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# Dynamic Response of Curved Composite Cellular Bridges

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Khaled M. Sennah, born 1962, received his civil engineering degree at Alexandria University, Egypt. Presently carrying out research on static and dynamic responses of curved composite bridges.

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John B. Kennedy, born 1932, received his engineering degree at University of Wales, U. K. His field of research has been on skew and curved composite bridges as well as soil-metal structures.

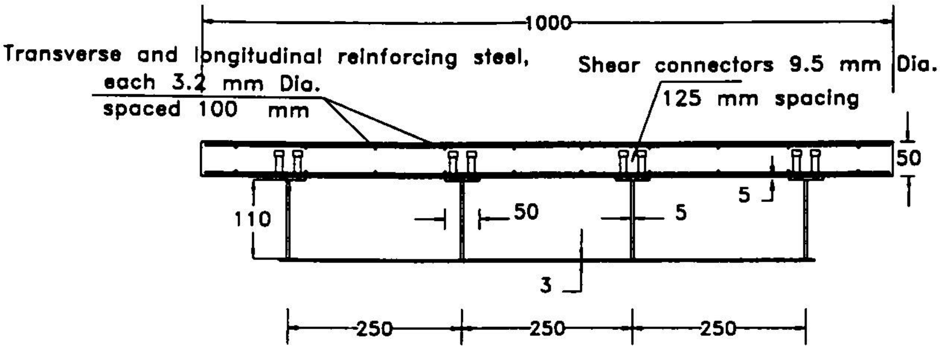
**Summary**

This paper is a summary of an extensive parametric study , using the finite-element method, in which 120 simply-supported curved composite bridge prototypes are analyzed to evaluate their natural frequencies and mode shapes. The parameters considered in the study are: end-diaphragm thickness, cross-bracing system, degree of curvature, and number of cells. Results from tests on four 1/12 linear-scale simply-supported composite three-cell bridge models of different curvatures are used to substantiate the analytical modelling.

**1-Results and conclusion**

Dynamic analysis of simply-supported curved multi-cell composite bridges was conducted using the finite-element modelling. This modelling was verified by results from free-vibration testing of four simply-supported composite three-cell bridge models. Figure 1 shows the cross-sectional details of the models. Two diaphragms, 5 mm thick, were placed radially at the extreme end sections. No inner bracings were used in the second model while in the other models, five cross-bracings of rectangular cross-section 13x5 mm were installed in the radial direction, at equal intervals. The span-to-radius ratios were 1.0 in both the first and second models, 0.375 in the third model, and 0.0 in the fourth model. Table 1 summarizes the natural frequencies and mode shapes of the bridge models. Good agreement between the experimental and theoretical findings can be observed. It is observed that the dominant mode of vibration of a curved bridge is a combined flexural and torsional mode, with the bridge frequency decreasing with an increase in the degree of curvature. Also, the presence of cross-bracings enhances the first two natural frequencies in the first model when compared to those in the second model. Figure 2 present the effect of end-diaphragm thickness on the dominant frequency. It is observed that the presence of end-diaphragms enhances the dominant frequency and its mode shapes. Figure 3 shows that for curved bridges, a minimum of three cross-bracings are adequate to enhance the dominant frequency due to increased torsional resistance. Figure 4 shows that the dominant frequency decreases with increase in the curved span as well as in the degree of curvature. In the case of one- and two-lane bridges, when the number of cells is $\leq 3$, increasing the number of cells increases the dominant frequency as shown in Figure 5. In the case of bridges with any number of lanes and with number of cells $\geq 3$, the change in the number of cells has no significant effect on the dominant frequency. Expressions for the first flexural frequency and hence the dynamic load allowance for this type of bridges has also been deduced and reported elsewhere*.

* Sennah, K. M. 1997. Static and dynamic responses of curved composite concrete deck-steel multi-cell bridges. Ph.D dissertation, University of Windsor, Windsor, Ontario, Canada.




