This solution is attractive becausewidening only needs to occur if and when traffic volumes warrant it. With the help of two examples how the Strutted Box Widening Method can be used to widen a variable-depth cast-in-place segmental bridge and a constant-depth precast segmental bridge. Design and construction considerations of the SBWM are addressed, and the advantages and disadvantages of the SBWM are outlined.

It is found that SBWM is an excellent solution for building an economic and efficient bridge to handle current traffic volumes, while at the same time planning ahead to build cost-effective and schedule-effective bridge widenings to handle future traffic volumes.

[2] This paper describes the overall design of the bridges plus the fabrication and erection of the segments. A special feature of these structures is the use of transverse ribs along both segment faces to accommodate the deck flare. Problems encountered during construction and their method of solution are also discussed. Deck width is varying from 14.85m to 16.56m. A special design feature of the bridges is the transverse ribs located along both segment faces. It was found that the transverse post-tensioned ribs with a 178 mm thick top slab were extended to accommodate the deck flare and resulted in a 10 percent reduction in the segment weight, Without the ribs, the deck flare would have required a considerably thicker top slab.

[3] This paper presents the bridge technologies applied to progressive erection of the Uchimaki viaduct. The technologies include concrete material as well as machinery for producing and erecting the precast segments and special form travellers for constructing the wing slabs. The span length is standardized into approximately 50 m.

Span-by-span erection with precast segments is adopted because of the sufficient project length and standardized spans. The traffic width of the Uchimaki viaduct is 16.5 m.

Applying span-by-span erection to the box girder with strutted wing slabs, two erection methodologies were compared under the conditions of this project. As the first option, precast segments including the entire cross section ‘whole segment’ are erected. As the other, the cross section is divided into several parts, which are erected progressively.

Progressive erection method was found to be beneficial in relation to pier segment erection, fabrication of precast segments and span-by-span erection. It was found impractical to cast whole segments because the casting yard has limited space. Whole-segment erection is considered to be more advantageous than progressive erection in relation to wing slab because progressive erection of divided parts of the girder cross section requires special form travellers for constructing wing slabs and a longer construction period. Struts are installed in a simple manner. In the case where progressive erection is adopted, minimizing the cost of special form travellers and shortening the construction period are very important.

[4] In this paper comparative study of wide deck box girder with rib and conventional single cell box girder is carried out. The bridge superstructure consists of the precast segmental prestressed concrete box girder segments with transverse ribs. The superstructure is a prestressed concrete continuous box girder with a 16.25-m-wide and 0.24-m-thick top slab and a 0.2-m-thick bottom slab, a depth of 2.6 m, a cantilever length of 4.5m, a 6.08-m-wide bottom slab and a 0.4-m-thick web. Each span is 40 m long, and each precast segment is 3 m long. The transverse ribs are located at the middle of the segment and are 0.3 m wide and 0.2 m deep near the cantilever end and 0.9 m deep near the web. For comparative study to evaluate the effects of the transverse ribs on the mechanical performance of the wide box girder, three types of

box girder models with different cross sections were established.

•Model 1: ribbed box girder based on the design scheme of the actual bridge

• Model 2: equivalent box girder for which the volume of the transverse ribs is redistributed to the top slab,

• Model 3: ordinary box girder.

The result shows that Stiffened ribs can effectively improve the stress state at the root of the cantilever as well as at the middle of the top slab and the overall structural stiffness of the box girder with transverse ribs was also improved. The maximum deflection of Model 1 was 10% less than that of Model 2 when subjected to symmetrical vehicle loads.

[5] In this paper the new type of PSC box girder bridge with concrete filled FRP struts is introduced in order to verify the efficiency and superiority of this type of bridge, the investigation in structural and economical effectiveness, durability and appearance was performed. In this study three different types of segment cross sections are analysed 1) Traditional box girder, 2) Box girder with cantilever rib, and 3) Box girder with struts.

In this study it is observed that Concrete filled FRP strutted box girder if found efficient as cantilever tip deflections are less, superstructure and substructure became light weight. Strut erection is simplified with the use for Movable scaffolding system (MSS). Also, Box girder superstructure looks aesthetically pleasant.

