Transverse moments in concrete bridge deck slabs - 1

D. S. Prakash Rao and K. Satyanarayana

Transverse moments in bridge deck slabs spanning between the main girders and transverse beams are usually computed by approximate methods because of the complex interaction between the beams and deck slab. Several bridges of multi-beam systems are analysed using the finite strip method, and the transverse moments in deck slabs are compared with the moments in fixed slabs in the first part of the paper, presented here. The second part of the paper, which will be published later, will deal with transverse moments in concrete box girder bridges.

The deck slab of a bridge spanning between longitudinal girders is subjected to transverse moments due to superimposed loads. Analysis of concrete bridge deck slabs is a complex problem because of the differential deflection of the longitudinal beams. Hence certain simplifying assumptions are made to compute these stresses. Such a practice usually leads to uneconomical designs[1, 2]. The provisions in the IRC code of practice[1] are not very precise on many aspects of analysis. No specific guidelines are available to designers, except the provision of reducing the moments obtained by assuming simple boundary conditions for the deck slab panel by 20 percent, and designing the positive and negative reinforcement for the same moments. It has been pointed out in reference 2 that the moments in deck slabs were nearly the same as those in fixed slabs of same dimensions. However, no comprehensive investigations have so far been reported on these aspects.

Transverse bending moments in multi-beam bridge deck slabs were computed using the finite strip method, and compared with those of fixed slabs. Influence of various parameters of the bridge cross section on these moments is also discussed.

Analysis

Multi-beam bridges of 7.5-m wide carriageway and 8.4-m wide overall width were analysed using lower order finite strips with simple boundary conditions[3]; 25 strips and 25 non-zero terms were generally adequate for convergence. The cross sections of the two, three and five-beam bridges considered in these investigations are indicated in Figure 1. The influence of variation of cross sectional parameters, such as depth, web spacing, web thickness, on transverse moments is discussed. In each case, the transverse moments of the multi-beam deck slab are compared with those of a fixed slab of the same transverse span as the spacing between main beams of the corresponding structure. Slab thickness of 150mm and Poisson's ratio of 0.15 for concrete were assumed in the analyses. A wearing coat thickness of 75mm was considered in dead load computations. Dispersion of the live loads through wearing coat at 45° was

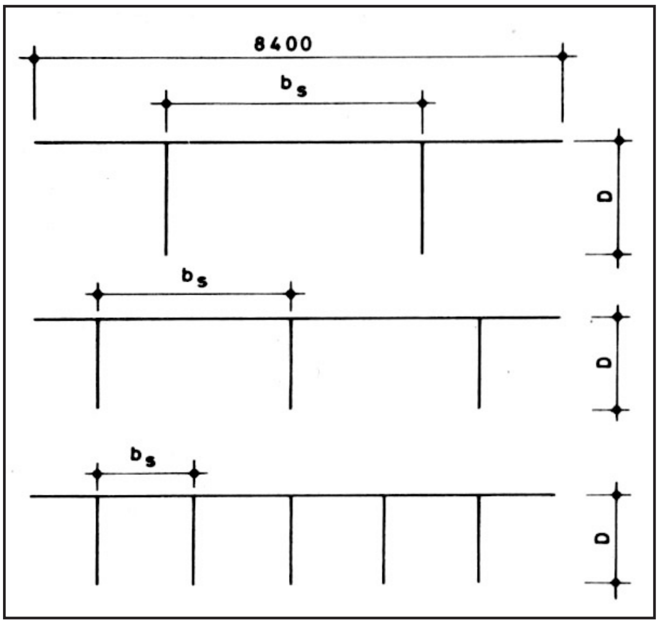

Figure 1. Cross sections of multi-beam bridges (t_t= 0.15m, t_w = 0.5m unless specified)

Notation

b_c ...	length of side cantilever
b_s ...	spacing between webs
D ...	girder depth
E ...	Young's modulus
M_F ...	bending moment in fixed slab
M_x ...	bending moment in deck slab
M_{fc}, M^{Fe}...	span and support moments respectively in fixed slab
M_{xc}, M_{xe}...	span and support moments respectively in deck slab
t...	thickness; the subscript f indicates top flange,
b...	bottom flange, and w web
δ...	vertical displacement

assumed. The structures were analysed for a span of 20.0m, but the validity of the conclusions was verified by analysing spans of 40.0m and 60.0m as well.

