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A REVIEW OF DESIGN METHODS OF TRANSVERSE REINFORCEMENT OF CONCRETE BRIDGE DECK ON PRESTRESSED GIRDERS

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ABSTRACT

A review of current practices in designing the transverse reinforcement of concrete bridge slab supported by wide-flange prestressed-T girders is presented. Slabs are commonly assumed to be supported continuously at the center points of girders, neglecting the effect of the girder flange stiffness. The design in this manner may produce conservative transverse reinforcement of the slab. As alternative a newly constructed bridge deck is chosen as a case study where the design based on this conservative assumption is compared with that considering the girder flange length, thickness and rigidity. The results of these two designs are compared. It is found that the amount of transverse reinforcement of the concrete slab obtained from the conventional design is considerably larger than that considering the girder flange stiffness. This promising finding warrants further investigation of the latter approach focusing on the effect of girder flanges in taking bridge loading in the transverse direction.

KEY WORDS: Prestressed girders, Bridge deck, Bridge design method and Transverse reinforcement.

1. INTRODUCTION

The design life of bridges is conventionally set to stand for satisfactory life duration. During this life span the bridge has to comply with certain basic requirements such as structural resistance, serviceability and durability, which are met by appropriate design, production, execution and use. Concerning the design, this is based on the consideration of ultimate and serviceability limit states that have to be verified for persistent, transient and accidental design situations. The objective of this paper is to provide a review on the work related to bridge super structure design, and to offer an insight of the real mechanism involved through a framework of a simple model. This is carried out to devise a sound basis for the possibility of a more economical design approach and justified recommendations for further research work.

Most of concrete slab bridges specifications were developed in 1940s [1].The AASHTO's Specifications [2] were produced from the works of various researchers [3-9], all of which predicted the ultimate strength capacity as pure flexure. However, ultimate strength tests results on old concrete slab bridges (with assumed low truck loads specification) showed that they are much stronger than the rating procedure suggested by AASHTO, which offers the possible existence of other factors necessary for enhancement [1]. This draws the attention of many researchers. In addition to this, the need for reduction or elimination of total internal steel reinforcement [10] for better durability has also helped in adding the research motivation on the subject. The first major change was the idea of compressive membrane forces in a member enhancing its capacity, which led to the invention of empirical method of design [11, 12]. It has later been revealed that the total deflection of bridge deck is not really flexural but also highly influenced by small girder spacing and/or large deck thickness [13].

In another development by Wisconsin Department of Transportation, a 203mm thick deck over Wisconsin 54W girder withstand over 890kN wheel load which is far above factored designed vehicle load of 160KN provided by AASHTO [2]

Bridge construction in Malaysia mostly uses prestressed beams with reinforced concrete slab deck. This slab system is overdesigned and inefficient because the design procedure usually follows the conventional assumption as is done in buildings. Furthermore, the vehicle loading that is considered in Malaysia is typically lower than the design values. In view of this a new design aspect should be looked in to more seriously.

At present the flanges and web thickness of the bridge girders are neglected when the design of the slab is done (figure 1). The flanges are only used as a supporting platform during the casting of slab. As a result, the slab transverse reinforcement is designed based on its pure flexural strength alone without considering the stiffness of the supporting girder elements. It is expected that, with proper design method, the flange and the web is able to resist vehicle loading together with the slab. As a result, the entire the entire slab reinforcement in the transverse direction can be reduced significantly. This will help to expedite the construction time and reduce the construction cost of the bridge structure.

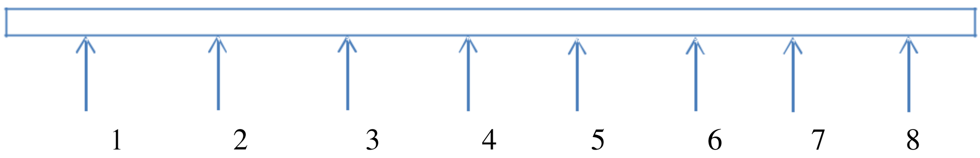

Figure 1. Slab on beam assumption

2. CASE STUDY

For reviewing and comparison purposes on existing bridge, the Jalan Kampung Kerinting bridge is selected to be used as a design case study. It is situated in the Kerinting Kelantan express way in Kelantan, Malaysia. The bridge consists of one-span post-tensioned wide T- beam with insitu deck slab type of structure of 40 meters length. The bridge is not skewed, the width of the deck is constant throughout (13.9 meters) with dual carriageway. It consists of 200mm thick deck slab and eight prestressed wide flanged T- beam and the abutments are cantilever wall types. The cross section of the bridge is shown in figure 2. The bridge had been designed in September, 2008. The analysis and design of the bridge are reviewed and summarily presented as follows.

