Project Summary
Texas Department of Transportation

0-5701: Cross-Frame and Diaphragm Layout and Connection Details

Background

Cross-frames play an important role in the behavior of straight and curved steel bridge systems. Cross-frames serve as braces that provide stability to straight girders during construction and serve as primary structural members in resisting torsion in curved bridges. Due to complexities in fabrication details and difficulties during erection and construction, cross-frames are often a large component of the cost of the overall bridge system.

For skewed steel bridges, cross-frames can pose particular difficulties. Cross-frames at the ends of the bridge and at interior supports are normally placed parallel to the skew, which requires connecting the cross-frames to the girders at the skew angle. TxDOT practices normally call for the use of a bent plate to make this connection. However, the conventional bent plate detail introduces significant flexibility in the cross-frame to girder connection, which reduces the ability of the cross-frame to properly brace and control end twist of the girder during construction. An additional difficulty with skewed bridges occurs with the layout of intermediate cross-frames, which are normally placed perpendicular to the girders and are continuous across the width of the bridge. The use of continuous intermediate cross-frames can result in large live load induced forces in the cross-frames during the service life of the bridge, which in turn contributes to fatigue problems.

The primary objective of this project was to develop an improved detail for attaching skewed cross-frames to girders that provides higher stiffness and better structural performance than the conventional bent plate detail. A secondary objective of this project was to evaluate the possible benefits of using staggered intermediate cross-frames to reduce live load induced forces in the cross-frames.

What the Researchers Did

The primary focus of the research was the development of the *split pipe* stiffener detail for connecting cross-frames to girders at a skew angle. With this detail, a section of pipe is split in half, and then each half is welded to the girder flanges and web. Cross-frames are then connected to the split pipe stiffeners by the use of a connection plate. The split pipe stiffener allows perpendicular connections to the cross-frame connection tab, regardless of the skew angle. The split pipe provides a stiffer connection between the cross-frame and the girder. More importantly, the split pipe stiffener increases the torsional stiffness of the girder by introducing substantial warping restraint. This increases the lateral torsional buckling capacity of the girder.

The performance of the conventional bent plate detail and the proposed half pipe stiffener detail for skewed cross-frame to girder connections was investigated by the researchers through an extensive series of experimental, analytical, and computational studies. Experimental and computation studies were also conducted to evaluate the feasibility of using a staggered layout for intermediate cross-frames in skewed bridges.

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What They Found

The results of the research showed that the split pipe cross-frame connection is much stiffer than the bent plate connection detail. More importantly, the split pipe stiffener offers warping restraint to the end of the girder which significantly increases the girder torsional stiffness and therefore significantly increases the girder elastic buckling strength. The research also showed that the fatigue life of the girder with the split pipe stiffener was similar or somewhat better than with conventional plate stiffeners. Consequently, the split pipe stiffener is not expected to cause fatigue problems for the girder. This research also found that cross-frame layout has a large impact on live load induced forces in the cross-frame members. Using a staggered layout for intermediate cross-frames results in significantly lower force levels in cross-frame members, compared to the more conventional continuous layouts.

What This Means

Based on the results of this research, the use of the split pipe stiffener is recommended for connecting skewed cross-frames to steel I-girders. The split pipe stiffener provides a much stiffer connection between the cross-frame and the girder as compared to the conventional bent plate connection. This increased connection stiffness makes the end cross-frames more effective in controlling girder end twist and therefore helps maintain girders in a plumb condition during construction. However, the most important advantage of the split pipe stiffener is the increased torsional warping restraint that the stiffener provides for the girder. Girders with split pipe stiffeners have significantly higher buckling capacities than girders with conventional plate stiffeners. This increased buckling capacity permits larger unbraced lengths for the girder, which allows the first line of intermediate cross-frames to be moved farther from the skewed end frames. This can alleviate congestion of cross-frames near the ends of skewed bridges and also alleviates the large live load induced forces that can occur in intermediate cross-frames that are placed close to the skewed end of a bridge. The increased buckling capacity of girders with split pipe stiffeners may also allow a reduction in the total number of cross-frames needed in a bridge. The split pipe stiffener can also serve as a bearing stiffener, and essentially requires a similar total length of welding compared to the current connection details employed in Texas that consist of two bearing plate stiffeners and two cross-frame connection plates. Consequently, the use of the split pipe stiffener is not expected to be more costly than the current bent plate detail, and has the potential to reduce construction costs by simplifying connection details and by allowing a reduction in the number of intermediate cross-frames. More importantly, the use of the split pipe stiffener will increase the safety and stability of steel bridges during construction.

The research also showed that using a staggered layout for intermediate cross-frames in skewed bridges is advantageous in significantly lowering live load induced forces in the cross-frame members. This force reduction can help mitigate fatigue problems at cross-frames over the life of the bridge. Therefore, the staggered layout for intermediate cross-frames is recommended in skewed bridges when the fabrication and installation costs are justified.

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