Influence of various parameters

The cross-sectional parameters of the structures were varied over a large range of practical interest in order to confirm the conclusions of these investigations [4]. However, only the results for dead load and IRC Class 70R track load are discussed here. Similar trends were observed for other IRC loads, which are not presented to avoid repetetion. Several locations of the live load on deck slabs were considered in order to obtain the critical values of moments.

The spacing between girders was varied from 4.0m to 6.0m for two-beam system, from 2.5m to 3.0m for three-beam system, and from 1.5m to 2.0m for five-beam system. The depth of the beams was varied from 1.0m to 3.0m, and the web thickness from 0.2m to 0.5m. The influence of each parameter is discussed briefly here.

Web spacing

The variation of M_{xc} and M_{xe},which respectively represent the span and support moments in deck slabs, for various spacings between the webs (b_s) is plotted in Figure 2 for various depths of girders. The span moments M_{Fc} and support moments M_{Fe} in slabs of the same span with fixed edges are also shown in Figure 2 for comparison. The dead load moments in deck slabs indicate good agreement with fixed slab moments, except when side cantilevers are large, compared to the web spacing, Figure 2(a). The relatively large cantilever moments reduce the dead load span moments, and increase support moments. This trend is discernible in the case of two-beam bridge of 4.0-m web spacing (side cantilever length be = 2.2m), three beam bridge of 2.5-m web spacing (b_c = 1.7m) and five-beam bridge of 1.5m spacing (b_c = 1.2m).

It can be seen that the difference between the deck slab moments and those in fixed slabs is generally less than about 10 percent for the live load span moments. The deck slab span moments are greater than those in the corresponding fixed slabs. The difference for live load support moments is more significant, being upto 17 percent for two-beam bridge with webs, 6.0-m apart; the deck slab moments are smaller than the actual ones in the deck slabs. However, it should be noted that in the case of web spacing of less than 2.0m, the span moments are likely to be much larger than those in fixed slabs, because of the effect of loading on adjoining spans, Figure 2(b). The deck slab in such cases appears to behave like a continuous span, rather than as a fixed span.

