

The work described in this document was performed by Transportation Technology Center, Inc.,
a wholly owned subsidiary of the Association of American Railroads.

Evaluation of Ultrasonic Impact Treatment for Steel Bridge Weld Details

Lucy Tunna, Richard Joy, and Duane Otter

Summary

Transportation Technology Center, Inc. (TTCI), a subsidiary of the Association of American Railroads (AAR), Pueblo, Colorado, has been monitoring the performance of an ultrasonic impact treatment (UIT) application to steel bridge fatigue prone weld details on a Canadian National Railway bridge.

Replacement of a span is a considerable expense in terms of materials, labor, and service interruption. Implementation of UIT could extend the life of certain types of steel bridges. Successful treatment of weld details and welded repairs has the potential to result in significant savings. The cost of UIT for this particular bridge has been minimal, with no train delay or bridge outage required.

Two tests are underway. In 2005, TTCI began a study evaluating the effectiveness of UIT for preventing fatigue crack initiation in existing fatigue-prone weld details. A more recent weld repair UIT study is evaluating the effectiveness of UIT on cracks that have been repaired by welding. Results to date include the following:

- UIT is a cost-effective method to extend the life of steel bridges with certain types of fatigue-prone weld details.
- The number of failures in untreated weld details is more than 3 times higher than that in treated details.
- UIT has been effective in reducing the likelihood of crack initiation by up to 80 percent for pre-existing fatigue-prone weld details in the bridge tested.
- The use of weld repairs on cracks in conjunction with UIT shows promise as a means of extending life of steel bridges with certain types of cracks. To date, there have been no failures in treated repair welds.
- UIT application procedures have been refined since the original installation in an effort to provide improved benefits.
- Additional tonnage is required to determine the long-term effectiveness of repair welds followed by UIT application.

This research has been conducted as part of the AAR Strategic Research Initiatives Program.



INTRODUCTION AND CONCLUSIONS

Since 2005, TTCI has been monitoring the performance of UIT application to a Canadian National (CN) bridge near Stevens Point, Wisconsin. The purpose of the study is to evaluate the effectiveness of ultrasonic impact treatment (UIT) in preventing fatigue crack initiation in welded steel bridge details.

UIT is a technology in which small pins repeatedly strike the surface of a weld at ultrasonic frequencies. The objective of UIT is to reduce tensile stress around welded joints and other weld details by inducing compressive stresses. Fatigue crack growth occurs when residual tensile stresses created by the welding process combine with additional tensile stresses from train loading.

Success of the UIT technology is being measured based on the extent of crack initiation in treated versus untreated details. Inspections have been carried out each year since test inception. Results to date are favorable, but additional railroad traffic is required to generate the amount of crack initiation necessary to determine the effectiveness of the UIT application, particularly for the most recently installed weld repair test.

Two tests are underway to evaluate the UIT technology. A study of preventative UIT measures is evaluating the effectiveness of UIT for preventing crack initiation in fatigue-prone details. This test has been underway for about 350 million gross tons (MGT). Results to date show the number of failures in untreated weld details is more than 3 times higher than that in treated details. A more recent weld repair study is evaluating the effectiveness of UIT on cracks that have been repaired by welding. This test has been underway for about 100 MGT. Results to date show no failures in treated repair welds compared to one failure in untreated repair welds.

TTCI is performing visual annual inspections of both the treated and untreated (control) areas. This digest addresses results from the annual monitoring inspections since test installation in 2005. References 1 and 2 provide results from previous laboratory and field UIT tests. Positive results from the previous tests suggested the need for a field study with a large number of details to provide statistical significance.

To test UIT effectiveness in preventing fatigue cracks, a 16-span steel bridge on CN near Stevens Point, Wisconsin, was selected (Figure 1). This bridge has approximately 200 weld details. Some of these details had existing cracks prior to the beginning of the test.

Figure 2 shows the typical crack locations, where the diaphragms are welded to the main beams. This bridge is an ideal candidate for this testing, because it had already accumulated a significant number of fatigue cycles, as evidenced by the existing cracks. The numerous existing fatigue cracks at the stiffener toe details indicated a high probability for additional crack initiation.



