EFFECT OF CROSS-FRAME SPACING ON THE MODAL PROPERTIES OF CURVED BRIDGES

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The behavior of bridges having horizontally curved geometry complicates their design and erection. In these systems, because of the geometry of the structure, gravity loading not only causes a vertical deflection in the girder, but also a twisting of the girder cross section. In this case, the cross-frames, in addition to restraining the lateral-torsional deformations, also play an important role in the distribution and transfer of load between girders and are recognized as primary members (primary members should be designed for strength and fatigue)(Davidson et al., 1996; Maneetes and Linzell, 2003; Linzell et al., 2004).

The interactions between girders and cross-frames in the vicinity of live loads resulting from truck tires produce considerable loads in the cross-frames, especially in bridges with skewed piers, which can lead to fatigue-induced failure. The distribution of forces resulting from live loads in the cross-frames will be proportional to the rigidity of their members. Therefore, the cross-frames must be designed based on the required stability and strength criteria. Unfortunately, by using common and conventional cross-frames and not designing them for the existing conditions, the problem of fatigue is exacerbated at the locations of cross-frames. The common sizes of cross-frames that are often used are usually larger than the sizes required for stability (Wang, 2002). On the other hand, the modal properties, depends not only on the magnitude but also on the manner by which the mass and stiffness of the system are changed. In particular, the American Association of State Highway and Transportation Official (AASHTO, 2010) specifies that cross-frames shall be designed to ensure:

1) Transfer of lateral wind loads from the bottom of the girder to the deck and from the deck to the bearings,
2) Stability of the bottom flange for all loads when it is in compression,
3) Stability of the top flange in compression prior to curing of the deck,
4) Consideration of any flange lateral bending effects, and
5) Distribution of vertical dead and live loads applied to the structure.

Because no guidelines are provided for the design of these cross-frames under dynamic or earthquake conditions, this study investigates the cross-frame spacing effects on the modal properties such as natural frequencies and mode shapes of simple-span horizontally curved steel I girder bridges. In addition, an empirical equation was developed to provide a guideline for setting the maximum cross-frame spacing according to modal properties.

The simulations and analyses have been performed by means of the finite element method in the Abaqus software (Abaqus Manual, 2010). In order to investigate the research objectives, 22 curved bridge systems have been considered. According to Figure 1, all of the models consist of 4 curved girders (G1 to G4) laterally spaced at 3.417 m, where the arc length of the outer girder (G1) is equal to 27.3 m. A concrete deck having a width of 11.80 m and thickness of 200 mm was selected. A view of the models and support conditions has been presented in Figure 2. According to Table.1, three groups (A to C) have been considered; which, to investigate the effect of cross-frame spacing on the modal properties, other models have been created by changing the number of cross-frames (N) in each group. The average curvature radius at the central axis of deck has been considered as R_{avg}. The cross-frames have a radial arrangement, and they divide the central subtended angle into equal portions. The K-type cross-frames have been selected and after design, their horizontal and diagonal members are selected as L150×150×12 and L120×120×12 Angles, respectively. Also, to investigate the respective effects of curvature and section height on the natural frequencies and mode shapes, radiuses of 30 and 70 m at the central axis of deck and web heights of 1.0 and 1.20 m have been considered.

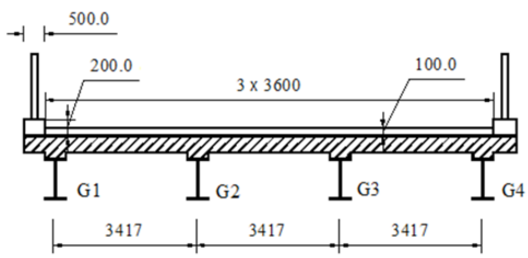

Figure 1. Bridge cross section

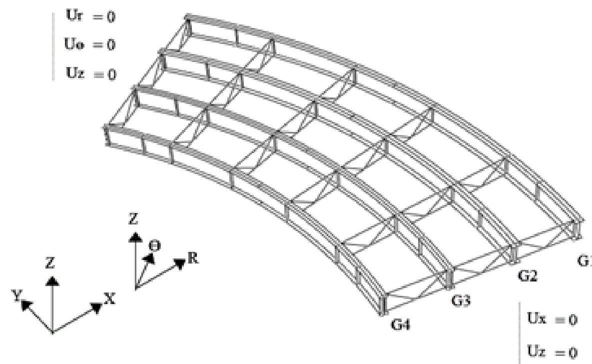

Figure 2. Support conditions in the finite element model with six cross-frames

Table 1. Specifications of models used in parametric studies

Group	R_{avg} (m)	Number of Models	Flanges (mm)				Web (mm)	
			G1,G2		G3,G4		G1,G2	G3,G4
			Top	bottom	Top	bottom		
A	30	7	450x25	500x40	350x15	400x25	1200x20	1200x10
B	70	7	450x25	450x35	350x15	350x25	1000x20	1000x10
C	70	8	600x40	600x40	500x30	500x30	1000x20	1000x10

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