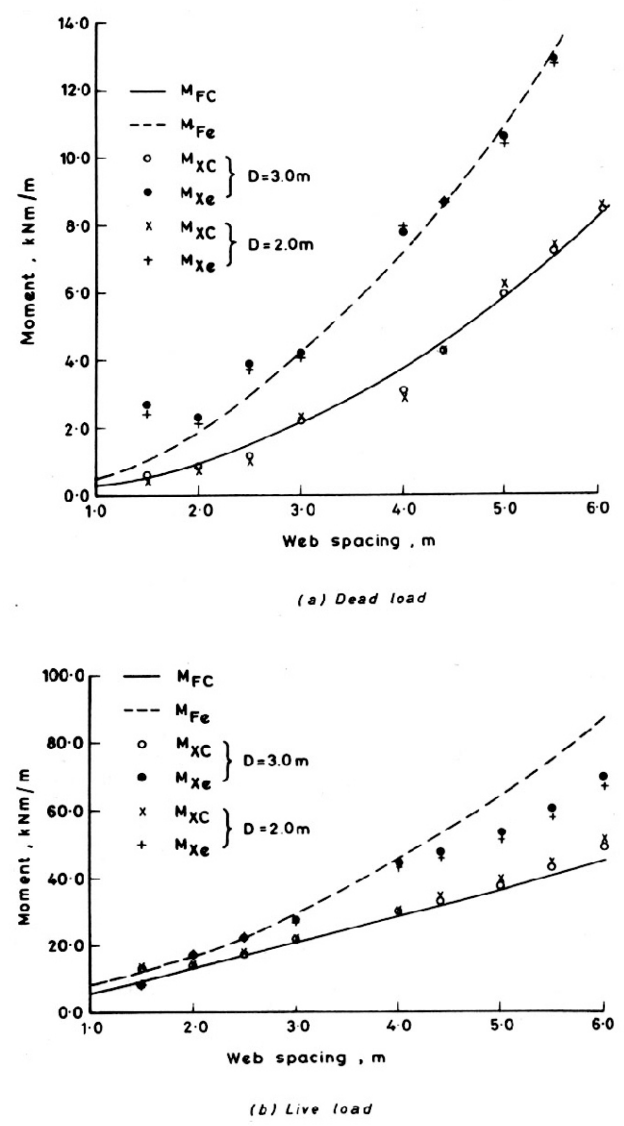

Figure 2. Bonding moments in deck slabs and fixed slabs

Depth of beams

Figure 2 indicates the variation of moments for the beam depths of 2.0m and 3.0m as well. In all the cases the difference in moments for 2.0-m and 3.0-m depth was not very significant, being generally less than about 5 percent. The deck slab moments agree better with the fixed slab moments as the beam depth increases, and by implication, as the longitudinal stiffness of the struture increases.

It should be mentioned that large relative displacements between the webs of two-beam bridges of shallow depth reduce support moments and increase span moments for live loads. The transverse deflection profile of a 2.0-m deep two-beam bridge with 4.4m web spacing for 70 R track load shown in Figure 3 clarifies this aspect. Thus, it can be said that the stiffer the longitudinal beams, the closer will be the deck slab moments to those in fixed slab.

Web thickness

Moments for web thicknesses of 0.3m and 0.5m are compared for deck slabs and fixed slabs in Figure 4; the ratio of deck slab to fixed slab moments (M_x/M_F) is indicated. It can be seen that the values corresponding to the web thickness (t_w) of 0.5m agree better with the values of fixed slabs than those for t_w=0.3m. The influence of large side cantilevers was discernible for dead load moments not indicated here. Live load moments in deck slab differ from those in fixed slabs by less than 30 percent for 0.3m web thickness, and by less than 20 percent for 0.5-m thick webs. In general, live load span moments are larger and support moments are smaller in deck slabs than in fixed slabs, Figure 4. The variation of the ratio of moments for deck slab and fixed slab presented in Figure 4 does not show a definite trend, because the deck slabs pertain to different bridge systems (number of beams).