Figure 1. CN Test Bridge near Stevens Point

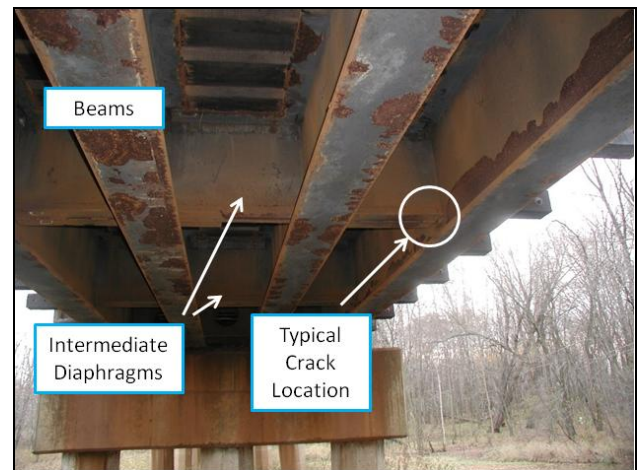


Figure 2. Underside of Test Bridge Showing Location of Weld Details

BRIDGE DESCRIPTION

The following is a summary description of the test bridge:

- Sixteen-span bridge with a total length of 432 feet
- Bridge built in 1966, former Soo Line standard design
- Four rolled steel beams per span on concrete piles and caps
- Open deck with timber ties and welded rail
- Fifteen to 25 freight trains per day; 60 miles per hour speed limit; approximately 50 MGT per year
- Mixed bi-directional freight traffic with maximum rail car weight of 286,000 pounds
- Higher percentage of loaded cars in southbound traffic
- The bridge was rated at over Cooper E70 and was assessed as adequate for the present operation of 286,000-pound car loading

UIT APPLICATION

For the first test on original shop welded details, 110 uncracked details were used for the study. Care was taken to inspect and select only uncracked details for this test. If there was any doubt, the detail was not included in the test. The details on the bridge spans were treated in a checkerboard pattern, alternating between north side and south side, to minimize various potential influencing factors. About half (46)

of the available details were treated with UIT, and 64 were left untreated as a control group.

UIT is applied using a handheld tool. The equipment is portable and can be carried by hand. Figure 3 shows the tool and related equipment. Figure 4 shows UIT application. Figure 5 shows a treated weld detail. For this bridge, all work was performed on the underside of the bridge and between train passages, removing the need for work windows or temporary track outages.



Figure 3. Handheld UIT Tool and Related Equipment



Figure 4. UIT Application



Figure 5. Treated Weld Detail

The interior beams of each span contain stiffener toes on either side of the beam. For these stiffeners, both sides of the web were treated for beams located on the west side of the bridge, and only the outside stiffener toe of the beams located on the east side of the bridge were treated. This difference in treatment process was carried out to test the effectiveness of one-sided versus two-sided treatment.

INSPECTION RESULTS – UIT FOR CRACK INITIATION PREVENTION

TTCI bridge team members have inspected this bridge annually to monitor crack initiation and growth since the inception of the test. Where necessary, a magnifying glass and flashlight were used along with a wire brush to clean the details of rust and flaking paint.

Figure 6 shows a summary of failure rates from 2005 to 2011. A total of 10 cracks were found in untreated details and 4 cracks were found in UIT details. One of the cracks in a UIT detail was in a location that was only treated on one side of the web. The crack initiated on the untreated side and propagated through the web. Results indicate that the failure rate for treated details is up to 80 percent better than for untreated details.

