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Hook-Bolt Fastener Performance on the FAST Steel Bridge

by Brian Doe and Duane Otter

Summary

The performance of five hook-bolt deck fastener systems is being evaluated on the steel bridge at the Facility for Accelerated Service Testing (FAST). The bridge deck is currently a Conrail open-deck design with dapped oak ties and hook bolt fasteners. The deck has carried over 900 million gross tons (MGT) of heavy axle load (HAL) traffic with 315,000-pound cars since its installation in late 1997. Observations by Transportation Technology Center, Inc. (TTCI) to date are:

- The original installation per Conrail design required maintenance after about 275 MGT of traffic to tighten loose and/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 and/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 thread-locking material (Loctite) were applied. This treatment has performed very well for over 460 MGT of traffic with little evidence of deterioration.
- Locking clips were installed in October 2001 with new hook bolts on the south side of span 2 (after a derailment damaged the original hook bolts). This installation also used double nuts and Loctite. This system has given satisfactory performance for almost 400 MGT with little maintenance to date.
- Spring washer assemblies, instead of nailed washer nuts, *in conjunction with locking clips*, are performing satisfactorily to date on worn ties. Current accumulated tonnage is about 115 MGT. 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.

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

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INTRODUCTION AND CONCLUSION

TTCI is performing an evaluation of the effects of HAL traffic on the hook-bolt deck fasteners on the steel bridge at FAST. The bridge deck is currently a Conrail open-deck design with dapped oak ties and hook bolt fasteners.

Five variations of hook-bolt fastener systems described later are under evaluation, in addition to the original installation. To date, the systems with the best performance have withstood over 460 MGT of HAL traffic, with no maintenance required. The poorest performing system only withstood about 30 MGT before numerous hook bolts were loose, turned, or broken.

Original Deck Configuration

The original hook bolt configuration, when the deck was installed, consisted of a 14-inch hook bolt with a washer nut. There is a hole in the washer-nut for a nail to be driven in to prevent the washer-nut from turning (see Figure 1). 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 until 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 at that time (Figure 2). Due to the relatively thick 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 the fluting could no longer engage the ties. In some cases, the nail worked out of the washer-nut, allowing rotation.

Retrofit 1

After aligning and tightening all hook bolts, this system withstood about 150 MGT of additional HAL traffic before a similar number of hook bolts were loose or rotated. The same hook bolts tended to be 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.

Retrofit 2

After establishing the performance of the original system in both new and worn ties, a common field retrofit was applied. The hook bolts were again aligned and tightened, with double nuts and a thread locking material (Loctite) applied to keep the nuts from loosening (Figure 3). This system has been in service for more than 460 MGT on a portion of the bridge, requiring no maintenance to date. This system is performing very well. On a portion of the bridge where this system was removed (for other test purposes), considerable effort was required to loosen the hook bolts even after more than 300 MGT of HAL traffic.

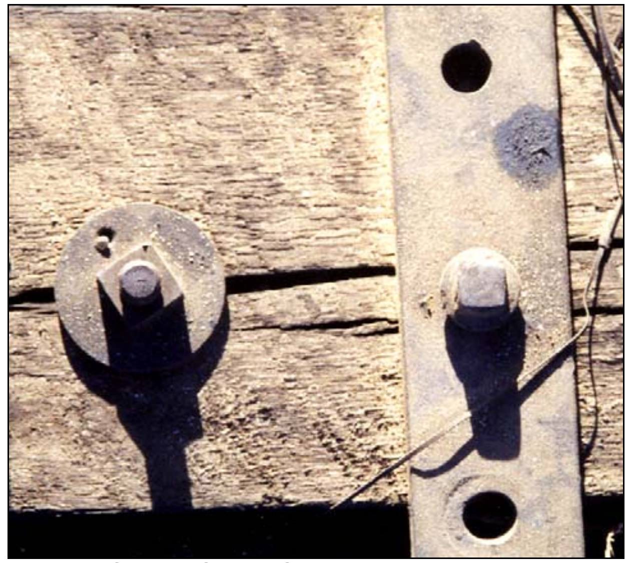

Figure 1: Original Conrail System using a Hook Bolt and a Washer Nut with a Nail through the Washer Nut to Prevent Rotation

Figure 2: Turned Hook Bolt

Figure 3: Double Nut and Washer Nut with Nail Hole

Retrofits 2 & 3: Under Moveable Bridge Joint Castings

When a two-piece casting moveable bridge joint was installed on the bridge, the double nut and Loctite system was used on every tie beneath the joint.[1,2] On those ties, the 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 hook bolts. On those ties beneath the joint castings, locking clips were soon added to prevent turning and loosening of the hook bolts (Figure 4). 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 5 and 6 show some typical instances 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 4: Hook Bolt with Locking Clip

Figure 5: Turned Hook Bolt with Locking Clip

Figure 6: Broken Hook Bolt with Locking Clip

Retrofit 3: Under Conventional Track

The train derailment at FAST in October 2001 destroyed the deck fasteners on one of the girders. On that girder, hook bolts with locking clips, in addition to double nuts and Loctite were installed as a replacement. This system has performed well for over 350 MGT with no maintenance required to date.

