

Dynamic Load Environment of Bridge Mounted Sign Support Structures

by Arthur Huckelbridge, Ph.D., Case Western Reserve University

This special student study at CWRU was initiated to investigate the fatigue failure of a bridge-mounted, welded aluminum truss sign support. This sign support is located in ODOT District 12, on interstate route 77 just south of Cleveland, on bridge no. CUY-77-0952 over the Cuyahoga river valley (see photo). One of the upper chord members of this truss fractured completely due to the development and growth of a fatigue crack at the welded joint connecting it to the end web diagonal. The sign support had been in service roughly 30 years. As the failure represented a potential safety issue for the traveling public, it was decided to try to determine the cause of the failure, in order to bring to light any concerns for other such structures throughout the state.



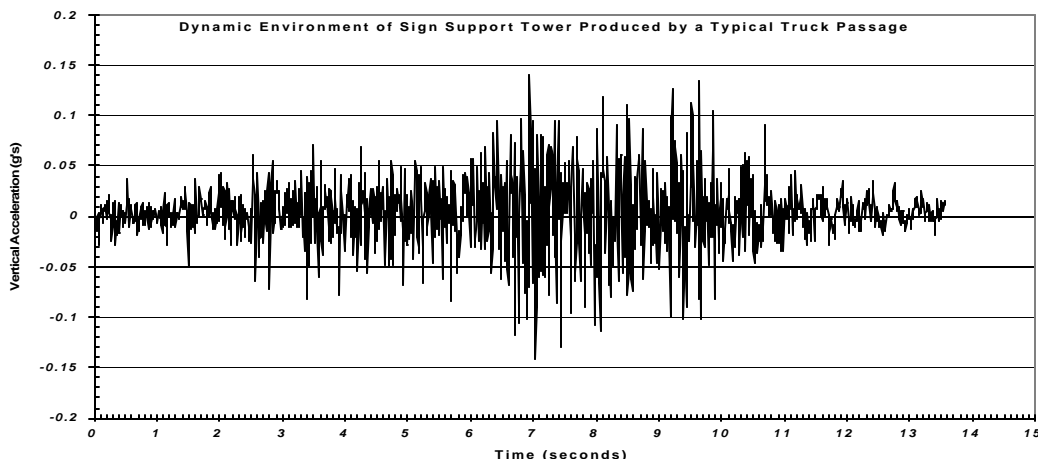
The bridge consists of 25 spans, with a total length of 3,023 ft. The sign support is located near the midspan point of the 5th span from the south end of the bridge; the length of this span is approximately 128 ft. The sign support truss itself has a span of approximately 73 ft, over the southbound lanes.

Non-cantilevered sign support structures, such as this one, are not typically prone to wind-induced fatigue problems, as their stiffness, and hence their natural vibration frequencies, are usually high enough to preclude damaging dynamic or aero-elastic wind response phenomena. There has been less research, however, on interactions between bridge vibrations and the dynamic response of such bridge-mounted sign supports.

Accelerometers were attached to measure vertical vibrations at the attachment points of the sign support towers to the bridge, as well as all three components of acceleration (vertical, lateral and longitudinal) at the sign support truss midspan, during passages of a “typical” truck

(an ODOT dumptruck, loaded with gravel to a gross weight of roughly 55,000 lbs, and traveling at approximately 50 mph). A typical vertical acceleration trace measured on the support tower is shown in the plot below.

