TECHNOLOGY DIGEST

TD-08-003
©JANUARY 2008

TIMELY TECHNOLOGY TRANSFER

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Update on Bridge Deck Fastener Performance on the FAST Steel Bridge

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Summary

The performance of several bridge deck fastening systems is being evaluated on the steel bridge at the Facility for Accelerated Service Testing (FAST) at the Transportation Technology Center, Pueblo, Colorado. Fastening systems tested to date include several variations using hook bolts as well as spring clips.

Results to date indicate that minor, inexpensive installation details can lead to significant increases in time required between maintenance. Details, such as the use of double nuts and threaded fastener adhesive, have proven to be particularly effective. At FAST, more than 500 million gross tons (MGT) of traffic passed over the bridge after this retrofit was applied before tightening was required.

Other hardware details, such as the use of locking clips, can also increase time between maintenance, particularly in high-impact areas near rail joints. Locking clips have proven to extend maintenance cycles at FAST. But, some other hardware variations offered little or no benefit under the heavy axle load (HAL) traffic at FAST.

Results for eight different deck fastener combinations are presented in this *Technology Digest*. Advantages and drawbacks, as well as failure modes, are noted based on the test experience at FAST.

The bridge deck at FAST is a Conrail open-deck design with dapped oak ties. The open deck has carried over 1,300 MGT of 315,000-pound HAL traffic since installation in late 1997.

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INTRODUCTION

With about nine million feet of bridges on the major U.S. and Canadian railroads, there are millions of deck fasteners in service, but there is little information available to compare and document performance of these systems. Results from this test have shown that small differences in hardware can offer a tremendous reduction in required maintenance. The potential savings in labor and track time is particularly important on many bridges that require special equipment or scaffolding to properly tighten the fasteners.

FAST has been used for full-scale railroad testing since 1976 at the Transportation Technology Center near Pueblo, Colorado. The track at FAST features a 2.7-mile loop with a wide variety of rails, ties, and other track components subjected to railroad loading. A test train circles the test loop approximately 500 times per week with an 80-car train. Car loading is 315,000-pound gross rail load, which is about 10 percent higher than the current maximum loading for most North American rail lines.

In 1997, a 121-foot two-span steel bridge was added to the test loop at FAST. Figure 1 shows the bridge. The bridge is on a tangent alignment between reverse curves. The test bridge has welded deck plate girder spans, with an open deck. The girders were designed in the 1950s and 1960s, according to the American Railway Engineering Association and Pennsylvania Railroad practices at that time. The 55.5- and 65-foot span girders were fabricated in 1968 and 1957, respectively. Both spans have two girders spaced at 6.5-foot centers. The second-hand girder spans were donated by Conrail. The bridge deck is currently a Conrail open-deck design with dapped oak ties. The girders have smooth top flanges. As Conrail donated the spans, the first deck and fastener system to be tested were to their specifications.

Figure 1. Conrail Open Deck Steel Bridge at FAST

To date, eight variations of bridge deck fastener systems have been under evaluation on the steel bridge at FAST. Over most of the bridge, every fourth deck tie is fastened to the top flanges of the girders. The objective is to determine which hardware will save time and reduce maintenance costs.

The systems with the best performance have withstood more than 500 MGT of HAL traffic with no maintenance required. The poorest-performing systems withstood less than 40 MGT before numerous fasteners were loose, turned, or broken. Figure 2 summarizes the performance of the eight systems tested to date.

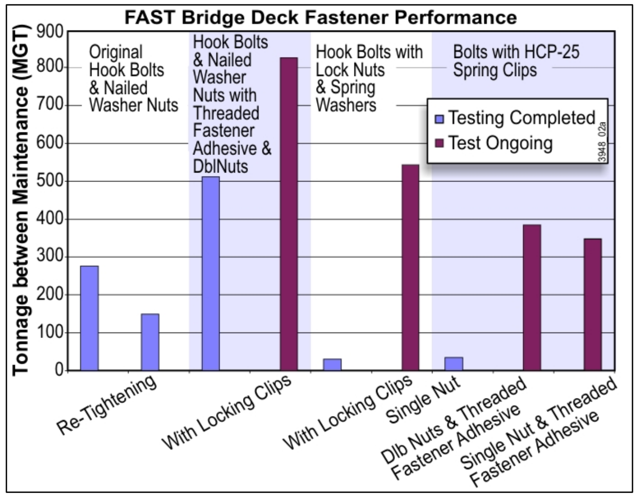

Figure 2. Deck Fastener Maintenance Intervals at FAST

FASTENER SYSTEMS PERFORMANCE

Original Hook Bolts and Nailed Washer Nuts Installation

The original Conrail hook bolt configuration, when the deck was installed, consisted of a 14-inch hook bolt with a washer nut. Figure 3 shows the hole in the washer nut for a nail to be driven in to prevent the washer nut from turning. The lower portion of the hook bolt neck is fluted – intended to engage into the tie to prevent turning. This system withstood about 275 MGT of HAL traffic before the hook bolts had to be straightened and the nuts tightened. At the time of the first tightening, there was one broken hook bolt and 22 spun hook bolts out of a total of 56 on the bridge (Figure 4). Due to the relatively-deep girder flanges, the fluting of the hook bolts was only minimally engaged in the ties. In many cases, the hook bolts turned loose over time. In the process, they rounded the holes in the deck ties so that the fluting could no longer engage the ties. Also, in some cases, the nail worked out of the washer nut, allowing rotation.