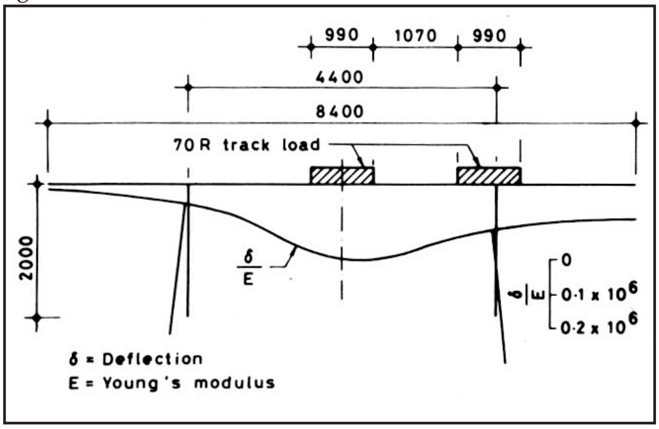

Figure 3. Deflection profile of two-beam bridge under live load

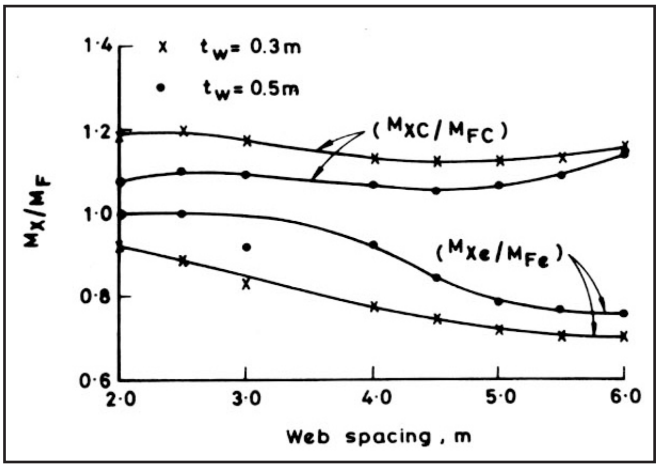

Figure 4. Comparison of live load moments in fixed slab and deck slab for various web spacings and web thicknesses (D=2.0m)

Span of the bridge

The longitudinal stiffness of the structure decreases with increase in span for a given depth of beams. The influence of this parameter was investigated for several structures, but was not found to be very significant. The moments in a two-beam structure(the most severe case) for a depth of 2.0m and 20.0m, 40.0m and 60.0m spans are presented in Figure 5. It can be noticed that the deck slab bending moments depart more from the values of fixed slab for dead loads than for live load. The values for a 60.0m bridge are smaller by about 33 percent for dead load span moments, and by about 20 percent for dead and live load support moments than the values in corresponding fixed slabs. However, the structure is likely to have larger depth for 60.0m span, which brings the deck slab moments nearer to the values in fixed slabs.

Conclusions

The investigations presented indicate that the moments in multi-beam deck slabs are nearly the same as those in fixed slabs of span equal to the spacing of main girders. The difference in deck slab and fixed slab moments is generally less than about 20 percent on safer side for deck slab live load support moments, and less than about 5 percent for dead loads. This trend was observed in all the cases investigated, except in the case of dead loads for bridges with large side cantilevers, and in the case of live loads for web spacing less than about 2.0m. Thus, the deck slab moments can be computed for fixed boundary conditions for usual cross-

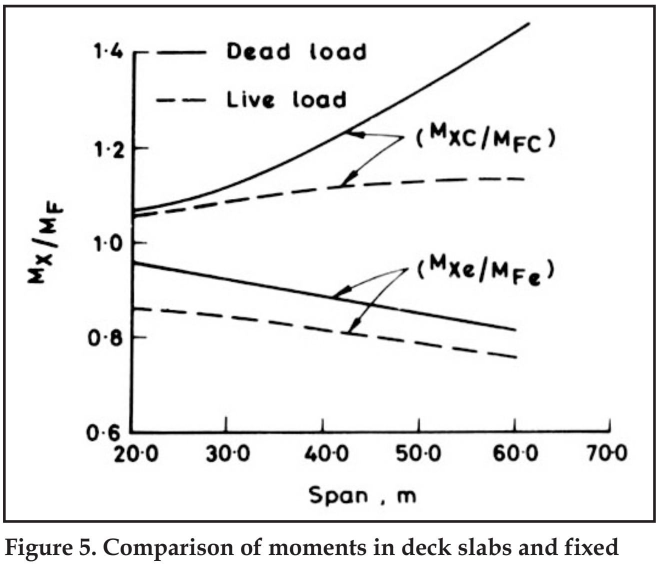

Figure 5. Comparison of moments in deck slabs and fixed slabs for various bridge spans (b_a = 5.0m, D 2.0m)

sections. Further investigations on these aspects for box girder bridges will be presented in Part 2 of this paper.

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Prof. D. S.Prakash Rao, Department of Civil Engineezing, Birla Institute of Technology and Science, Pilani,Rajastan.

K.Satyanarayana, Undergraduate Student, Birla Institute of Technology and Science,Pilani,Rajastan.

(Source: ICJ January 1991, Vol. 65, No. 1, pp. 33-36)