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Project Summary Report 0-4178-S
Project 0-4178: Structural Fatigue Details
Authors: K.H. Frank
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PROJECT SUMMARY REPORT

Fatigue Strength of Signal Mast Arm Connections: A Summary

Introduction

This project investigated the fatigue characteristics of traffic cantilever signal mast arms shown in Figure 1. The cantilever mast arm is cost-efficient and relatively simple to design. The overall structure is more aesthetically pleasing than a cable structure or a truss cantilever structure. The same characteristics that make this traffic signal structure desirable also represent the most negative factors of the structure; it is a non-redundant structure and the mast arm is very flexible.

The details of the typical unstiffened, socketed connection are shown in Figures 2 and 3. This is the most common type of connection between the mast arm and the connection box on the upright mast. The term socketed comes from the socket hole cut into the end plate to accept the mast. The hole allows the drainage of the molten zinc from the interior of the arm during the galvanizing process. An unequal leg fillet weld is used on the outside to connect the arm to the end plate with the interior weld serving as a seal weld.

The hole cut into the end plate to accept the mast arm significantly reduces its bending stiffness. A typical service fatigue failure is shown in Figure 4. The failure occurs when there is cracking at the toe of the fillet weld connecting the end plate to the arm. Galloping of the mast arm from steady winds blowing on the back of the signal or gusts from trucks passing under the arm produce the repeated fatigue stresses that cause the cracking.

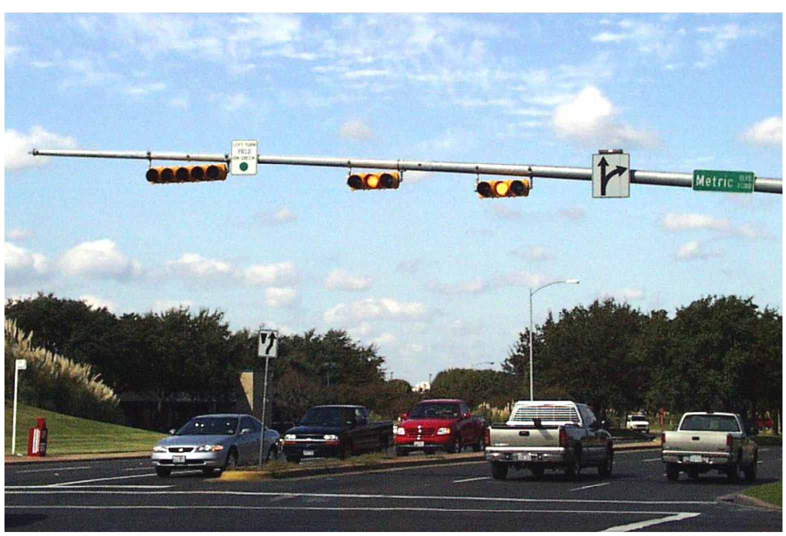

Figure 1. Typical Cantilever Signal Support

Figure 2. Typical Mast Arm Connection

What We Did…

The purpose of this study was to determine if the fatigue provisions of the recently adopted 2001 edition of the AASHTO Highway Signs, Luminaires and Traffic Signal Specifications are accurate. Most existing structures do not meet the fatigue provision of the new specifications. Also, the specifications indicated that the addition of stiffeners to the connections would greatly increase fatigue performance. The study examined the accuracy of the specification with full-scale fatigue tests of the mast arm and its connections.

What We Found…

During this project, fifty-five full-size mast arm connection specimens were tested to determine their fatigue resistance. The present specifications were found to overestimate the fatigue life of connections with stiffeners. Several connection details exhibited improved fatigue performance; however, the improvements were not as significant as the specimens treated with Ultrasonic Impact Treatment (UIT). Increase in the end plate thickness was also found to provide an inexpensive means of increasing the fatigue performance of the connection. An extensive finite element analysis generated stress concentration factors for a variety of connection geometries.

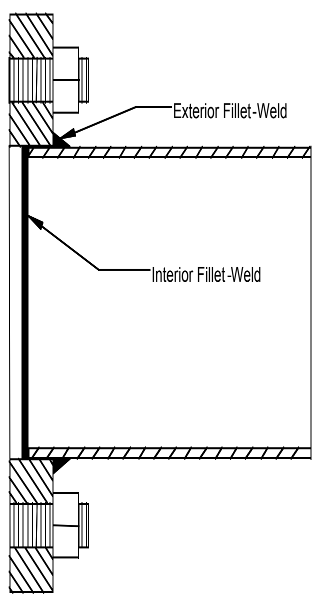

Figure 3. Cross Section of Typical Socketed Connection

These finite element analyses extended the range of geometries beyond those included in the experimental project.

Based on the results of the tests performed during this test program, the following conclusions can be made:

- The test results confirm the classification of the unequal leg fillet welded socket connection detail as an E' category detail.
- The design provisions for the stiffened connection details do not predict the actual behavior. The research shows that a longer stiffener is better than a shorter stiffener, contrary to the design provisions. The design equations also did not accurately predict the location of first crack initiation.
- The UIT weld treatment process provided significant fatigue life improvement when the treatment was performed under certain conditions. Specifically, when the difference between the maximum stress

Figure 4. Mast Arm Fatigue Failure

in the treatment area and the stress when treated is low (less than approximately 10 ksi), the UIT weld treatment dramatically improves the fatigue life.

The test results also indicate that the galvanizing process influences results of the UIT weld treatment. The test specimens that were treated prior to galvanizing did not benefit from the treatment, indicating that the galvanizing process negated any improvement due to the weld treatment process. Although the UIT Retrofit procedure was the only retrofit solution tested, the results of these tests indicate a very significant fatigue life improvement through the use of this treatment method. At this time, the UIT Retrofit procedure provides the best method for improving the fatigue life of a connection already in service.

- Increase in the end plate thickness for a 10-inch mast arm from 1.5 inches to 2 inches increased the fatigue life from category E’ to category D. This improvement is not represented in the current specifications, as the base plate thickness is not a variable in the fatigue design provisions. The finite element analysis confirmed the experimental result and indicated that the improvement in fatigue strength with increasing base plate thickness diminished with plate thickness beyond 2 inches.
- The full penetration weld exhibited a significant fatigue life improvement; however, this was in part due to the reduced stress caused by the thick backing bar.

The Researchers Recommend...

1. The end plate thickness for 10-inch arms should be increased to 2 inches. This simple change in the design provides the simplest method of increasing the fatigue life of this connection. Further study is required to develop recommendations for larger size arms.
2. UIT treatment is an effective means of increasing the fatigue life of service mast arms. Implementation of these recommendations will increase the fatigue life to at least Category D, which should be sufficient to prevent fatigue fractures in most applications.

For More Details...

Research Supervisor:	Karl H. Frank, P.E., (512) 471-4590 email: kfrank@uts.cc.utexas.edu
TxDOT Project Director:	Heather Gilmer, Construction Division, (512) 506-5921 email: hgilmer@dot.state.tx.us
TxDOT Research Engineer:	Tom Yarbrough, RTI, (512) 465-7685 email: tyarbro@dot.state.tx.us

The research is documented in the following reports:

- 0-4178-1, Fatigue Strength of Fillet-Welded Transverse Stiffeners with Undercuts, April 2005
- 0-4178-2, Fatigue Strength of Signal Mast Arm Connections, July 2004

To obtain copies of a report, contact: CTR Library, Center for Transportation Research, (512) 232-3126, email: ctrlib@uts.cc.utexas.edu

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