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Bridge Life Extension through Ultrasonic Impact Treatment of Weld Details

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Summary

Transportation Technology Center, Inc., working with Canadian National, is studying the performance of ultrasonic impact treatment (UIT) on steel bridge weld details in comparison to untreated weld details. After 4 years of study, performance to date indicates that UIT has prevented or delayed crack initiation in all fully treated weld details. In comparison, about 8 percent of the untreated details have cracked during this time.

Cracks were observed in untreated portions of two partially treated weld details. This shows the importance of performing a complete treatment rather than a partial treatment.

Installation of a bolted plug rail on the bridge caused a notable increase in fatigue crack activity near the bolted rail joints. (The rail joints were not originally planned as part of this study.) Removal of bolted rail joints from track on bridges is an effective way to reduce the stress state and extend the life of existing railroad bridges.

For this study, a 16-span steel bridge near Stevens Point, Wisconsin, was selected. The bridge contains over 200 weld details of similar type, many of which were already cracked at the beginning of the study. The existing cracks indicated that the bridge was already well along in terms of fatigue cycle accumulation, and that more cracking could be expected in the near future.

Future plans call for in-field weld repairs of several cracks, followed by UIT on selected repairs. If in-field repairs with UIT are successful in extending the bridge life, they could result in considerable potential savings compared with bolted splice repairs or other retrofits.

This study is being conducted as part of the Association of American Railroads' Strategic Initiatives Research Program on bridge life extension.

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INTRODUCTION

Transportation Technology Center, Inc. has been monitoring the performance of UIT to a Canadian National (CN) bridge in Stevens Point, Wisconsin.

This study is being done to evaluate the effectiveness of UIT in preventing fatigue crack initiation in welded details. UIT has previously been investigated for application on bridges.[1,2] And while it demonstrated potential to reduce fatigue cracking, there was a need to evaluate the application on a long-term basis with a statistically significant sample.

Success of UIT technology is being measured based on the amount of crack initiation in treated welds compared to untreated welds. For this study, several years of railroad traffic have been needed to generate the amount of crack initiation necessary to make a preliminary assessment of the effectiveness of the UIT application.

Test Procedure

The CN bridge at Stevens Point was selected because it has many spans that are reasonably accessible, and it already had some fatigue cracks, indicating the likelihood of more cracks to occur in the near term. This bridge offers about 200 weld details for this study. Figure 1 shows a schematic plan view of the bridge and the portions treated. Span 11 was not included in the test because it is over water. Spans 1 through 4 were not included because a number of cracks in those spans had previously been repaired or retrofit. The treatment pattern alternates to minimize differences from one rail to another.

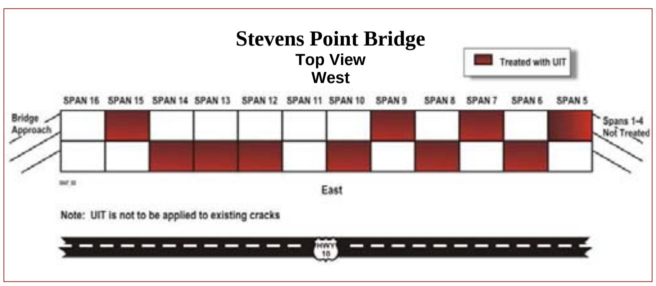

Figure 1: Schematic of Test Bridge and UIT Application Pattern

Figure 2 shows an overview of the test bridge. Figure 3 shows the bottom side of a typical span. The details of concern are the welds between the beams and the cross-frame diaphragm members. Figure 4 shows a typical weld between a cross-frame and a beam, after application of UIT. Note the UIT leaves a hammered white metal finish.

Figure 2: Overview of Test Bridge

Figure 3: Bottom Side View of Typical Span Showing Beams and Cross-Frame Members

Figure 4: Treated Weld Detail between Beam and Cross-Frame Member

Test Results

The bridge was thoroughly inspected prior to the application of UIT. UIT was not applied to any existing cracks. Due to the presence of several cracks on the west side of span 13, the UIT was applied to the east side of that span, in a deviation from the alternating pattern. Cracks were categorized as follows: Small cracks (SC) are defined as barely visible, medium cracks (MC) are clearly visible, but are smaller than 1 inch in length, and large cracks (LC) are larger than 1 inch in length.

The original UIT application was in April 2005. Inspections were conducted during the fall of 2006, 2007, and 2008. Changes in crack lengths, as well as new cracks, were noted. Table 1 summarizes the most recent inspection results and changes since the UIT application.

Table 1: Bridge Inspection Results for Weld Details

Parameters	Number of Details	Crack Initiation Rate
UIT Treated Details	46	
Cracked Since Start of Test	0	0.0%
Cracked in Untreated Portion of Weld	2	
Control Untreated Details	71	
Cracked Since Start of Test	6	8.5%
Cracked Details at Start of Test	83	41.5%
Unable to Inspect	18	

The results in Table 1 show that to date, no cracks have developed where UIT has been applied. By comparison, six new cracks have developed in untreated weld details. In some of the details, there was only partial application of UIT. Two cracks have developed in untreated portions of partially treated details. In one case, only one weld toe was treated — the other toe has since developed a crack. In the other case, a crack initiated on the back side of the web, where UIT was applied on only one side of the web. These cracks illustrate the importance of applying a full treatment rather than only a partial treatment to critical details.

