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Performance Based Analysis of Bridge Deck For Distinctive Girder Types

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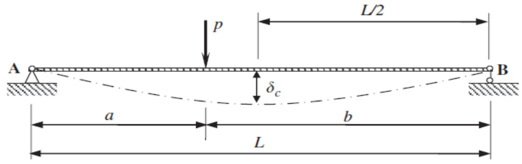
***Abstract* - Bridge decks must withstand one of the most damaging types of live load forces i.e. vehicle loads. In this research work, the bridge deck is modeled as a simply supported beam with the bridge deck slab spanning in one direction. Analysis for discrete model is done using the finite element method. This Thesis presents the results related to finite element analysis (FEA) of simply supported reinforced concrete bridge deck of different deck thicknesses (375mm to 825mm) and constant width of 12 m, without footpath under Indian Road Congress (IRC) vehicle load classes. Hence, a total of 128 numbers of cases were analyzed. The Dimension of deck slabs are taken from standard drawings of the Ministry of Road Transport & Highways-1991. And the deck was supported by four distinct types of girders for IRC Class 70R and IRC Class AA loading. The study indicates that the thickness of deck slab contributes a major role in carrying the vehicle loads. The increase in thickness reduces the loss in ultimate Moment carrying capacity; decrease the maximum deck stress and live load deflection; helps distribute deck live loads more evenly to the girders and increases the deck service life.**

Keywords—Concrete bridge deck slabs; Highway; Finite element analysis; Simply supported; Vehicle load classes.

I. INTRODUCTION

Bridge decks must withstand one of the most damaging types of live load forces i.e., the concentrated and direct pounding of truck wheels. A primary function of the deck is to distribute these forces in a favorable manner to the support elements below. The ratio of live to total load stresses is high in bridge decks usually much higher than in most of the other components of the bridge.

The bridge deck is modeled as a simply supported beam (Fig 1) or multi-span continuous beam, and the vehicle/bridge interaction force is modeled as one-point or two-point loads at a fixed spacing moving at a constant speed. In India, in the case of bridge deck slabs spanning in one direction, the bending moment per unit width of slab caused by the IRC vehicle loads can be calculated by estimating the width of slab that may be taken as effective in resisting the bending moment due to the loads (Fig 2) and accordingly the deck slab is designed for that bending moment. The dynamic performance of bridges can be affected by many factors. Different types of vehicles, vehicle speeds, and road surface conditions could all contribute to different bridge dynamic performances. The effects of heavily loaded trucks can be determinant for the evaluation of deck slabs.



$$\delta_c = \frac{pb}{6EIL}\left[\frac{L}{b}\left(\frac{L}{2}-a\right)^3 - a^3 + (L^2-b^2)\frac{L}{2}\right] \quad a<\frac{L}{2}$$

$$\delta_c = \frac{pb}{12EI}\left(\frac{3}{4}L^2 - b^2\right) \quad a \geqslant \frac{L}{2}$$

Fig.1 simply supported beam

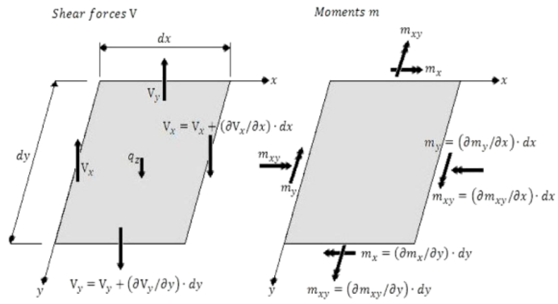


Fig.2. Sectional Forces And Stresses Of A Finite Plate Element

II. METHODOLOGY

The identification and analyses of the bridge deck is done for various types of loads and load classes, mainly live loads and self-weight of the structure. The modeling is carried out by using a standard FEA package which helps in proper modeling and accurate analysis of the bridge deck for various parameters of loads, loading types and type of structural elements supporting the deck. A virtual model of the bridge deck system is created using the software to obtain results for forces, displacements, bending moments etc. The virtual model can be simulated and modified for the application of various load classes and different girder supports, and are used further for the purpose of analysis.

III. PROBLEM STATEMENT

The important parameters that influence bridge-vehicle interaction are studied with a systematic approach in identifying the parameters of vehicles moving on bridges and a system of various load classes is identified. A finite element model is described and the results of a parametric study are presented in a systematic manner including displacements, forces, bending moments etc. finite element analysis (FEA) of concrete bridge deck supported by distinctive girder types for a range of deck slab thicknesses and load classes is carried out using FEA software package STAAD.Pro V8*i*.