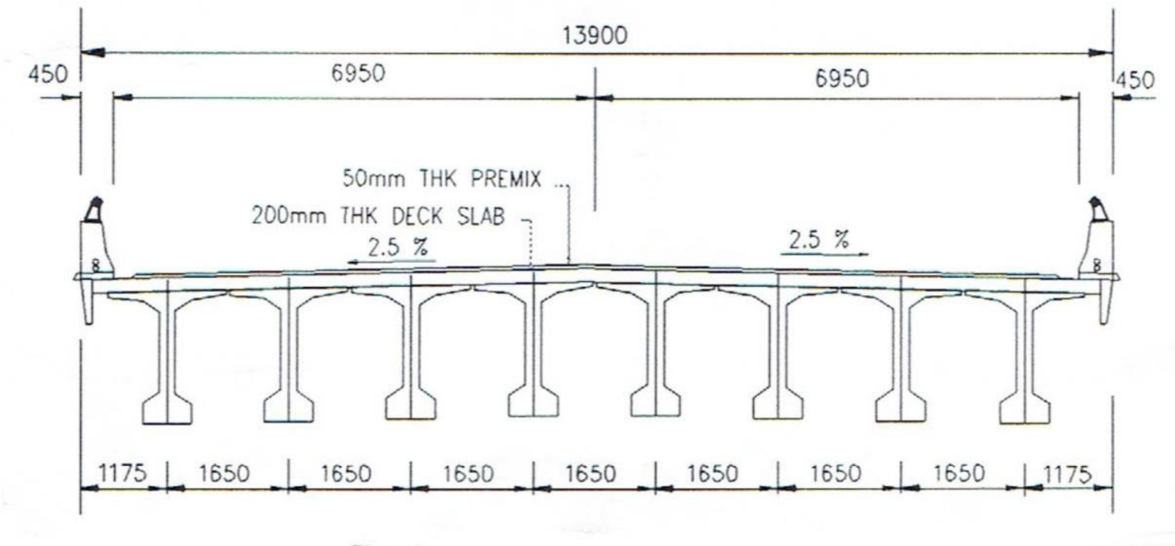

Figure 2. Kerinting bridge cross section

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3. DESIGN OF SLAB DECK USING THE CONVENTIONAL METHOD

The bridge had been designed using the conventional method on the basis of assumptions made in accordance with the British standard codes of practice (BS5400, BS8110, BD37/01 BD52/93, BD33/94, BD60/04 and BS 8004). The summary of the design parameters are shown below:-

Width W = 13m
Total length = 40m
Premix = 100mm
Slab Thickness = 200mm,
Number of Notional length N = = 4

The slab was designed transversely as one way spanning supported by the longitudinal prestressed T-beams and the beams were modeled as point reactions to the slab. Results were obtained for moments and shear forces under the symmetric loading configuration of Figure 1 and presented below:

Table 1 Moment at supports

Support number	1	2	3	4
Moment (kNm)	2.02	78.08	63.4	28.7

Table 2 Span moments

Span number	1	2	3	4
Moment (kNm)	-28.76	54.8	55.1	3.04

The moments obtained were then used to design the reinforcement, in which a steel area of 1341mm^2/mm (T16 at 150mm centers) was provided for the slab.

4. DESIGN USING MODIFIED APPROACH

The bridge is then analyzed and designed differently by considering the effect of concrete flange and web thickness in bearing the slab load as is the case in real constructed deck configuration (Figure 3). The analysis has been carried out by means of the finite element model using LUSAS software version 14.

The concrete slab and the beam were modeled using thick shell elements the element is Hexahedral 3D stress with linear interpolation order. The boundary conditions comprises of the supports conditions of the T- beam which is fixed in vertical and horizontal directions at one end pinned (vertically restrained) at the other end, a designed load for the existing case study bridge is applied uniformly over the deck slab surface (figure 4). Concrete material is applied on both the deck slab and the T-beam using the same property values of Young's modulus, Poisson's ratio, mass density and coefficient of thermal expansion for the case study bridge.

A section through 3D solid continuum model is then created in which a line parallel to the vertical axis is drawn across the section (Figure 5a). This slice section is then processed to create the stress contours (Figure 5b) and the eventual results for local forces including moments and shears in transverse direction of the deck system configuration.