*Fig, 1. Cross-sectional details of models*

| Model No. | L (m) | L/R | First natural frequency (Hz) | | | Second natural frequency (Hz) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Experimental | Finite-element | Mode shape | Experimental | Finite-element | Mode shape |
| 1 | 2.6 | 1 | 38 | 39 | LF-TS | 125 | 133 | TS |
| 2 | 2.6 | 1 | 36 | 38 | LF-TS | 81 | 91 | TS |
| 3 | 2.6 | 0.375 | 44 | 46 | LF-TS | - | 138 | TS |
| 4 | 2.6 | ∞ | 45 | 47 | LF | - | 136 | TS |
| Note: LF: Longitudinal flexure; TS: Symmetric Torsion | | | | | | | | |

*Table 1. Natural frequencies and mode shapes of tested bridge models*

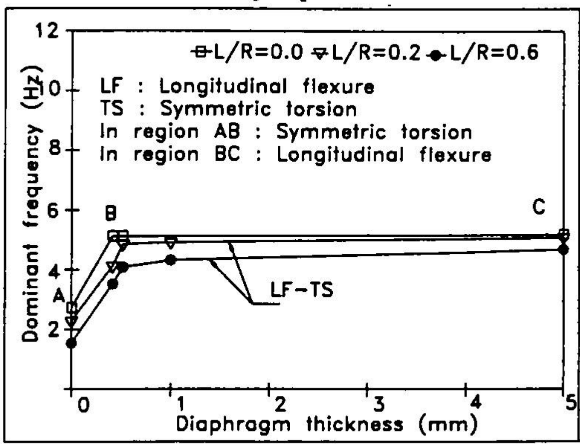



*Fig. 2. Effect of end-diaphragm thickness on the dominant frequency of three-lane five-cell bridges*

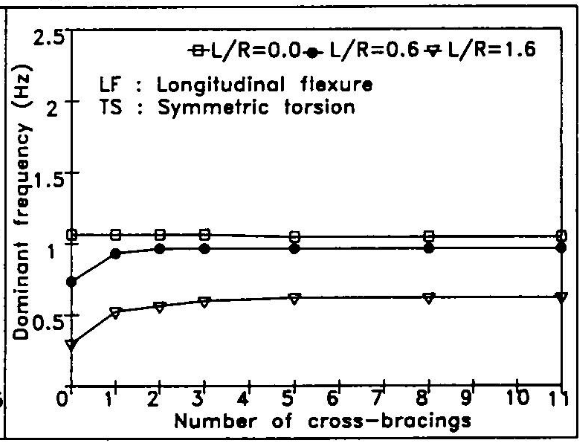



*Fig. 3. Effect of cross-bracings on the dominant frequency of two-lane three-cell bridges of span = 100 m*

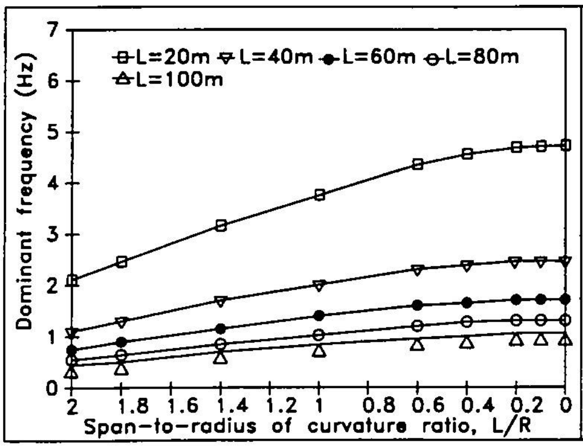



*Fig. 4. Effect of curvature on the dominant frequency of two-lane three-cell bridges*

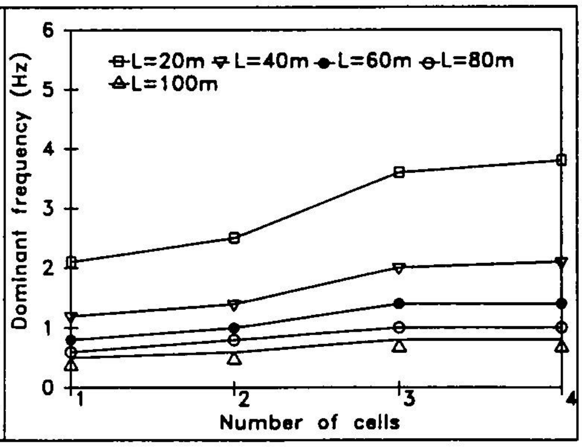



*Fig. 5. Effect of number of cells on the dominant frequency of two-lane three-cell bridges with L/R=1.0*