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Update on Bridge Deck Fastener Performance on the Facility for Accelerated Service Testing Steel Bridge

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, in 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 paper. 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 (lb) HAL traffic since installation in late 1997.

Figure 1. Open Deck Steel Bridge at FAST.

BACKGROUND

With about 9 million feet of bridges on the major U.S. and Canadian railroads, there are millions of deck fasteners in service; however, little information is available to compare and document their performance. Results show 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.

The track at FAST, used for full-scale railroad testing since 1976, features a 2.7-mile loop with a wide variety of rails, ties, and track components subjected to railroad loading. An 80-car test train circles the test loop approximately 500 times per week. Car loading is 315,000-lb 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, open-deck steel bridge was added to FAST (Figure 1) on a tangent alignment between reverse curves. The test bridge has welded deck plate girder spans. The girders were designed 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 second-hand spans have two girders spaced at 6.5-foot centers and smooth top flanges. As Conrail donated the spans, the first deck and fastener system to be tested were to their specifications, using dapped oak ties.

To date, eight variations of bridge deck fastener systems have been evaluated on the bridge. Figure 2 summarizes their performance. 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.

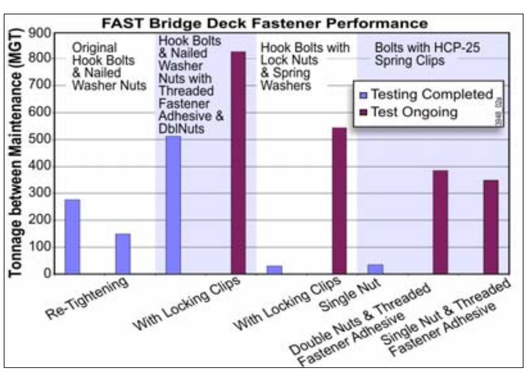

Figure 2. Deck Fastener Maintenance Intervals at FAST.

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 became loose, turned, or broke.

FASTENER SYSTEMS PERFORMANCE

Original Installation

The original Conrail hook bolt configuration consisted of a 14-inch hook bolt with a washer nut with a nail hole to prevent the washer nut from turning (Figure 3). This system withstood about 275 MGT of HAL traffic before the hook bolts were straightened and the nuts tightened. During the first tightening, there was one broken hook bolt and 22 spun hook bolts out of 56. Due to deep girder flanges, the fluting of the hook bolts was minimally engaged in the ties. In many cases, the hook bolts turned loose over time, rounding the holes in the deck ties so that the fluting no longer engaged the ties. 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.

After aligning and tightening all hook bolts, the original hook bolts and nailed washer nuts withstood about an additional 150 MGT before a similar number of hook bolts became loose or rotated, again attributed to rounded holes in 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 Fastener Adhesive

After the original system performance was established with new and worn ties, a common field retrofit was applied. The hook bolts were aligned and tightened with double nuts. A threaded fastener adhesive (Loctite) was applied to keep the nuts from loosening (Figure 4). Maintenance was required due to loose or spun hook bolts after 511 MGT.

Figure 4. 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 [Ref. 1,2]. On those ties, high dynamic loads vibrated the hook bolts loose daily (1 MGT). Several hook bolts broke at both the bottom and top.

On ties beneath the joint castings, locking clips were added to prevent the hook bolts from turning and loosening (Figure 5). These locking clips significantly reduced the amount of hook bolt maintenance required (5 to 10 MGT intervals). Figures 5b and 5c show conditions that required maintenance. Fastener maintenance dropped to the levels experienced on the remainder of the bridge only when the casting joint was removed from the bridge.

Figure 5. Hook Bolt Fasteners with Locking Clips, (5a) Typical, (5b) Turned Hook Bolt, and (5c) 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 from a derailed car. This combination performed well for over 825 MGT with no maintenance required and 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 6a). In theory, the spring washer should keep the hook bolt in contact with the bottom of the flange. On worn ties at FAST, this system required maintenance after about 30 MGT. Failure modes for individual fasteners included hook bolt turning, hook bolt breaking, and spring breaking. 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 6b). Each of these problems were experienced on this particular girder at FAST.

Figure 6a (left). Locking Nut, Spring Lock, and Washer. Figure 6b (right). Broken Spring Lock on Hook Bolt Hook Bolts with Lock Nuts, Spring Washers, and Locking Clips.

Concurrently, the second girder was equipped with a similar system of hook bolts with spring lock washers and locking nuts, but with locking clips. This system accumulated over 540 MGT of HAL traffic with no maintenance required. The addition of the locking clips has been particularly effective. This test is ongoing with additional accumulated tonnage.

Bolts with HCP-25 Spring Clips and Single Nuts

This commonly used bridge deck fastening system consists of bridge deck bolts with spring clips to engage the bottom of the flange. Several sizes of spring clips are available, depending on the girder top flange thickness.

The HCP-25 model was recommended for the steel bridge at FAST, with a flange thickness of approximately 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 similar to an elastic rail fastener on a rail base. Ears on the spring clip engage the ties to prevent rotation. After approximately 35 MGT, the nuts on close to a third of the fasteners loosened and several spring clips rotated requiring maintenance. Figure 7b 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 7a, 7b, and 7c). Note that the top flanges steel bridge is 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 7a (left). HCP-25 Spring Clip with Single Nut. Figure 7b (center). Rotated Spring Clip and Gouge in Girder Flange. Figure 7c (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 7c). This system has performed satisfactorily, accumulating over 380 MGT of HAL traffic with no maintenance required, but was also susceptible to some gouging. This test is ongoing with additional tonnage being accumulated.

Bolts with HCP-25 Spring Clips and Single Nuts with 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, but was also susceptible to some gouging. This test is ongoing with additional tonnage being accumulated.

CONCLUSIONS

The performance of eight bridge deck fastener systems is being evaluated on the FAST steel open-deck bridge with dapped oak ties. The deck has carried over 1,300 MGT of HAL traffic with 315,000-lb cars since its installation in late 1997. Observations to date are:

- The original installation required maintenance after about 275 MGT 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 maintenance was needed.
- During the second alignment and tightening maintenance, double nuts and Loctite were applied. This system has performed very well in three different fastener systems.
- Locking clips were installed in October 2001 with new hook bolts on one girder. Installation has been effective in two different fastener systems.
- Spring washer assemblies in conjunction with locking clips are performing satisfactorily to date on worn ties. Lack of a tightening specification for the spring washers is a concern.
- Spring washer assemblies without locking clips lasted only about 30 MGT before a significant number of hook bolts loosened and turned. Again, lack of a tightening specification is of 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.

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