Model studies of a slab bridge with stiffened edge beams

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In a slab bridge, if the kerbs are cast monolithic with the edge beams and are designed as L-beams – usually referred as stiffened edge beams – the distribution pattern of longitudinal and transverse moment changes, leading to economy in design. The paper describes the details of laboratory studies carried out on a model reinforced concrete slab bridge provided with stiffened beams.

A large number of reinforced concrete (RC) slab bridges are built every year in India, both for bridging new crossings and for replacement of old cross drainage works. The slab bridges are provided with safety kerbs which are cast subsequent to laying of concrete in deck slab. The kerbs constitute an additional dead weight and function independent of the structural slab. However, if the kerbs are cast monolithic with deck slab and are designed as L-beams, the distribution pattern of longitudinal and transverse moments changes, leading to economy in design. The longitudinal beams along the edge of deck slab are known as stiffened edge beams.

It was reported that due to provision of stiffened edge beams, the longitudinal bending moment is likely to reduce by 25 percent, although transverse bending moment is marginally increased by about 8 percent[1]. The analysis of the slab bridge with edge beams is quite cumbersome involving usage of numerous parameters for determining edge shear forces, moments, etc. The Cement and Concrete Association (C & CA) London, performed tests on perspex models of T-beam and slab bridges with simulated HB loading applied on them, to verify the orthotropic plate theory. The edge beams in the experiment were made integral with footpaths which are not supported by bearings. In a typical RC slab bridge, the soffit of kerb and deck slab would be at the same level. Thus, both deck slab and 'edge beams' would be resting on the 'bearings' on a defined area at the supports. Hitherto, no experimental work is done on concrete slab bridge models having integrally cast kerbs which act as edge beams. This paper describes details of the laboratory studies on a model RC slab bridge with stiffened edge beams (integrally east kerbs) with findings from the test data.

Work done at C & CA

A set of charts (figures) were compiled at the Cement and Concrete Association by Rowe and others for the design of both concrete T-beam bridges and slab bridges during late fifties. The method of analysis is based on orthotropic plate theory, which was proposed for application to inter-connected beam system. In the method extended to slab bridges, the clear width of the carriageway between the kerbs is denoted by 2b and a set of nine reference stations divide the

