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Update: Cracks in the Welded Girders of the Steel Bridge at FAST

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Summary

With regular monitoring and inspections, the steel bridge at FAST continues to remain in service, despite having accumulated nearly 700 MGT and over 4 million load cycles on a significant crack in a tension flange. Also, several new cracks have developed and propagated in both the 65- and 55.5-foot spans of the steel bridge at the Facility for Accelerated Service Testing (FAST). Remedial measures have proven effective. Since installation, the bridge has accumulated over 800-million gross tons (MGT) and 5-million load cycles of 39-ton-axle-load traffic.[1]

Thus far there has been no experience to suggest that inspections are needed more frequently. Transportation Technology Center, Inc. continues inspections at 25 to 30 MGT intervals. Appropriate safety measures are in place for continued train operations.

Results from this ongoing fatigue test are intended to help railroads extend the safe service life of their steel bridges. As well, the monitoring tools developed and evaluated in this test will be valuable in helping railroads to better prioritize bridge maintenance and renewal budgets.

Observations

- Rail joints on the bridge produced impact loads that appear to have initiated several cracks and accelerated growth of other cracks.
- Stop-hole drilling retrofits and bolted splice repairs are both performing well to date.
- Many cracks seem to have become dormant after initially appearing. This is likely due to stress redistribution or release of residual tensile stresses.
- Details treated with ultrasonic impact treatment to prevent cracking are showing no signs of cracking to date.
- Effective inspection, maintenance, and safety methods have successfully extended the service life of the steel bridge at FAST.

This study is being conducted as part of the AAR's strategic research initiative on railroad bridges, as well as the FAST program, which is funded in part by the Federal Railroad Administration.

INTRODUCTION AND CONCLUSIONS

The ongoing full-scale steel bridge fatigue test at FAST offers a unique opportunity to monitor and evaluate crack initiation and growth in a controlled railroad environment. Numerous weld cracks in the tension zone of the steel girders of the steel bridge at FAST (known as the FAST Steel Bridge) became visible during the early period of service.[1]

Most of these cracks developed in the tension region during the initial 225 MGT (1.4-million load cycles) of heavy axle load (HAL) traffic over the bridge. Many of these cracks now appear to be dormant. The primary cause of these cracks is the weld detail, which is not consistent with the current AREMA guidelines.[2] No new cracks were observed between 225 and 560 MGT (3.5-million load cycles) in the 65-foot span. However, propagation and growth of existing cracks were monitored during this period.

Several new cracks developed between 560 and 825 MGT (5.2-million load cycles). They are mainly in the top lateral braces and diaphragms; all but one is in the 65-foot span. Nearly all of the new cracks occurred in the vicinity of bolted rail joints. It is very likely that the impacts from train traffic over the discontinuous rail surface contributed to the initiation of these cracks. Other factors that may have contributed to initiation of these cracks include weld issues and out-of-plane bending. The 55.5- and 65-foot span girders were fabricated in 1968 and 1957, respectively, according to then-prevailing weld details and practices. Some of the new cracks have been repaired with bolted splices. Other new cracks are in areas not critical to the capacity of the bridge.

The higher number of cracks in the 65-foot span might be attributed to the relatively lower lateral stiffness of the span as well as the different weld details and practices. The X-type diaphragms are spaced at 16 feet in the 65-foot span as compared to 11 feet in the 55.5-foot span. The lower lateral stiffness of the 65-foot span due to diaphragm spacing may have allowed more out-of-plane bending that contributed to initiation of cracks in the regions normally considered as the compression zone.

Thus far, the rate of crack initiation and crack growth has not indicated a need to inspect more frequently than the initial practice at FAST of 25 to 30 MGT intervals (0.15- to 0.2-million load cycles).

Development History of Cracks at FAST

Figures 1 and 2 show the development history of cracks during the service life of girders at FAST. The different types of cracks observed are:

- Cracks below intermediate web stiffeners
- Cracks in diaphragm members or connections (Figure 3)
- Crack in tension flange (Figure 4)
- Cracks in lateral braces (Figure 5)
- Crack in the weld detail of stiffener and compression flange (Figure 6)

