0-4586: Revision of AASHTO Fatigue Design Loadings for Signs, Luminaires, and Traffic Signal Structures, for Use in Texas

Background

New provisions for fatigue design in Section 11 of the Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals issued in 2001 have made it difficult to find economical AASHTO-compliant design solutions for cantilevered traffic signal structures. The provisions were developed based on a body of research that included limited wind tunnel testing and fatigue testing of traffic signal structures and their connections. Those prior studies recommended further work to clarify the behavior of such structures in field tests and to parameterize the effectiveness of motion-mitigation devices to inhibit oscillations and, hence, cyclic loading that leads to fatigue damage.

This research project addresses these important questions by means of full-scale controlled and field tests on traffic signal structures. Fundamentally, the objective of this project is to re-evaluate the fatigue design loads for traffic signal structures in the AASHTO specifications.

What the Researchers Did

Field tests were performed to assess galloping-induced forces. Three cantilevered traffic signal structures in Texas were monitored for approximately nine months to estimate the magnitude of these forces as experienced in the field. An analytical model was developed and used to perform parametric studies for predicting the galloping potential of traffic signal structures with various properties.

Field tests were performed to assess truck-induced gust loads of two cantilevered traffic signal structures. Over 400 truck events were observed in the field.

Full-scale controlled tests measured deflections of the tips of the arms of two traffic signal structures and correlated these with wind speed measurements. Tests were carried out for signals with and without solid backplates, with vented backplates, and with and without a damping wing.

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What They Found

Though four large-scale displacement events were recorded, no true galloping events were observed in the field tests. Analytical models developed showed that modifying a traffic signal structure's aerodynamic properties is the most effective method to eliminate galloping potential. This can be done by attaching a damping wing to the tip of the mast arm to counteract the negative aerodynamic damping of the signals.

Based upon results from the field tests, it was determined that truck-induced gusts are not a critical design loading for cantilevered traffic signal structures. On the basis of back-calculated pressures for the strains measured in the field tests, the AASHTO-specified equivalent static pressure for fatigue design for truck-induced gusts is extremely conservative. Natural wind gusts can cause much larger stresses at the connections. Therefore, if a cantilevered traffic signal structure with symmetrical connection details for in-plane and out-of-plane loading is designed for natural wind gusts, then truck gust loading need not be considered.

Contrary to the conclusion of previous studies, vortex shedding was found to be a significant cause of mast arm vibrations. It was observed that the largest amplitude vertical oscillations occurred when the wind speed was steady between 5 to 10 mph, which combined with the solid backplate's vertical dimension, suggests a Strouhal number of approximately 0.1, characteristic of vortex shedding for this shape. These vibrations generally occurred when the wind approached the arm from behind the signal. Large-amplitude vertical vibrations of the mast arms with signals with solid backplates occurred for the most part at low wind speed ranges, and as the wind speed increased the amplitude of the vertical vibrations decreased; this reflects the typical behavior of vibrations induced by vortex shedding. Vented backplates and damper plates did not appear to alter the response significantly.

What This Means

The field tests conducted in this study suggest that sustained large-amplitude displacements due to galloping are not a common occurrence, and that for many structures, galloping is not possible and should not be a design consideration. Also, damping wings are capable of reducing or cancelling negative damping potential that can result in galloping. With regard to truck-induced gust loads, it was found from the field tests that these loads are generally very small and need not be considered in fatigue design of cantilevered traffic signal structures. Design for natural wind gusts more than adequately accommodates truck-induced gust loads. Finally, from the full-scale controlled tests, it was found that vortex shedding is likely to be more important for signal structures than had been believed; even with low wind speeds in an appropriate range, large-amplitude vertical oscillations of the arm can occur, making vortex shedding more important for fatigue design than was anticipated at the start of this project.

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