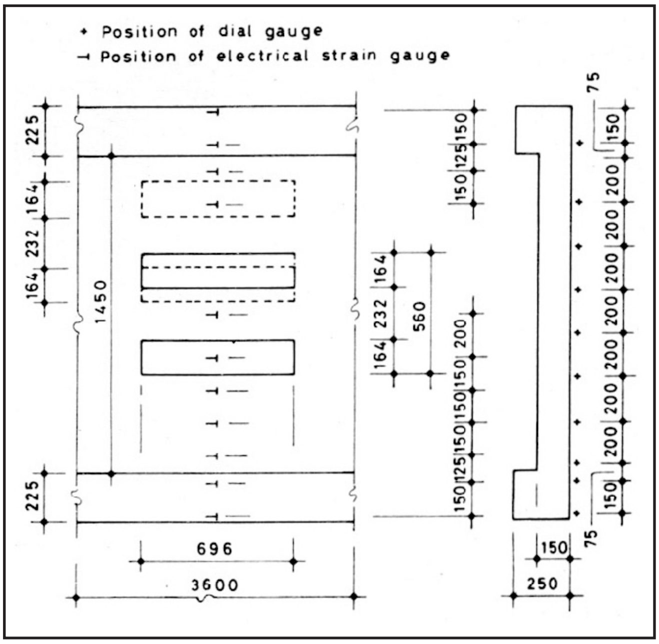

Figure 1. Cross sectional details of the RC slab bridge

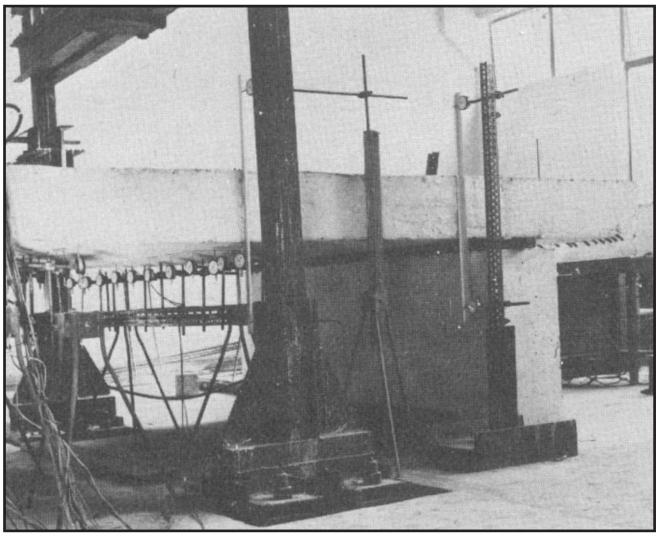

Figure 2. Instrumentation for deflection measurements

same into eight equal parts. The reference stations are denoted by 0, ± $b/4$, ± $b/2$, ±$3b/4$, ± b. The design charts given by Rowe provide the values of proportionate load effects (bending moment, torsional moment, shear force) due to placement of a unit load at a standard reference station and its influence on all the nine stations. The proportionate Ioad effect transferred at each reference station is known as "Distribution Coefficient (D.C.)" which depends on flexural parameter, θ = b/ 2a and torsional parametera = 1 (for slab bridges). It is denoted by K for longitudinal bending moment, tt for transverse bending moment, etc. The D.C. is defined as the ratio of actual load effect divided by the average load effect at any reference station.

Depending on the geometrical parameters of the slab bridge (which define flexural and torsional parameter), the D.C's at various stations have been presented in a set of figures. The actual live load positions are then superimposed on the equivalent plate, and the weighing factors X for each reference station calculated. The modified D.C's are obtained by multiplying k with tabulated D.C. values. It may be stated that the actual load effects are computed assuming placement of unit load. However, for slab bridge, shear forces are generated at the junction of edge beam and deck slab. Simultaneously, the torsional moments are also developed in the edge beam across.

In the final analysis, all the vectors are considered for the evaluation of longitudinal and transverse moments. The analysis takes into account the deflection and slope compatibility at the interface of edge beam and slab. As mentioned before, Rowe performed tests on a perspex model of T-beam slab bridge subjected to scaled down British Standard H.B. loading in which only deflections were measured. The details of study have been presented elsewhere[1].

It was indicated that the edge moments can be neglected in the analysis, when the ratio of flexural to torsional stiffness is greater than five, provided that the flexural stiffness per unit width of edge beam is not considerably greater than that of equivalent orthotropic plate. It will be sufficiently accurate to consider only the effect of edge shear forces and deflection compatibility to obtain the longitudinal and transverse moments in the slab and the bending different reference stations indicates the summation effect due to live and edge shear forces distributed across the section.

Similarly, the value of longitudinal strain at any place indicate the portion of bending moment carried by the slab segment between two different reference stations due to net effect of live load and edge shear forces.

The experimental data presented by C & C.A. does not indicate the true transverse distribution of load and strain (stress) at different locations. This is due to limitations of instrumentation on small models.

Experimental work

In order to understand the true behaviour of slab bridges with stiffened edge beams, a laboratory test on large size RC model has been attempted by the authors. A scale model of 5.17:1 representing a 12m span and 7.5-m wide RC slab bridge designed as per 1RC specifications was chosen for study. Figure 1 shows the cross-sectional details of the RC slab bridge. The model has a total length of 2400mm and a dear carriageway width of 1400mm. It has two kerbs of 225mm width and 250mm total depth on either side. The flexural parameter of the model and its prototype has a value of 0.6 for the dimensions chosen.

The model was cast using M25 concrete with mild steel reinforcement (which was readily available) placed in both longitudinal and transverse directions. The edge beam portion is doubly-reinforced with stirrups placed at appropriate spacing. To ensure monolithic action, the entire slab was cast in one operation and compacted. The model was cured for 28 days and white-washed before instrumentation and testing. One end of the slab was placed over a 1900-mm long roller of 42-mm diameter and the other end was positioned on equally long square steel bar of 45mm size covering the full width of