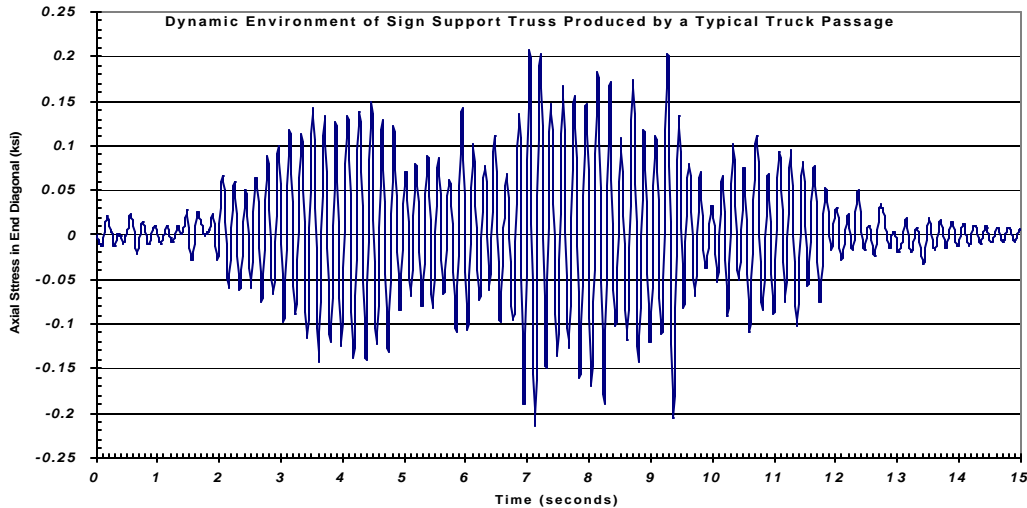
One of the surprising features of the bridge vibration record was its length. Significant vibrations lasted nearly 15 seconds, even though the time that the truck was actually on the span containing the sign support truss was less than 2 seconds. Obviously, due to considerable structural continuity over the piers, vibrations began while the truck was still several spans away from the span containing the sign, and continued until the truck was several spans past the span containing the sign.



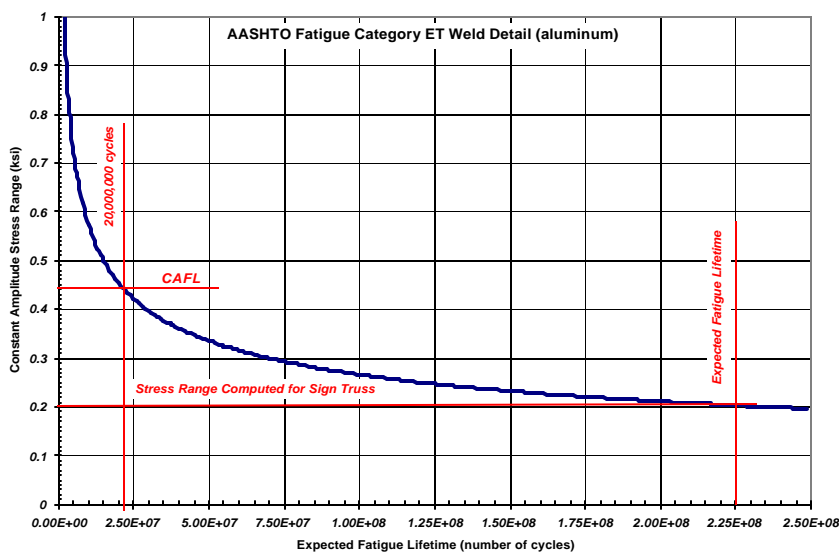
- Continued on back -

Dynamic Load Environment - Continued from Front

The stress history of an end web diagonal, as computed by a finite element program and utilizing the measured truck-induced acceleration record above as input, is shown in the graph below. The sign truss vibration takes place primarily at the natural vibration frequency of the sign truss, which is approximately 5 Hz. In the 15 second response record produced by a single truck passage, roughly 82 cycles of sign support response take place.



The equivalent constant amplitude RMC stress range, for the variable amplitude trace shown above, is approximately .20 ksi, which is well below the AASHTO constant amplitude fatigue limit (CAFL) of .44 ksi for this weld detail (category ET). One should keep in mind, however, that the AASHTO CAFL is intended to provide a fatigue lifetime of roughly 20,000,000 cycles, which is generally considered adequate for wind induced vibrations. If one extends the category ET S-N curve beyond the CAFL, the expected fatigue lifetime for a stress range of only .20 ksi would be approximately 225,000,000 truck passage cycles, as shown in the plot below. The fatigue lifetime of 225,000,000 cycles, at roughly 82 response cycles per truck passage, would correspond to an expected fatigue lifetime of approximately 2,700,000 truck passages.



On a busy interstate route such as I-77, 2,700,000 truck passages can certainly take place in less time than the expected lifetime of the bridge itself. At a rate of 200 truck passages per day, for example, the expected lifetime would be roughly 37 years, which is only slightly above the age of the sign truss at the time of its failure.

These preliminary findings would seem to indicate that there is cause to look carefully at bridge-mounted sign support structures for fatigue issues. Of particular concern would be longer structures, where vehicles are on the bridge for a long enough period of time for the sign structure to accumulate a considerable number of response cycles.