PUTTING RESEARCH TO WORK **BRIEF**

Fatigue Risks in the Connections of Sign Support Structures

The latest edition of the AASHTO design specifications (AASHTO 2001) introduced provisions for fatigue design. However, many structures presently in service were designed before fatigue provisions were part of the design specifications. The fatigue design procedures now included in these specifications do not address the variability in fatigue life that is likely for structures in service, nor do these provisions allow engineers to quantify the risk of fatigue-induced fracture for structures that have been in service. As a result, Wisconsin undertook a research effort to assess the risk of fatigue-induced fracture in existing sign support structures that were designed before the latest AASHTO specification revisions.

What is the Problem?

Wisconsin has encountered problems with the connections contained in, and the in-service performance of, several cantilevered mast-arm sign support structures. Several instances of cracks and failures in mast-arm sign support structures were observed in Osseo and other locations within the state. There is an unknown probability of future failures in mast-arm-to-pole connections typical of sign support structures in Wisconsin.

Research Objective

The researchers aimed to achieve the following objectives:

- Formulate, and apply a reliability-based procedure for quantifying the risk of fatigue-induced fracture in mast-arm sign support structures and to generate inspection protocols for these structural systems.
- Identify mast-arm support structural system configurations that are likely to result in enhanced susceptibility to premature fatigue-induced cracking.
- Identify regions within Wisconsin that may be more susceptible to having structures with fatigue problems.

Methodology

Researchers conducted the following tasks to achieve their objectives:

- A systematic reliability-based approach was used to assess the risk of fatigue-induced fracture in sign support structures in Wisconsin. A significant amount of experimental fatigue testing data, as well as measured wind speed and direction data, were collected and analyzed.
- New connection detail categories, E2, E3, and E4 were synthesized from the myriad of fatigue tests conducted since 1970 on connections that are typical of those seen in mast-arm sign support structures in Wisconsin. These new detail categories are based upon stress concentration factors (SCF) developed using high-fidelity finite element analysis. Two typical connection types, Osseo-type and Milwaukee-type were investigated.
- A random variable model for modeling error uncertainty was formulated using data from a field monitoring station located in Milwaukee and comparison of acquired data with high- and low-fidelity finite element modeling.

Investigator

Christopher Foley
Marquette University
christopher.foley@marquette.edu

Results

- The magnitude of maximum stresses in the Milwaukee-type sign support is greater than those in Osseo-type sign support structures. The maximum stresses in Milwaukee-type sign support tend to form near the locations 80-90 degrees relative to vertical axis. Maximum stresses in the Osseo-type sign support structures migrate to locations in the 60-80 degrees from vertical axis.
- E4-type mast-arm connection detail is expected to have a service life of approximately one year. An E3-type detail is expected to have service life in the range of 5-8 years and this depends on the orientation of the mast-arm relative to North. The E2 detail type is expected to have service life in the range of 20-28 years depending upon orientation.
- The reliability-based assessment process suggests that E3 and E4 detail types be avoided in mast-arm sign support structures. Connection details similar to Osseo-type sign support structures have significant stress concentration factors (E4 detail category) and should be avoided as well. Milwaukee-type connection details are categorized as E2-type behavior and are preferable.
- If an Osseo-type configuration can be implemented with E2 detail categories, 50-year service lives should be expected and inspections of these types of sign supports may never need to occur. In the case of Milwaukee-type mast-arm configurations with E2 detail types, first inspection intervals range from 13-36 years depending upon location with Milwaukee, Wisconsin experiencing the shortest interval.
- Mast-arms oriented in the N-S direction will have lower service lives than those in other orientations. The Osseo-type sign support structures are expected to have significantly lower service life (higher number of inspections) than the Milwaukee-type sign support structure.
- The following table summarizes the suggested inspection thresholds for mast-arm sign support structures in Wisconsin as a function of mast-arm type and detail configuration.

Location	Mass-arm configuration and detail type	Service-Life (years)					
		E2 Detail		E3 Detail		E4 Detail	
	Inspection Interval	Milwaukee Type	Osseo Type	Milwaukee Type	Osseo Type	Milwaukee Type	Osseo Type
Milwaukee	First Inspection	13	>50	5	19	1	1
	4 year Inspection Interval (utilized by WisDOT)	40	>50	10	43	N/A	2
Eau Claire	First Inspection	28	>50	9	38	1	2
	4 year Inspection Interval	>50	>50	20	>50	N/A	3
La Crosse	First Inspection	19	>50	6	26	1	2
	4 year Inspection Interval	>50	>50	14	>50	N/A	3
Green Bay	First Inspection	16	>50	6	24	1	1
	4 year Inspection Interval	48	>50	13	>50	N/A	2
Madison	First Inspection	36	>50	12	50	1	2
	4 year Inspection Interval	>50	>50	26	>50	2	3
Oshkosh	First Inspection	22	>50	7	31	1	1
	4 year Inspection Interval	>50	>50	16	>50	N/A	2
Wisconsin Rapids	First Inspection	33	>50	10	41	1	2
	4 year Inspection Interval	>50	>50	21	>50	N/A	3

Recommendations

The Osseo-type mast-arm configurations should not be used, however, if they are, they should be inspected much more frequently than a Milwaukee-type mast-arm structure. It is suggested that an Osseo-type sign support be inspected annually. Inspecting a Milwaukee-type sign can be done much less frequently (e.g. at fabrication, then in 10-year intervals up to 50 years). In addition, inspection cycles vary based on location.

Project Manager

Travis McDaniel
WisDOT Bureau of Structures
travis.mcdaniel@dot.wi.gov

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