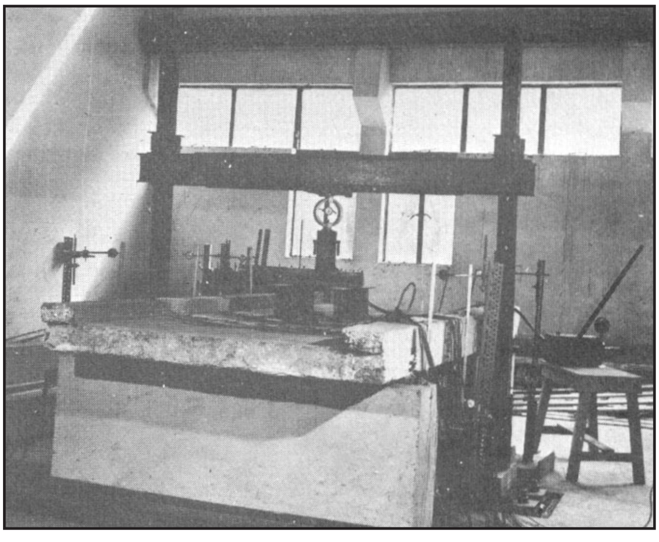

Figure 3. Experimental set up for testing

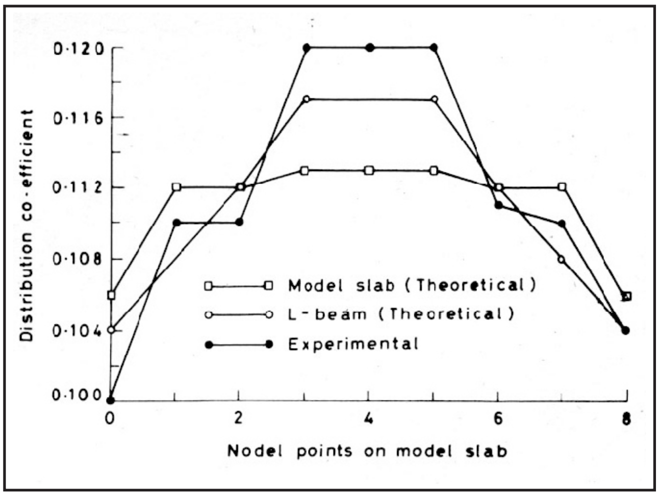

Figure 4. Load distribution for model slab (Class-AA centric loading)

the slab together with edge beams. It may be noted that the length of roller/ rocker supports for slab bridges would be the same as actual width (clear width plus edge beams), unlike T-beam slab bridges where the width of supports to mount bearings would be less than the actual width of bridge to achieve economy. The contact between the model and the roller/rocker (square rod) support was ensured with the application of a thin layer of plaster of paris between the two.

Instrumentation

For ease of testing and instrumentation, it was decided to place the model on high-rise pedestals after choosing a clear span of 2420mm. For application of class AA tracked loading, a prefabricated assembly reduced by the scale factor of 5.17 was chosen to simulate class AA tracked loading. The assembly could be placed at any position across the width to produce the desired load effect.

Among various methods of instrumentation used in the laboratory, both the deflection and strain measurements are reliable and simple to adopt. Therefore, the deflection measurements were made and dial gauges at desired locations and surface strains measured with electrical resistance strain gauges fixed on the concrete model. The locations for deflection/strain measurements have also been indicated in Figure 1.

The vertical deflections of slab were measured from soffit at midspan under the load. Glass strips were fixed to the soffit at all locations to provide smooth contact surface for the spindle of the dial gauges. Figure 2 shows instrumentation for the deflection measurements.

Strain measurement

For measurements of strain at different locations, Bakelite base electrical resistance strain gauges of 65-mm length with gauge resistance of 120 ± 0.5 ohm and gauge factor 2.0 were fixed on the prepared smooth surface of slab and edge beams at different location at each transverse section of mid span of the model slab. The electrical resistance strain gauges were fixed with the help of epoxy cement and afterwards these strain gauges were water-proofed with a thin layer of wax to prevent early damage from humidity.

The electrical resistance strain gauges were fixed at each location in perpendicular rosette formation. The dummy gauges were mounted on the vertical face of edge beam at the support and the terminal ends of the gauges were soldered to low resistance lead wires and were connected to a data logging system for strain recording. Half bridge configuration was used with common dummy gauges.