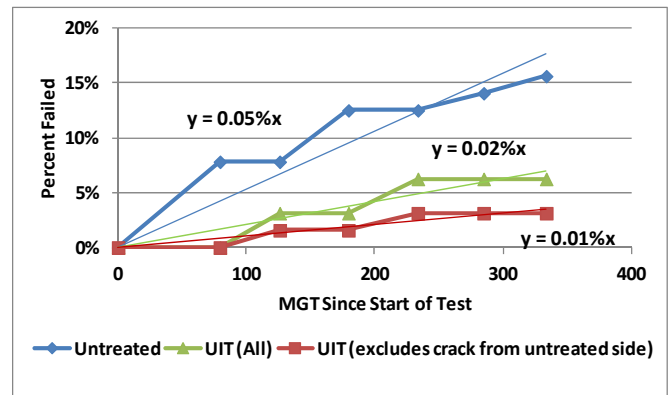


Figure 6. Failures — UIT for Crack Initiation Prevention (0 to 350 MGT)

UIT FOR WELD REPAIRS

Based on the success of the UIT application after 4 years of service, bridge engineers asked if UIT could be used in conjunction with repair welds to extend the life of a steel span. To address this issue, CN and TTCI engineers developed a weld repair plan and test plan, using four spans of this bridge containing several cracks. Weld repairs were made to 24 cracked weld details. Half of these repairs were then treated with UIT. The other half were left untreated to serve as a control. All work was done from the underside of the bridge with no train delay or bridge outage required.

As of the December 2011 inspection, one of the untreated weld repairs had cracked, while none of the UIT repairs had cracked. These results are encouraging, although the accumulated tonnage is still relatively low compared to that expected during the life of the bridge. Inspections are expected to continue annually until definitive conclusions can be drawn. Figure 7 shows a welder making repairs. Figure 8 shows a weld repaired detail after UIT.



Figure 7. Welder Repairing Cracked Detail



Figure 8. Weld Repaired Detail after UIT

IMPROVEMENTS IN PROCEDURES

In the 4 years since the original UIT was applied, the provider has made improvements in the procedure, resulting in a more extensive and thorough UIT application. The original application was at the toe of the weld only. Figure 9 shows an example, with a crack originating in the untreated portion of the weld. The vendor now recommends more thorough treatment including the entire weld and surrounding parent metal such as applied to the weld repair shown in Figure 8.

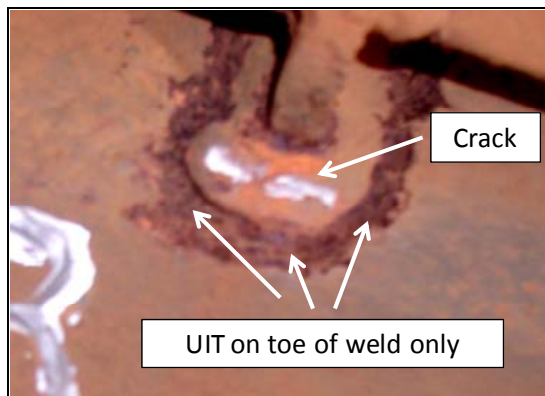


Figure 9. UIT Application on Toe of the Weld Only

CONCLUSIONS

Results to date indicate that UIT is a cost-effective method to extend the life of steel bridges with certain types of fatigue-prone weld details. UIT has been effective in reducing the likelihood of crack initiation by up to 80 percent for pre-existing fatigue-prone weld details in the bridge tested.

The use of weld repairs on cracks in conjunction with UIT shows promise as a means of extending the life of steel bridges with certain types of cracks. To date there have been no failures in treated repair welds. However, additional tonnage is required to determine the long-term effectiveness of repair welds followed by UIT application.

UIT application procedures have been refined since the original installation in an effort to provide improved benefits.

ACKNOWLEDGEMENTS

The authors are thankful for the assistance and cooperation of CN for this test, in particular, Chief Engineer Structures and Engineering Standards Nigel Peters, Manager Bridges and Structures Jose Cavaco, and Manager of Structures Kevin Halpin. The authors are also grateful for the donation of UIT services provided by Applied Ultrasonics.

REFERENCES

1. Sougata, R., J. W. Fisher, and B. T. Yen. June 2001. "Fatigue Resistance of Welded Details Enhanced by Ultrasonic Impact Treatment (UIT)," *Proceedings ISOPE 2001*, Stavanger, Norway.
2. Uppal, A. S., D. Yoshino, and L. Tehini. July 2001. "Ultrasonic Impact Treatment of Vertical Stiffener Welds at FAST Bridge," *Technology Digest TD-02-013*, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.