IV. FINITE ELEMENT MODEL

The dimensions are taken from Standard Drawings of MORT & H (1991). The slab is modeled using a plate element and it is discretized into finite element mesh which consists of quadrilateral shell elements. The shell elements representing the slab are 0.5m X 0.5m quadrilateral shell elements with four nodes and six degrees of freedom per node. The slab has constant length of 10m and constant width of 12m. This resulted in a slab model with 525 nodes, 480 plates and 3,150 degrees of freedom. A sketch of the finite element mesh is shown in Fig 3. These plates have all the characteristics as same as the concrete slab as a whole. These plates can handle stresses individually. The horizontal elements used are the standard beam elements.

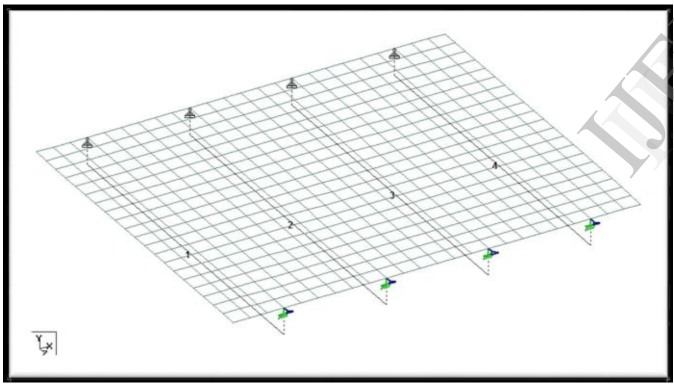


Fig. 3. Isometric View of Model of Concrete Slab with supporting girders.

V. INVESTIGATIONS

The self-weight of the structure is calculated from the geometry of the bridge section. The modulus of elasticity of concrete is taken as 21.7kN/mm^2, density of concrete 23.5kN/m^3 and Poisson's ratio 0.17. The standard vehicle loads considered are IRC Class 70R and Class AA loads with edge and center loading conditions.

A total of 128 numbers of cases are investigated and the most important results and discussions of the analysis are presented in tabulations containing the longitudinal bending moment results of deck slab analyses. The results are compared with different types of girders which are represented in the graphs and tables.

VI. ANALYSES RESULTS

In the first case the prismatic Tee beam girder is taken and the analysis is done which produced the following results shown in table 1. The variation of the bending moment along the span for increasing thicknesses of the deck can be observed in fig 4. In second case the ISMB600 steel section girder is taken and the analysis is done which produced the following results shown in table 2. The variation of the bending moment along the span for increasing thicknesses of the deck can be observed in fig 5.

Table 1: longitudinal banding moment of deck with Tee beam girder

Span (m)	Deck Thickness (mm)	Girder type			
		Prismatic Tee beam			
		Centered Loading		Edge Loading	
		70R	AA	70R	AA
10					
	375	92.62	103.38	116.65	128.48
	425	93.37	104.16	117.74	129.60
	475	94.17	104.98	118.89	130.78
	525	95.01	105.84	120.09	132.02
	575	95.87	106.73	121.33	133.29
	675	97.63	108.55	123.88	135.92
	745	98.88	109.84	125.69	137.78
	825	100.30	111.31	127.75	139.90

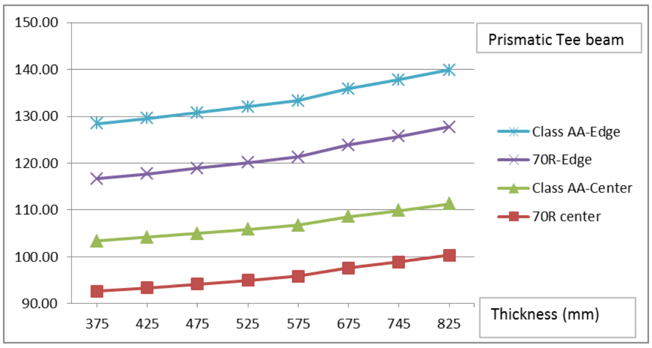


Fig 4: Bending moments along span kN-m/m.

