



Tech Brief

Fatigue Performance of Variable Message Sign & Luminaire Support Structures

Volume 1- Fatigue Related Wind Loads on Highway Support Structures

FHWA-NJ-1998-009-TB

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HERE'S THE PROBLEM

Cantilevered sign and signal support structures are used extensively on major interstate highways and at local intersections for the purposes of traffic control. The cantilevered support structures are attached to a single vertical support as opposed to two supports used in traditional overhead structures. The single support increases motorist safety by minimizing the probability of vehicle collision and is also more economical than overhead support structures. Until the new AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals are produced, designers have little guidance for fatigue related design issues in signs, signals, and luminaire support structures. Several of these cantilever sign supports had failed, causing injury or death to motorists.

AND, HERE'S THE SOLUTION

To determine equivalent static pressures for fatigue loads on cantilevered highway support structures through continuous monitoring of a cantilevered Variable Message Sign (VMS) on a New Jersey Interstate..

HOWCAN IT BE DONE?

By performing laboratory and field testing to isolate the problem areas, and develop improved details to enhance the design. By conducting field tests that instrument the structure with strain gages, pressure transducers, and a wind sentry, and by conducting laboratory tests with the enhancements.

THESE ARE OBJECTIVES...

- To gather data on the magnitude of truck-induced wind gust loads and if necessary refine the static load range for truck-induced wind gusts recommended in NCHRP 10-38.
- To obtain the static and dynamic characteristics of the support structure, such as stiffness, natural frequency and damping ratio.

- To drive trucks under the sign in an attempt to quantify the magnitude of truck-induced gusts.
- To measure any significant dynamic response from random truck traffic and other wind-loading phenomena.

HERE IS WHAT WE DID...

This study began with a thorough review of previous research relevant to the design of Variable Message Sign support structures to resist truck-induced gusts and other wind-loading phenomena. Design guidelines recommended are to be used as guidelines in the design of future structures to be resistant to fatigue and excessive dynamic displacement, despite worst-case truck-induced wind loads.

Measurements were considered to include pressures near the Variable Message Sign (VMS) and strains at all critical locations. Pressure transducers were intended to measure the pressure resulting from the upward gust of air that large trucks produce when going under the signs at high speeds. The stress ranges deduced from the strain histories would be compared to the stress ranges calculated using the fatigue design load ranges recommended in the NCHRP 10-38.

The VMS monitored was located on Interstate 80 in New Jersey. The VMS was originally located on State Route 17 in northern New Jersey, however, it was reported to have large amplitude vertical displacements at the end of the cantilever.

Short-term field tests were performed to obtain the dynamic characteristics of the sign structure, as well as its response to truck gusts. Strain gages were placed on the anchor bolts, column, stubs, and truss to obtain strain measurements.

Eight Omega PX163 differential pressure transducers, with a measurement range of plus to minus 1250 Pa were placed on the front face of the sign. The pressure transducers were intended to measure the pressure from truck-induced gusts. These transducers were placed within four-inch diameter PVC pipe, and the truck-induced gusts were directed to the pressure transducers through pilot tubes and a short section of quarter inch diameter tubing.

A wind sentry equipped to measure wind speed and direction was employed to determine the effects of the natural wind on the sign support structure. This was positioned at the top of the column that supported data acquisition equipment for the long term testing.

All data was collected with a Campbell Scientific CR9000 Data Logger.

The beginning stage of the short-term test was to establish the stiffness, natural frequency, and damping ratio of the sign support structure. This test was performed with two different configurations. The second phase of the test was to determine the effect of truck-induced wind gusts on the structure. Two trucks were hired to drive under the sign and the upward gusts from these trucks was measured with pressure transducers.

Drivers noted their speed and ratio it back, so that a correlation could be made with the truck-induced wind gusts and truck speed.

The short-term testing did not allow for as much data to be collected as was needed. Delays in equipment and instrumentation shortened the schedule; secondly, the test trucks did not end up running as much as was originally planned.

The short-term testing successfully determined the dynamic characteristics of the VMS support structure. Data indicated that the stiffness at 0.24 kN/mm (1.38 kip/in). The natural frequency in the two damping modes were established at 0.87 cycles/s and 1.22 cycles/s. The pull test determined a static calibration for the comparison of calculated to measured stresses in the structure. The actual stresses were determined to be typically less than the calculated stresses.

Long-term testing was intended to collect data from any significant event on the Variable Message Sign for three months from June until August 1997. The data logger was placed in an enclosure that was mounted to the column erected to the VMS support structure. The wind sentry, solar panels, cell phone antenna, and a lightning rod were placed on top of this column.

The long-term testing monitored the gages that determined to be critical from the results of the short-term test. The pressure transducers, wind speed and wind direction were monitored. The data collected in the long-term testing was to be transmitted back to the lab through a cellular phone link through the connection of a cellular phone transceiver and cellular phone modem that enabled remote communications with the logger. This allowed for data to be received and new programs sent to make any needed changes.

The cellular phone communication with the logger resulted in a lot of variability in the quality of the communication. In addition, there was significantly more power needed to run all of the instrumentation and equipment.

CONCLUSIONS...

Results of the short term testing of the static and dynamic characteristics of the support structure, such as stiffness, natural frequency, and percent of critical damping indicated that the stiffness was 0.24 kN/mm, the first and the second modes were 0.87 cycles/s and 1.22 cycle/s respectively. The percent of critical damping for the first and second modes were 0.57 and 0.25 percent respectively. Long term monitoring was performed to capture the structural response to natural wind gusts, galloping, and truck-induced wind gusts. The highest natural wind speed was recorded at 7.5m/s. It is believed that stronger winds are present in the winter and spring, therefore a natural wind gust design pressure of 250 Pa was recommended. A galloping design pressure of 1000 Pa was recommended. Truck-induced wind gusts were measured and a linear gradient for the truck-induced gust design pressure was determined. The truck-induced gust design pressure ranged from 1760 Pa at 0 to 6m above the surface of the road to 0 Pa at 10.1m and over.

WHAT IS THE NEXT STEP?

Future research that is to be done concerning the long-term monitoring of sign support structures could include exploration of power supply, communication, pressure measurements, strain measurements, and additional truck-gust measurements, as well as wind induced vibrations.

This study indicated that the larger solar panels would be needed to adequately keep marine batteries charged for future monitoring, in addition, the cellular phone communication link was unsuccessful. A higher power transceiver and modem designed for wireless transfer of data needs to be investigated further.

Future research should use back-calculation to obtain pressure based, on strain, measurements; future research should not include the pressure transducers, but rather rely on the strain gage data.

The truck-gust measurements should be performed in a different manner to enhance repeatability of the data. This can be accomplished by doing additional testing on several different occasions to increase the probability of getting a day with significant increased head winds on the truck.

Finally, future research should occur in non-summer months when there are greater chances of strong winds. Historical wind records from nearby weather stations and airports can help confirm the best times of year to monitor wind data in this area. Future structures to be monitored should be perpendicular to the direction of wind flow and have the natural wind gusts be a head wind for traffic- thus, helping to better quantify the effects of natural wind gusts and truck-induced gusts.

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A final report is available online at <http://www.state.nj.us/transportation/research/research.html>

If you would like a copy of the full report, please FAX the NJDOT, Bureau of Research, Technology Transfer Group at (609) 530-3722 or send an e-mail to Research.Bureau@dot.state.nj.us and ask for:

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