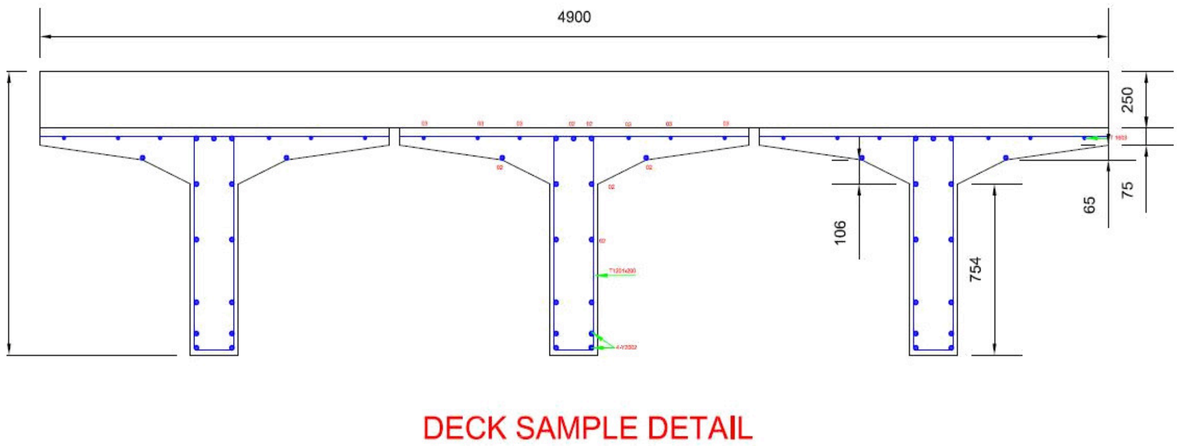

Figure 3. Typical slab on beam girder configuration

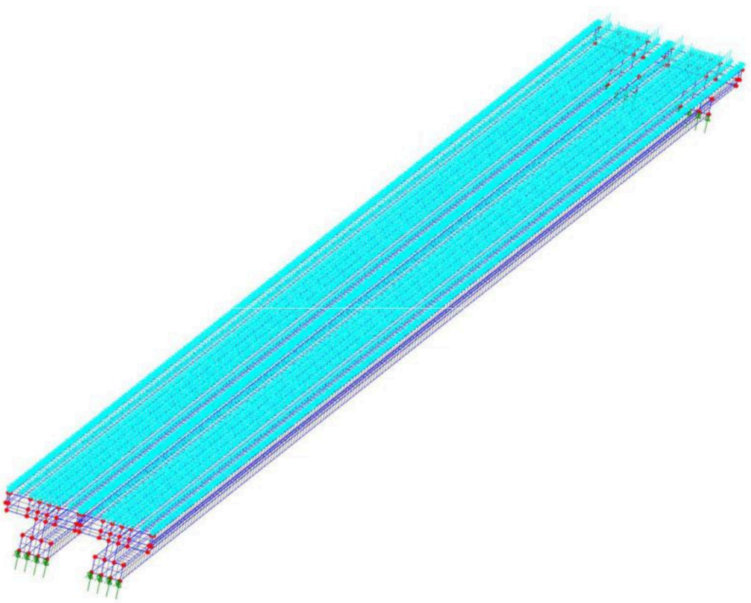

Figure 4. Support conditions and loadings for the system configuration

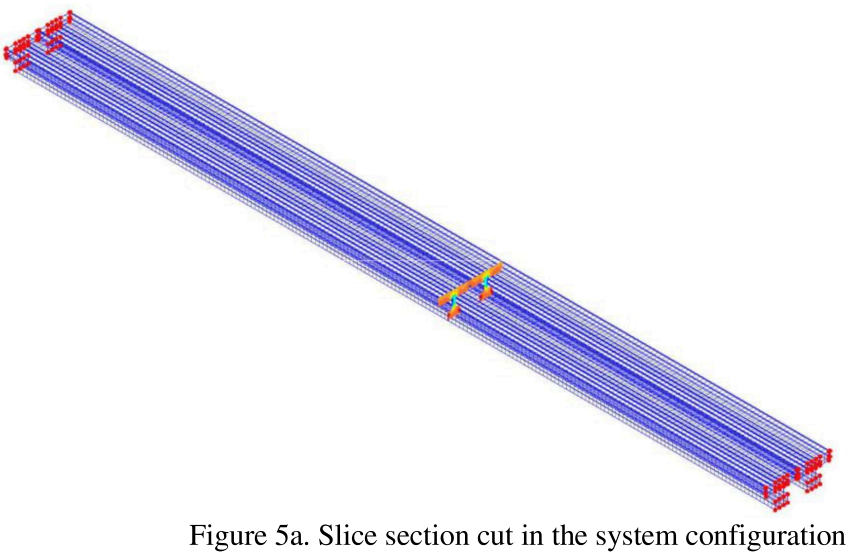

Figure 5a. Slice section cut in the system configuration

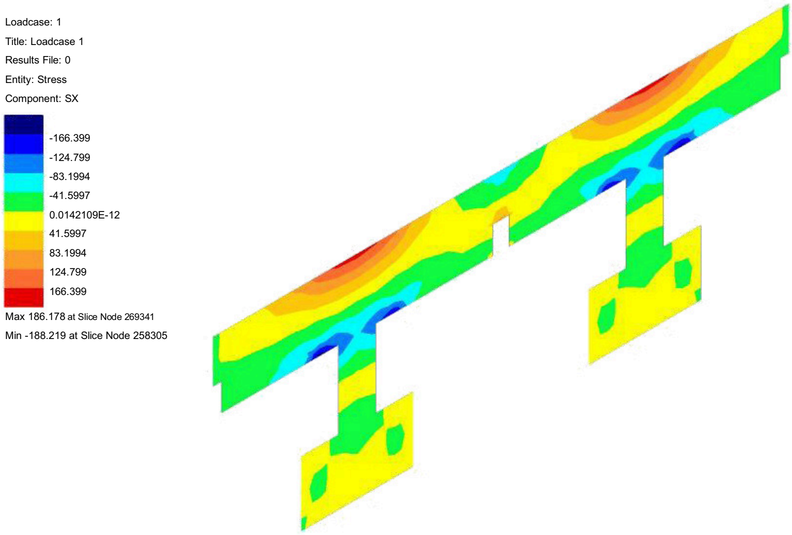

Figure 5b. Magnified Slice showing stress contour of the transverse direction

The computed outcome can be summarized as followings.

SLICE ANALYSIS RESULTS
Title: Loadcase 1
Fx on slice 83.45
Fy on slice 0.3283E-07
Fz on slice -0.6620E-01
Mxx about slice x axis 0.2222E-06
Myy about slice y axis 0.1660E+05
Mzz about slice z axis 0.4261E-08

From the results obtained the maximum moment was found to be 0.22×10^{-5} kNm in transverse direction. Therefore, the required area of steel is 3.3×10^{-5} mm^2. A comparison of results can be seen in Table 3.

Table 3. Results comparison

Item	Conventional method	Modified Approach	Percentage difference (%)
Maximum displacement (mm)	0.1306	0.054	58.65
Maximum moment (kNm)	78.08	0.22×10^{-6}	100
Area of reinforcement required (mm^2/mm)	1161.68	3.3×10^{-5}	100
Area of reinforcement provided (mm^2/mm)	1341.0	375	72.04

5. DISCUSSION

The maximum displacement and moment obtained from the first design method of the case study bridge are found to be much higher than those obtained from the proposed new design approach in the transverse direction because the supporting area provided by the beam flange and web thickness considered in the latter contribute greatly to the slab behavior. It is clear that a set of closely spaced girders should have an outstanding stiffness that can provide a full confinement to the slab. The percentage of difference shows a significantly huge margin (almost 100% for moment) which shows that the assumption used in the conventional method of design is very conservative.

Furthermore, considering the fact that the vehicle wheel contact area is normally 0.46m [14], designing the system in such a way that the clear space between adjacent flanges is about 100mm or less, vehicular loads could be directly supported by the T-beam girders by making the slab deck acts as the load transferring structure. In so doing, the method would greatly improve the economy aspect of the slab deck design, and this reducing the long term maintenance cost for reinforcement corrosion within the slab deck.

6. CONCLUSION

Design methods for concrete bridge deck system have been reviewed. The findings can be summarized as follows:-

- The conventional method for bridge deck slab, in which T- beam girders are assumed to act as concentrated reactions, requires a large amount of steel reinforcement for the transversely induced moments in the slab.
- Slab supporting T- beams produce an outstanding contribution in the bearing of bridge deck loading due to the wide amount of flange area they possess and their good restraining ability resulting from their high stiffness.
- The result comparison hinted on the need for thorough investigation in to the degree of stiffness enhancement of T-beams on slab carrying capacity and other parametric studies associated with the system configuration on improving the design methods and assumptions.

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