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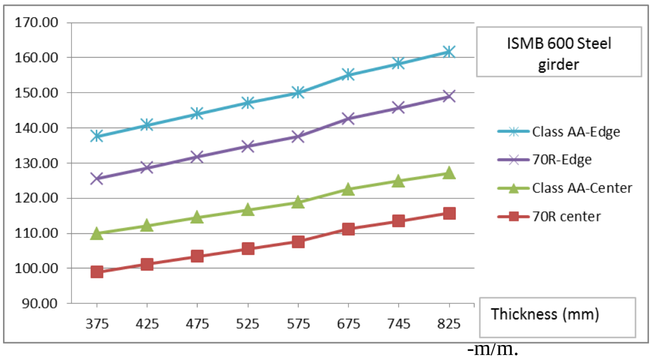
Table 2: longitudinal banding moment of deck with ISMB600 steel girder

Span (m)	Deck Thickness (mm)	Girder type ISMB 600 steel section			
		Centered Loading		Edge Loading	
		70R	AA	70R	AA
10	375	98.99	109.94	125.56	137.64
	425	101.23	112.25	128.68	140.86
	475	103.45	114.53	131.77	144.03
	525	105.59	116.74	134.73	147.08
	575	107.62	118.83	137.55	149.97
	675	111.27	122.60	142.62	155.18
	745	113.50	124.90	145.76	158.38
	825	115.74	127.20	148.98	161.60



-m/m.

Fig 5: Bending moments along span kN

The stress contours for prismatic Tee beam girder is shown in fig 6 and for ISMB600 steel section is shown in fig 7.

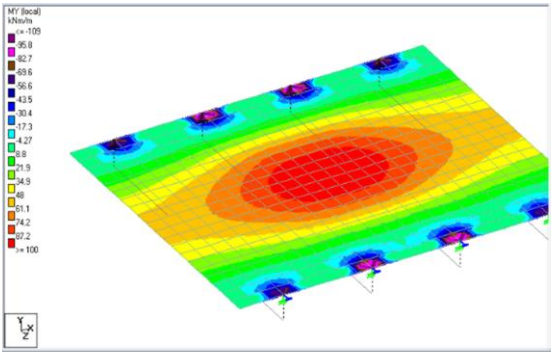


Fig 6: stress contour for Class 70R Center loading for prismatic Tee beam Girder.

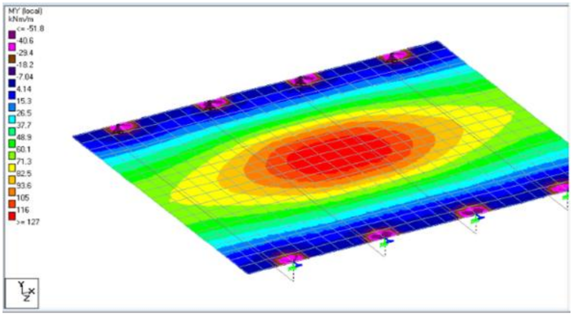


Fig 6: stress contour for Class 70R Center loading for ISMB600 Steel Girder.

VII. CONCLUSIONS

Based on the results of this investigation, the following conclusions can be drawn regarding the maximum longitudinal bending moments:

- The accuracy of the model was validated. The STAAD.Pro software calculates accurate results and predicts behavior not generally obtained through manual calculations. The capability of the software is to represent the model to predict deflections, strains, and stresses while minimizing unnecessary complexities.
- The maximum longitudinal bending moments caused due to IRC class 70R center loading for deck slab with rectangular girder and I section concrete girder show a correlation between them. The maximum bending moment values are seen to be nearly equal to each other with only slight differences in the values.
- For IRC class AA edge loading and IRC class AA center loading, the maximum bending moments along span for rectangular girder converge with I section concrete girder.
- In case of IRC class 70R Edge loading, the moments are seen to vary with the type of girder as well as the thickness of the girder. No moment value is converging with other in this case. Also the maximum bending moment values increase with the increasing thickness of the deck slab.
- For Both the load classes and all the load cases considered, ISMB-600 steel girder is seen to produce higher bending moment values for both edge loading and center loading. The values for ISMB-600 girder are much greater when compared with the other two types of girders.
- The thickness of deck slab also contributes a major role in carrying the vehicle loads. The increase in thickness will reduce the loss in ultimate Moment carrying capacity of the deck.
- Other positive effects will be in the deck-girder system. There will be increase in section Modulus; hence there will be decrease in the maximum deck stress and live load deflection.
- Increasing the deck thickness will also help distribute deck live loads more evenly to the girders.
- The only negative effects of increasing the deck thickness will be increases in the deck unit Weight. However, increasing the deck thickness would also increase the deck service life. This should increase the durability and longevity of the decks.

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