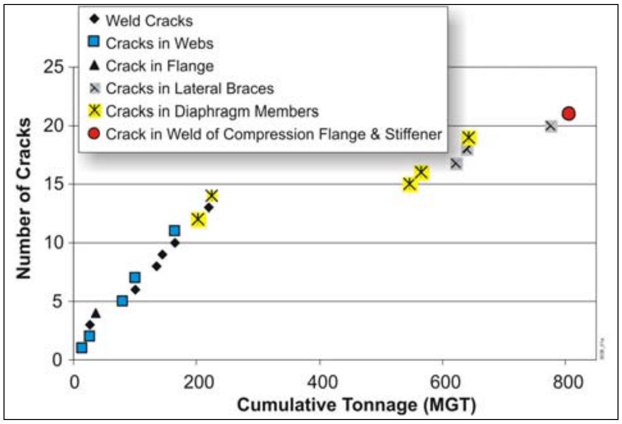

Figure 1a. Crack Development History — 65-foot Span

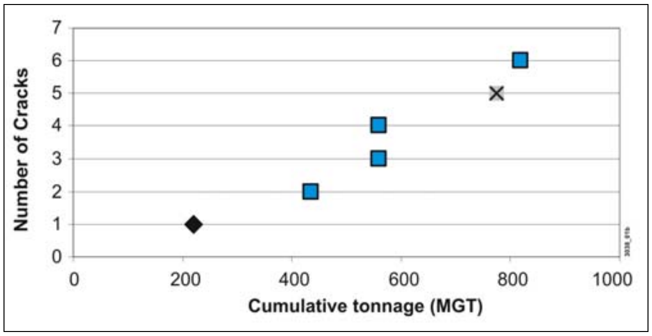

Figure 1b. Crack Development History — 55.5-foot Span

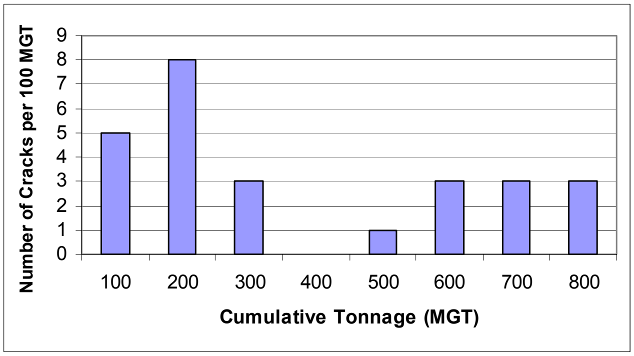

Figure 2. Rate of Crack Development

Figure 3. Crack in Diaphragm Connection

Figure 4. Crack in the Flange

Figure 5. Lateral Bracing
(Top) Fractured (Bottom) Repaired with Bolted Splice

Figure 6. Crack in the Weld of Stiffener and Compression Flange

During the period from 493 MGT to 547 MGT, a set of two-piece austenitic manganese steel casting moveable bridge rail joints were installed on the bridge deck.[3]

The rails from the moveable bridge joint were attached to the running rails using conventional bolted joint bars. After 547 MGT, the moveable bridge joint was removed and replaced with plug rails. The plug rails were attached to the running rails using the same conventional joint bars. Those conventional joints remained in place until the installation of new rail at 777 MGT.

The moveable bridge rail joints were the type used on vertical lift moveable bridges. The joints caused increased dynamic vertical and lateral loads, which may have induced cracking in some lateral bridge braces. The impact from the joint also accelerated the crack growth in a nearby crack.[4]

Cracks Below Intermediate Web Stiffeners

Cracks below the intermediate web stiffeners were the first to show up in the steel bridge, with several of the same type appearing shortly after the beginning of HAL traffic. All cracks of this type appear to have initiated in the welds between stiffeners and tension flange during early periods of service (up to 225 MGT). Apparently, many of the cracks have since become dormant.

To date, cracks of this type have been observed on 12 of 26 intermediate stiffeners on the 65-foot span and 4 of 22 intermediate stiffeners on 55.5-foot span. The clearance between web-flange and web-stiffener welds in the 65-foot span is 3/4 inch, and the welds overlap at the bottom of intermediate stiffeners. The clearance between stiffener and flange on the 55.5-foot span is 1 inch and the welds do not overlap. Presumably, the 55.5-foot span has fewer cracks because its web-flange and web-stiffener welds have more clearance than those in the 65-foot girders.

Many cracks that initiated in the welds have propagated into the webs. The 65- and 55.5-foot spans experienced five and three such cracks, respectively. In the 65-foot span, one crack was arrested with two 7/8-inch-diameter holes shortly after it was discovered. No growth has been noted since. Another crack was arrested in the web with a hole, but the other end of the crack propagated down into the tension flange within the following 50 MGT of HAL traffic. Only minimal crack growth has been noted since then. The other three web cracks in the 65-foot span have not been treated, and seem to remain dormant.