Bolted Rail Joints Increase Crack Initiation

During the most recent inspection, a total of five new cracks were found. Two of them were located in spans 5 and 6. The remaining three were in the remaining nine spans in the test. Spans 5 and 6 had bolted rail joints from a rail plug repair. It is likely that the bolted rail joints caused increased impact forces leading to the higher rate of crack initiation in these spans. In addition, several existing cracks grew significantly, particularly in span 5. The new cracks and crack growth in spans 5 and 6 were under the east rail with only one exception, as shown in red on Figure 6. The bolted rail joints were also on the east rail.

Increased fatigue crack initiation and growth under rail joints have previously been noted on the steel bridge at the Facility for Accelerated Service Testing. It is important to remove bolted rail joints from bridges as soon as possible to minimize the chances of crack initiation and growth in steel bridges.

Figure 5: Bolted Rail Joints on East Rail above Span 5 and Span 6

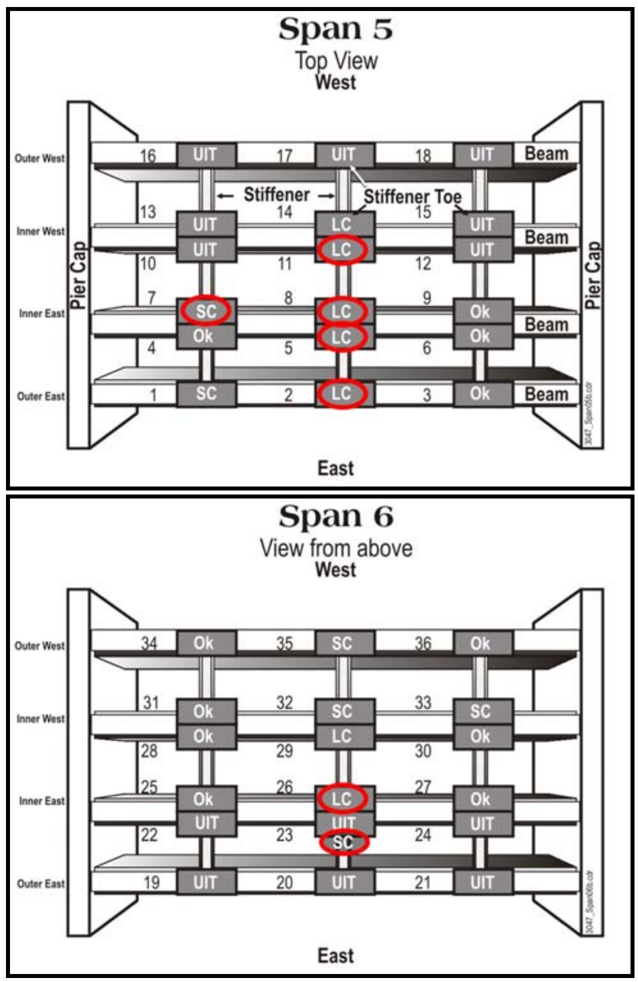

Figure 6: Changes in Spans 5 and 6 (Denoted in Red) Under Bolted Rail Joints

Figure 7 shows the crack in detail number 23 on span 6. It propagates from the untreated weld on the opposite side through the web and through the UIT that was applied only to one side of the web. A bolted rail joint is located above this detail.

Figure 8 shows the crack in detail 93. Detail 93 was treated at the toe of the weld to the beam web. But the crack appears above the treatment on the untreated toe of the weld to the stiffener.

Figures 9 and 10 show additional cracks found in the most recent inspection.

Figure 7: Crack in Partially Treated Weld in Span 6

Figure 8: Crack in Weld above Treatment Application in Span 10

Figure 9: Crack in Weld above a Previous Crack in Span 14

Figure 10: New Medium Crack on Previously Okay Detail in Span 10

Bridge Description

The CN Stevens Point Bridge is a 16-span bridge 432 feet long (Figure 11). The bridge was built in 1966. There are four beams per span, on concrete pilings and caps. Train traffic is about 15 to 25 freight trains per day, at a speed limit of 60 miles per hour, for an annual tonnage of 51-million gross tons. The traffic includes bi-directional mixed freight traffic with maximum gross rail load of 286,000 pounds. Southbound traffic has a higher percentage of loaded cars.

Fatigue cracks exist under a majority of stiffener toes on spans 1 through 4, most of which have had holes drilled through the crack tips, with bolts placed in the holes.

Figure 11: Train on Test Bridge

FUTURE WORK

To monitor the effectiveness of UIT application on welded details, the Stevens Point Bridge will continue to be periodically inspected. Plans for a future test include weld repairs of selected medium and large cracks. Half of the new repair welds will have the UIT applied to relieve the tensile stresses, and half will be untreated to serve as the control welds.

References

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2. Uppal, A.S., D. Yoshino, and L. Tehini. July 2002. "Ultrasonic Impact Treatment of Vertical Stiffener Welds at FAST Bridge." *Technology Digest* TD-02-013, AAR/TTCI, Pueblo, CO