Research Project: SP309B4M
Date: June 2015

RESEARCH SUMMARY

SERVICEABILITY-RELATED ISSUES FOR BRIDGE LIVE LOAD DEFLECTION AND CONSTRUCTION CLOSURE POURS

Problem

The Load and Resistance Factor Design (LRFD) method has evolved to become a more reliable approach to bridge design in the past century. Nevertheless, safety is always the number one concern in the design of bridge structures. Equally important, and sometimes harder to account for in the design, is to make sure that the bridge can be constructed with common practices and that the bridge functions as the public expects. A good example of this is a new bridge that has adequate strength, but has noticeable deflection under live loads. In this case the vehicle passengers as well as pedestrians will feel uncomfortable when driving or walking over the structure because they believe the bridge is inadequately designed.

Objective

This study investigated the design criteria and practices in an effort to improve the quality of bridge designs in the State of Maryland and beyond. This first criterion investigated was the live load deflection for steel bridges. Since the live load deflection criteria in the AASHTO LRFD Bridge Design Specifications (2014) is optional, the Maryland State Highway Administration (SHA) establishes no maximum limit on deflection and leaves the burden on the designers to establish limits. This study developed a menu of criteria that designers could choose from in their bridge designs. The second design/construction criterion investigated was designing and detailing bridge deck closure pours. A closure pour is a small area of concrete bridge deck that connects two portions of a bridge deck placed in different stages of construction. For staged construction, the designer should consider the deflections of the bridge on either side of the closure pour to ensure proper transverse fitting.

Description

Previous and current practices and future planning on the serviceability of bridges have been documented. State-of-the-practice methods from federal and other state agencies were collected. Three bridges were chosen for refined analyses to investigate the live load deflections. Field measurements for these three bridges were collected from the research team to facilitate this study. Thirty steel girder bridges from the Maryland State Highway Administration's (SHA) inventory were selected for statistical analyses. Steel bridges designed with the live load deflection limit have been evaluated.

Closure-pour analyses were conducted by line-girder models, two-dimensional grid models or three-dimensional finite element models. All three methods generate accurate enough camber diagrams to predict differential deflections between stages for straight girder systems, if creep is not considered. Creep effect could be alleviated by proper camber and scheduling on pouring.

In order to achieve these two objectives, the following tasks were completed:

1) Current, previous and future planning practices on the serviceability of bridges have been documented.

SHA State Highway Administration
Maryland Department of Transportation

RESEARCH SUMMARY

2) Collect and study state-of-the-practice methods from federal and other state agencies.
3) Develop several finite element models, with different analysis software, for the entire bridge to compare the differences in deflection for the bridge model versus the simple single girder analysis traditionally performed by SHA. Both two-dimensional grid and three-dimensional finite element models can be used for the live load deflection analysis as well as the staged construction analysis.

Results

Bridge structures should be designed with sufficient strength but designers also need to ensure the deflection is within an acceptable range so that drivers or passengers in the vehicles would not believe the bridge is unsafe.

Based on this study, an excerpt of the conclusions reached is listed here. (For the full list of conclusions, please refer to the link to the Final Report listed below.)

A. Findings associated with bridge live load deflections -
   1. Span Length (L)/800 is appropriate to be the live load deflection limit for steel bridge design no matter what type of design load or design method is applied.
   2. The live load deflection from the HS-25 design truck alone in the ASD method (employed by SHA from 1990 - 2008) is larger than the deflection from the HL-93 load type with lane plus a quarter truck loads in the LRFD method. Therefore, if the "HS-25 equivalent" truck is required by Maryland for deflection criteria, a factor of 1.25 is suggested for usage in the HL-93 design truck to obtain conservative results.
   3. Comparing the numeric results from two-dimensional grid models and three-dimensional finite element models, the line girder method proves to be an acceptable application for live load deflection analysis of steel beam/girder bridges with all lanes loaded.

B. Findings associated with bridge construction closure pours -
   1. The general practice in Maryland is to use a line-girder program to establish the camber diagrams. The result is generally accurate enough and acceptable in practice.
   2. Multiple camber diagrams can be calculated by the line-girder models, two-dimensional grid model or three-dimensional finite element model. All three methods generate results accurate enough for straight girder systems, if the creep effect is not considered.
   3. Maryland adopted the generally recommended practice of a minimum closure width of three (3) feet and diaphragms/cross frames in the staging bay of structural steel girders not rigidly connected until later. There is no ill effect for non-connected practice.

Report Information

Link to the final report: http://www.roads.maryland.gov/OPR_Research/MD-15-SP309B4M_Serviceability-related-Issues-Bridge-Live-Load-Deflection_FinalReport.pdf

For more information about the study please contact:
Chung C. Fu, Ph.D., P.E., F. ASCE
University of Maryland, College Park
Phone: 301-405-2011
Email: ccfu@umd.edu