[6] In this present study, cost analysis and design of prestressed concrete girder is presented, the analyse and design of concrete girder is done by consideringa IRC class 70 R loading. Software STAAD PRO is used for the analysis and design of prestressed concrete girders. Before using the software for analysis, it will be validated by comparing its results with the corresponding classical theory result.

It is concluded that box girder is costlier than I girder. It has also seen that losses are more in I girder as compared to Box girder.

[7] This paper discusses the parametric study of two different cross-sections of box-girder for same loading conditions to find the most economical cross-section. The design standard of India, IRC was followed in design of Box-girder superstructures subjected to IRC class AA loading. Analysis is carried out using the MIDAS Civil Software which is based on finite element method of analysis. A 30 m span length and 10 m width bridge deck is being analysed in this work.

The result shows the multi cell box girders are costlier as compared to the single cell box girder, when the loading and support condition were kept same for both the cross-section. It shows that the single cell pre-stressed concrete box girder is most suitable and economical cross-section for 2 lane Indian national highway bridges.

[8] RCC T-beam and Box girder of 25 m span length is considered in this work. IRC loading of class A is applied in superstructure and analysis is done using STAAD Pro. Dead load calculations is done manually. Cost analysis is done in both the cases.

It is observed that the service dead load bending moments and Shear force for T-beam girder are lesser than two cell Box Girder Bridge. Moment of resistance of steel for both has been evaluated and conclusions drawn that T-Beam Girder has more capacity for 25 m span. Shear force resistance of T-Beam Girder is more compared to two cell Box Girder for 25 m span. Cost of concrete for T-Beam Girder is less than two cell Box Girder as quantity required by T-beam Girder. Quantity of steel for T-beam Girder is less so cost of steel in T-Beam is less as compared to two cells Box Girder Bridge. For 25 m span, T-Beam Girder is more economical but if span is more than 25 m, so Box Girder is always suitable. This type of Bridge lies in the high torsional rigidity available because of closed box section.

[9] This paper presents the comparative study of PSC box girder and PSC I girder bridge. For the purpose of comparison three different spans with three different lengths to span ratios have been considered. Losses of prestressing are considered as IRC:112-2011. Load and stresses and selection of vehicle according to lanes of bridge are considered as IRC: 6. Superstructure is modelled and analysed in CSI bridge 2014.

After analysing Box Girder and Tee Girder it is concluded that as the span increases the box girder shows better results. The numbers of prestressing cables required for box girder superstructure are less compared with Tee girder superstructure. Box girder option is found more efficient for longer spans.

[10] In this paper the study has been carried out to investigate the effect of number of cells in box girder bridge by evaluating the bending moment, shear force and deflection. Also, the variation of longitudinal and shear stresses. For this purpose

two, three and four-cell box girder considered. The carriage way width is kept constant for all the models as 7.5 m and the footpath considered is 1.25 m on both the sides. The boundary condition is simply supported, span of 50 m with l/d ratio of 25, depth of the box girder is 2 m. Superstructures are modelled in SAP200 using shell elements.

Outcome of the study revealed that on increasing the number of cells, the self-weight of the box girder bridge increases, for live load case increasing number of cells found not much advantageous.

[11] Paper presents the experimental effect of the number of cells on the structural behaviour of reinforced concrete box girder. Three simply supported box girder specimens with different numbers of cells were cast by using self-compacting concrete and experimentally tested the first reference specimen is with one cell, thesecond specimen is with two cells and the last specimen is with four cells.

The testing resultsshow that the ultimate load in the two-cell and four-cell specimens is higher compared with theone-cell specimen by (20.1% and 23.3%) respectively. Increasing the number of cells decrease the cracks width and increase the number of cracks, all the specimens failed with diagonal shear.

III. CONCLUSIONS

This literature study shows the comparison between various types of PSC girderbridge decksviz. (1) I girder, (2) single cell box girder, (3) multicell box girder, (4) spine and wing box girder with transverse ribs, &(5) spine and wing box girder with strut.The advantages and disadvantages of these different structural forms are discussed considering outcome from analysis and design.In some of the technical research papers construction aspects and erection techniques are also discussed with required time and cost. As it is a review paper, the results and detailed work will be discussed in final paper.

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