Rotational measurement

The edge beam can undergo torsional rotation under the loading due to continuity with slab which bends transversely and this bending moment varies along the span. For measurement of rotation of edge beam, two locations were chosen, one at support and the other at mid span section. A pair of dial gauges of 0.01-mm least count were mounted at each location from independent stand. For the magnification of rotational displacement, a 80-mm long aluminium angle was fixed on the vertical face of edge beam such that it projected 400mm in both upward and downward directions. Figure 2 shows the instrumentation for rotational measurements.

Testing procedure

An incremental live load was applied through a hydraulicjack and its magnitude recorded through a proving ring. Two load positions were chosen to perform the test, viz, to produce maximum bending moment on the span and the other to produce maximum transverse moment. The load positions hereafter referred to are : central position and eccentric position.

The reading of dial gauges for deflection measurement at different locations including those for rotational movements were recorded before the commencement of test. The half bridge of electrical resistance strain gauges were also balanced for null reading at the commencement of load test. The load was applied in increments of 5kN upto a maximum load of

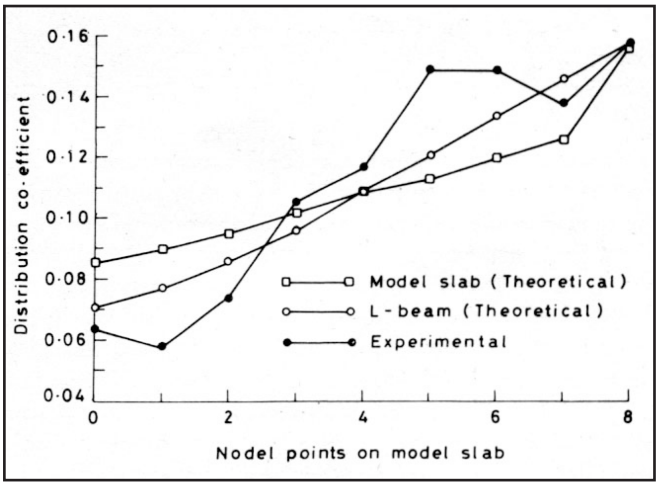

Figure 5. Load distribution for model slab (Class-AA eccentric load)

Table 1. Strain values (mlcrostrain) at various nodal points on model slab

	Class AA centric loading								
Nodal points	1	2	3	4	5	6	7	8	9
Theoretical	11.50	12.02	12.46	13.00	13.02	13.00	12.46	12.02	11.50
Experimental	13.00	14.50	18.00	15.20	14.00	13.00	14.00	10.00	10.00
	C lass AA exentric loading								
Nodal points	1	2	3	4	5	6	7	8	9
Theoretical	6.67	6.95	7.38	7.88	8.43	8.77	9.31	9.74	12.14
Experimental	3.80	4.20	5.50	5.00	6.00	10.00	12.00	14.00	20.00

50kN and deformations (strain and deflections) noted at each stage of loading. Figure 3 shows the experimental set up for testing.

Analysis of data

In the theoretical analysis, the contribution made by edge moments has been neglected. The recorded values of surface strain enable evaluation of longitudinal moments in sections of slab and edge beams. It is a ssumed that Young's modulus of concrete is 25kN/ mm^2 and the surface strain recorded is almost equal to that at the level of reinforcements. The vertical deflection data at midspan provides load distribution across the width of slab. The theoretical and observed values of distribution coefficient for different load positions have been presented in Figures 4 and 5. The surface strain values due to theoretical and experimental values of moments for both central and eccentric load positions have been presented in Table 1.

For analysis, the edge beam was treated both as L-beam or a rectangular beam, but there was no significant difference in the values of distribution coefficients in treating either way. Also, the difference in values of distribution coefficients by considering the equivalent width of orthotropic plate is clear width between kerbs or total width of cross-section, is insignificant. The theoretical values of strain were calculated from the data of moments by elastic analysis and by moment area method, respectively.

Observations and conclusion

1. The transverse strains developed due to applied load at midspan section were negligible, indicating little or no increase in transverse moment due to IRC class AA loading.

2. The torsional moments developed in the edge beams are negligible, justifying the approach adopted in CRRI studies.

3. The treatment of edge beam as either rectangular beam or L-beam has no effect on the overall distribution pattern of load effect.

4. The observation made on the model RC slab corroborate the theoretical approach adopted by the authors.

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