Figure 3. Original Conrail System using a Hook Bolt and a Washer Nut

Figure 4. Turned Hook Bolt

Re-Tightening Original Hook Bolts and Nailed Washer Nuts

After aligning and tightening all hook bolts, the original hook bolts and nailed washer nuts withstood about 150 MGT of additional HAL traffic before a similar number of hook bolts were loose or rotated. This is attributed to the rounding of the holes in the ties and resultant inability of hook bolt fluting to engage the ties. In this case, the same hook bolts tended to be loose or rotated.

This case serves as a baseline for comparison to the other cases, as the ties were now considered to be worn.

Hook Bolts and Nailed Washer Nuts with Double Nuts and Threaded Fastener Adhesive

After establishing the performance of the original system with both new and worn ties, a common field retrofit was applied. The hook bolts were again aligned and tightened, with double nuts and a threaded fastener adhesive (Loctite) applied to keep the nuts from loosening (Figure 5). This system lasted in service for 511 MGT on a portion of the bridge until maintenance was required due to loose or spun hook bolts.

Figure 5. Double Nut and Washer Nut with Nail Hole

Fasteners under a Moveable Bridge Joint

When a two-piece casting moveable bridge joint was installed on the bridge, the hook bolt and nailed washer with double nut and adhesive system was used on every tie beneath the joint.[1,2] On those ties, high dynamic loads vibrated the hook bolts loose daily (1 MGT). Several hook bolts also broke. Breaks occurred at both the bottoms and the tops of the hook bolts. On those ties beneath the joint castings, locking clips were soon added to prevent turning and loosening of the hook bolts (Figure 6a). The addition of the locking clips significantly reduced the amount of hook bolt maintenance required on ties beneath the casting joint (5 to 10 MGT intervals). Figures 6b and 6c show some typical conditions that required maintenance. Only when the casting joint was removed from the bridge did the need for fastener maintenance drop to the levels experienced on the remainder of the bridge.

Figure 6. Hook Bolt Fasteners with Locking Clips, (6a) Typical, (6b) Turned Hook Bolt, and (6c) Broken Hook Bolt

Hook Bolts and Nailed Washer Nuts with Double Nuts, Threaded Fastener Adhesive, and Locking Clips

The combination of hook bolts and nailed washer nuts, with double nuts, threaded fastener adhesive, and locking clips was installed on one girder to repair damage incurred by a derailed car. This combination of fasteners has performed well for over 825 MGT with no maintenance required. This test is ongoing with additional tonnage being accumulated.

Hook Bolts with Lock Nuts and Spring Washers

In conjunction with a rail change, the deck fasteners on two girders were changed. On one girder, hook bolts with spring lock washers and locking nuts were used (Figure 7a). In theory, the spring washer should keep the hook on the hook bolt in contact with the bottom of the flange at all times. On the worn ties at FAST, this system required maintenance after about 30 MGT of HAL traffic. Failure modes for individual fasteners included hook bolt turning, hook bolt breaking, and spring breaking. A concern is that there is no recommendation for tightening the spring lock. If too loose, the hook bolt is likely to turn. If too tight, either the spring or the hook bolt is likely to break (Figure 7b). Each of these problems was experienced on this particular girder at FAST.

Figure 7a (left). Locking Nut, Spring Lock, and Washer. Figure 7b (right). Broken Spring Lock on Hook Bolt

Hook Bolts with Lock Nuts, Spring Washers, and Locking Clips

Concurrently with the above installation, the second girder was equipped with a similar system of hook bolts with spring lock washers and locking nuts. On the second girder, however, locking clips were used as well (Figure 6). This system has performed satisfactorily, accumulating over 540 MGT of HAL traffic with no maintenance required. Note that the addition of the locking clips has been particularly effective in this case. This test is ongoing with additional tonnage being accumulated.