Two web cracks in the 55.5-foot span remain active. These cracks are under the first intermediate stiffeners of each girder near the bearings at the center pier. This location is below the area where the moveable bridge joints have been installed. Figure 7 shows that this crack became more active while the moveable bridge rail joint was installed. The length of cracks in the north and south girders increased from 10 to 15 inches and 2 to 5 inches, respectively. Only minimal crack activity has been observed since the rail joint was removed.

Some vertical stiffener welds in the 55.5-foot span were treated with Ultrasonic Impact Treatment (UIT).[4] UIT is capable of changing residual tensile stresses in weld and web areas by introducing compressive stresses. The change in stress measured during application at TTC was as much as 8.2 ksi. To date, no crack activity has been observed at any of the treated locations. Long-term performance of the UIT is currently being monitored.

Cracks in Diaphragm Members

On the north girder of the 65-foot span, all angles at the top of the diaphragms are welded to one side of the intermediate stiffeners at some locations. When the bridge was subjected to lateral loads or uneven vertical loads, out-of-plane bending may have caused an eccentric resultant force on the stiffeners. Three out of five diaphragms with these connection details initiated cracks that have propagated into the stiffeners (Figure 3). On the south girder, diaphragm angles tend to be welded on both sides of the stiffener at the top of the girder. The applied diaphragm forces are more balanced. No crack has been observed in the south girder diaphragm connections.

Cracks in Lateral Braces

To date, the 65-foot span has experienced three cracked lateral braces between top flanges. In two of the braces, the entire cross section cracked. They have been repaired with bolted splices. In one of these braces, the crack was not completely through the cross section until after the splice was installed. It appears that these cracks initiated in welds, under higher dynamic loads from the bolted rail joints. Each cracked brace is in the vicinity of a bolted rail joint. No cracks were observed on these braces before joint installation.

One brace with a crack has not yet been repaired. The crack is only partially through the cross section. It is being monitored, as the rail joints were recently removed from the bridge deck near that location. Figure 5 shows a brace repaired with a bolted splice.

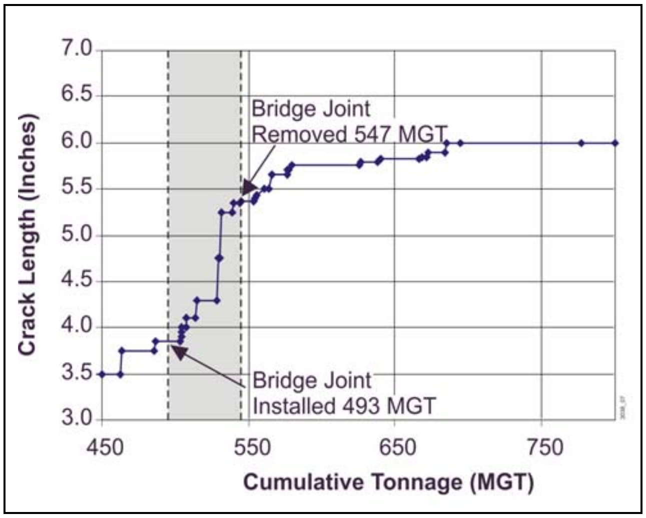

Figure 7. Crack Growth during Time the Mechanical Rail Joint was Installed

Crack in Weld Detail of Stiffener and Compression Flange

Figure 6 shows a crack that initiated recently. There is no diaphragm or lateral bracing attached to this stiffener. Rotation of the compression flange or out-of-plane bending of the web may have played a part in initiating this crack.

References

1. Otter, D., Oliva, D., and Joy, R. December 1998, “Cracks in Welded Girders of The FAST Bridge.” *Technology Digest* TD98-030, Association of American Railroads, Transportation Technology Center, Inc.
2. *Manual for Railway Engineering*, American Railway Engineering and Maintenance of Way Association, 2004, Landover, Maryland.
3. Sasaoka, C., Davis, D., Otter, D., and Doe, B. July 2002 “Evaluation of Specialized Rail Joints for Moveable Bridges under HAL Traffic,” Technology Digest TD02-016, Association of American Railroads, Transportation Technology Center, Inc.
4. Sasaoka, C., Davis, D., Otter, D., and Doe, B., September 2003, “Testing Rail Joints for Moveable Bridges,” Railway Track & Structures, pp. 21-23.