Florida Department of Transportation Research

Steel Plate Girder Diaphragm and Cross-Bracing Loads

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Steel bridge designs are integrated so that every component contributes to structural integrity, including the concrete bridge deck, which connects to the girders and makes the structure rigid. Until the deck is completed and the concrete is hardened, the structure is vulnerable to collapse and must be stabilized with cross-frames or diaphragms. Many methods are available for designing cross-frames; however, their prediction of cross-frame forces may not agree, leading to different designs.

In this project, Florida International University researchers developed procedures, instructions, and recommendations intended to lead to more uniform design of cross-frames. To facilitate using these methods, the researchers limited their efforts to two-dimensional methods of analysis. They considered I-girder bridges of three types: straight; straight with skew supports; and horizontally curved.

The researchers reviewed the many functions of cross-frames and the sources of cross-frame forces in different bridge configurations, showing how methods of analysis are matched to configurations. Methods were discussed in detail to reveal strengths and limitations. Specific discrepancies in the methods used by different commercial software were described. Methods considered ranged in complexity from hand calculation of forces to three-dimensional finite element methods (FEM).

The researchers chose two straight skewed bridges to compare how methods of analysis affect detailing. Because girder loads change at different stages of construction, designs must be detailed for a specific phase. In this project, analysis methods were used with the three bridge designs at both erected fit and final fit stages. Erected fit, also called steel dead load fit, is when the steel structure is completed, and final fit, also called total dead load fit, is when the decks and other components have been added to the steel structure. The researchers developed an improved procedure for using 2D grid analyses to calculate cross-frame forces and other structural responses of bridges detailed with dead load methods for both erected and final fit. They found that whether the framing layout was contiguous or staggered influenced both traditional and their improved 2D grid analyses.

Cross-bracing system installed on a skew bridge.

The researchers also presented a simplified 3D FEM analysis for simulating lack-of-fit and calculating cross-frame forces for the final fit detailing method. 3D FEM using birth and death cross-frame elements were introduced to simulate lack-of-fit. The use of birth and death cross-frames was simpler than using initial strain, and it evaluated cross-frame forces with the same accuracy.

The researchers studied many framing layouts, detailing methods, cross-frame configurations, and design methods for sizing cross-frame members. They presented advantages and disadvantages of the framing layout with intermediate cross-frames parallel to skewed support and the associated split pipe connection detail.

This review of cross-brace design and development of a consistent approach to that design will lead to better standards and safer and more stable construction practices.

Project Manager: Dennis Golabek, FDOT Structures Office
Principal Investigator: Atorod Azizinamini, Florida International University
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