Bolts with HCP-25 Spring Clips and Single Nuts

Another commonly used bridge deck fastening system consists of bridge deck bolts with spring clips to engage the bottom of the flange (Figure 8a). Several sizes of spring clips are available, depending primarily on the thickness of the girder top flange. The HCP-25 model was recommended for the steel bridge at FAST, with a flange thickness of about 2.5 inches. On one girder, this system was installed and tightened per the manufacturer's recommendation. When properly installed, the spring clip remains in contact with the bottom of the flange at all times. The spring clip provides a toe load in the same fashion as does an elastic rail fastener on a rail base. Ears on the spring clip engage the ties to prevent rotation. After about

35 MGT, the nuts on about a third of the fasteners had come loose and several of the spring clips rotated requiring maintenance. Figure 8b shows a rotated spring clip. The top flange experienced some gouging caused by the spring clips. This resulted from longitudinal movement between deck ties and girder (Figures 8a, 8b, and 8c). Note that the top flanges of the FAST steel bridge are smooth. On spans with protruding rivet heads in the top cover plate, the rivet heads become embedded in ties, and would likely prevent such movement in conjunction with this type of fastening system.

Figure 8a (left). HCP-25 Spring Clip with Single Nut. Figure 8b (center). Rotated Spring Clip and Gouge in Girder Flange. Figure 8c (right). HCP-25 Spring Clip with Double Nuts

On one girder, the HCP-25 spring clips were installed using double nuts and threaded fastener adhesive (Figure 8c). This system has performed satisfactorily, accumulating over 380 MGT of HAL traffic with no maintenance required. The comment regarding gouging also applies to this configuration. This test is ongoing with additional tonnage being accumulated.

Bolts with HCP-25 Spring Clips and Single Nuts with Threaded Fastener Adhesive

When the original spring clip installation required maintenance, the hardware was re-aligned and tightened using threaded fastener adhesive. This single-nut installation in comparison with the double-nut installation will help distinguish the benefits provided by double nuts and threaded fastener adhesive. This system has performed satisfactorily, accumulating nearly 350 MGT of HAL traffic with no maintenance required. The comment above regarding gouging also applies to this fastener configuration. This test is ongoing with additional tonnage being accumulated.

FUTURE TESTING

In addition to accumulating additional tonnage on the systems that are still performing satisfactorily, tests are being planned for other types of fastening systems.

CONCLUSIONS

The performance of eight bridge deck fastener systems is being evaluated on the steel bridge at FAST. The bridge deck is a Conrail open-deck design with dapped oak ties. The deck has carried over 1,245 MGT of HAL traffic with 315,000-pound cars since its installation in late 1997. Observations to date are:

- The original installation per Conrail design required maintenance after about 275 MGT of traffic to tighten loose or rotated hook bolts and replace one broken hook bolt.
- High dynamic loads due to a moveable bridge casting joint caused a drastic increase in maintenance demand for fasteners on ties supporting the joint castings.
- As hook bolts rotated loose, their fluting rounded the holes in the bottoms of the deck ties.
- After alignment and tightening of loose or rotated hook bolts, about 150 MGT of traffic was accumulated before similar maintenance was again needed.
- During the second alignment and tightening maintenance, double nuts and a threaded fastener adhesive (Loctite) were applied. This system has preformed very well in three different fastener systems.
- Locking clips were installed in October 2001 with new hook bolts on one girder. Their installation has been effective in two different fastener systems.
- Spring washer assemblies, instead of nailed washer nuts, in conjunction with locking clips, are performing satisfactorily to date on worn ties. Of concern is the lack of a tightening specification for the spring washers, as evidenced by both broken springs and broken hook bolts.
- Spring washer assemblies without locking clips lasted only about 30 MGT at FAST before a significant number of hook bolts loosened and turned. Again, lack of a tightening specification for the spring washers is a concern.
- Bridge deck bolts with spring clips are performing well in two installations with threaded fastener adhesive.
- Bridge deck bolts with only single nuts and no threaded fastener adhesive lasted only about 35 MGT before maintenance was required.

ACKNOWLEDGEMENTS

This study is being conducted as part of the FAST/HAL program, jointly funded by the Association of American Railroads and Federal Railroad Administration. Technical oversight is provided by an advisory group of railroad chief bridge engineers and AREMA bridge committee chairmen.

REFERENCES

1. Sasaoka, Charity, David Davis, Duane Otter, and Brian Doe. July 2002. “Evaluation of Specialized Rail Joints for Moveable Bridges under HAL Traffic.” *Technology Digest* TD-02-016. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.
2. Sasaoka, Charity, David Davis, Duane Otter, and Brian Doe. 2003. “Testing Rail Joints for Moveable Bridges.” *Railway Track & Structures* (September): 21-25.
3. Doe, Brian and Duane Otter. April 2005. “Hook-Bolt Fastener Performance on the FAST Steel Bridge.” *Technology Digest* TD-05-010. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.
4. Otter, Duane and Brian Doe. 2005. “Bridge Deck Fastener Evaluation at FAST.” *Railway Track and Structures* (July): 16-18.