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Executive Summary Report

Dynamic Load Environment of Bridge Mounted Sign Support Structures

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Problem

A bridge-mounted welded aluminum sign support structure suffered a fatigue failure on Interstate Route 77, just south of Cleveland, OH. The sign support structure was a 72 foot span, bridge-type, four chord space truss, comprised entirely of tubular members. The failure was located at a diagonal to chord joint, initiating at the weld toe and progressing completely around the circumference of the chord until fracture of the chord member occurred.

Bridge-type sign structures typically have a high enough natural frequency that wind-induced vibrations are not a major design concern. For that reason an investigation was undertaken to arrive at an explanation of the fatigue failure.

This investigation involved a combination of finite element analysis, field testing under actual truck loading, and laboratory fatigue testing of remnants of the actual failed structure.

Objectives

The objectives of the study consisted of the development of a technical understanding of the cause of the observed fatigue failure and to make a determination of what previously unidentified fatigue concerns might exist for this category of sign support structures.

Description

The investigation was conducted in three main steps; 1) fatigue testing in the laboratory of surviving segments of the failed sign, 2) collection of dynamic response data of the identical replacement structure in situ, and 3) finite element modeling and simulation of the bridge and truss structural system.

The welded aluminum space truss indicated a typical fatigue failure, with a fatigue crack initiating at a welded chord/diagonal connection detail (AASHTO fatigue category ET). Fatigue testing in the laboratory of surviving segments of the structure produced an identical fatigue failure at a similar location after 3,000,000 load cycles at a nominal 1 ksi stress amplitude.

Field monitoring of acceleration data at three different locations of the in-situ replacement truss was conducted in order to characterize the dynamic behavior of the truss and the bridge structural system. A finite element model of a segment of the multi-span bridge which includes the location of the sign support truss, was assembled.

In the modeling of the truss two external loading conditions, namely traffic load and wind load, were originally considered. It was presumed that these two load sources were most likely to produce dynamic response in the bridge/sign truss structural system. Computed and measured fundamental natural frequencies were high enough, however, (greater than 3 hz) to narrow the investigation to traffic induced vibrations.

Conclusions & Recommendations

Both modal analysis and time history analysis for moving vehicle loads were performed. The analysis results indicated that the failure was a classical fatigue rupture, induced primarily by the dynamic effect of moving truck traffic on the bridge. Even though inferred stress levels were well below the CAFL for the AASHTO category ET detail in question (.44 ksi), the extremely high number of low amplitude traffic-induced stress cycles (in the hundreds of millions), combined with the absence of an endurance limit for welded aluminum, resulted in the observed failure. The predicted lifetime of the replacement sign support structure is approximately that exhibited by the original structure, namely thirty to forty years, and regular inspection is advisable.

Implementation Potential

A policy of frequent inspection of bridge-mounted aluminum sign support structures would seem warranted. These structures are potentially subjected to many more vibration cycles than their ground-mounted counterparts.