Retrofit 4

In conjunction with installation of a thick-web rail moveable bridge joint, the deck fasteners on two girders were changed. On one girder, hook bolts with spring lock washers and locking nuts were used (Figure 7). On the worn ties at FAST, this system required maintenance after about 30 MGT of HAL traffic. Failure modes for individual fasteners included turning of the hook bolts, breaking of hook bolts, and breaking of the springs. A concern is that there is no recommendation for the tightening of 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 8). Each of these problems was experienced on this particular girder at FAST.

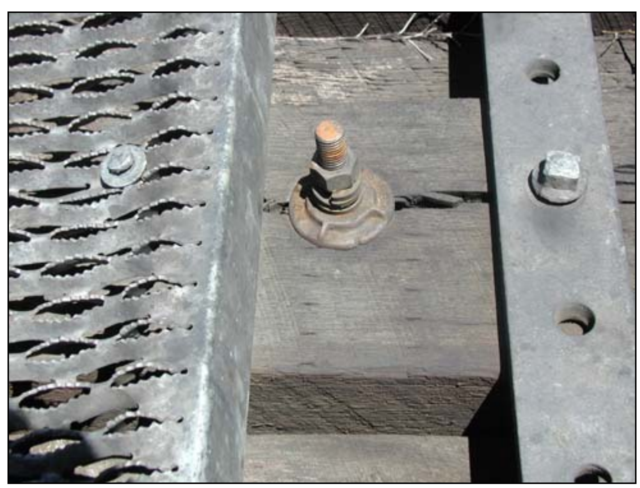

Figure 7: Locking Nut, Spring Lock and Washer

Figure 8: Broken Lock Spring on Hook Bolt

Retrofit 5

At the same time as 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 4). This system has performed satisfactorily, accumulating over 100 MGT of HAL traffic with no maintenance required.

The same concern regarding lack of a spring tightening specification applies to this system. The locking clips, however, prevent turning of the hook bolts in case the spring is not tight enough.

Figure 9 provides a summary of the performance of the various systems thus far.

FUTURE TESTS

In addition to accumulating additional tonnage on the systems that are still performing satisfactorily, tests are being planned for other types of fastening systems. One popular system under consideration uses a standard bolt and a spring clip rather than a hook bolt.

References

1. Sasaoka, Charity, D. Davis, D. Otter, and B. Doe, "Evaluation of Specialized Rail Joints for Moveable Bridges under HAL Traffic," *Technology Digest* TD02-016, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado, July 2002.

2. Sasaoka, Charity, D. Davis, D. Otter, and B. Doe, "Testing Rail Joints for Moveable Bridges," *Railway Track & Structures*, September 2003, pp. 21-25.

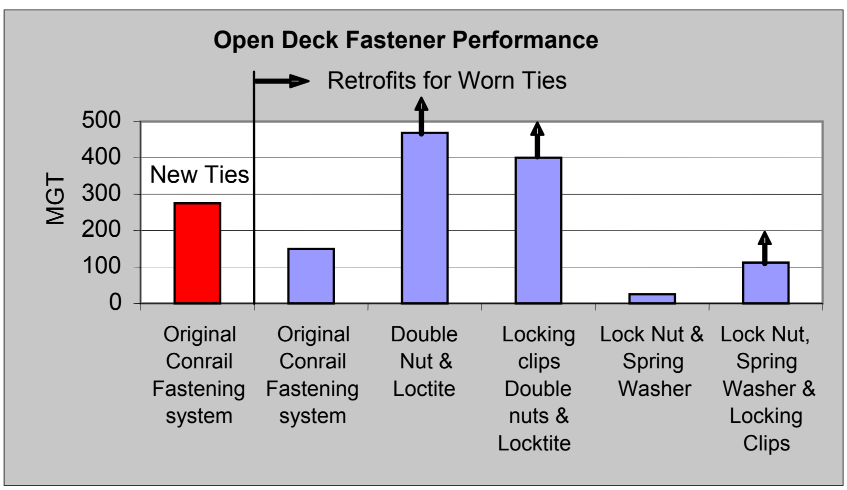

Figure 9: Comparison of Hook Bolt Fastener Performance