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Effect of Missing or Broken Fasteners on Gage Restraint of Concrete Ties

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Summary

In 2009-2010, the Transportation Technology Center, Inc. measured gage restraint of mainline concrete tie track affected by missing or broken fasteners. Measurements were taken at the Facility of Accelerated Service Testing and at the western mega site in revenue service.

A concrete tie rail fastener provides gage restraint through the toe load (hold-down force) on the base of the rail provided by the tie clips and through lateral resistance from the insulators pressing against the base of the rail. Missing or broken fasteners can reduce the track's gage strength. The research showed the following:

- Missing or broken field side clips were found to have less effect on gage restraint than missing or broken gage side clips. Missing field side insulators had a greater effect on gage restraint than missing gage side insulators. Gage side clips appeared to play a bigger role than field side clips in preventing gage widening due to rail roll. On the other hand, field side insulators had a bigger role than gage side insulators in resisting gage widening due to rail translation.
- It took eight consecutive ties missing only clips or insulators to reduce gage restraint below the maximum limit. When both clips and insulators were missing, however, it took only three consecutive ties to reduce gage restraint below the maximum limit.

Measurements were taken in warm and cold temperatures for both tangent and 2-degree curve track locations. Measurements were taken primarily using a light track loading fixture and were verified using the Track Loading Vehicle.

The research presented in this *Technology Digest* addresses one of the concerns for the performance of concrete ties under heavy axle load train operations, including missing or broken fasteners, rail seat abrasion, pad wear, loss of toe load, improper fastener configuration, and excessive lateral rail movement. A similar study was done for wood ties in 1994.[1] The research is funded jointly by the Association of American Railroads and the Federal Railroad Administration under the revenue service mega site testing program.

INTRODUCTION

Gage restraint is a key requirement for track integrity and track strength. It is essentially the ability of track to maintain proper track gage for safe train operations. For concrete tie track, gage restraint is provided primarily by rail fasteners. A rail fastener (Figure 1) often consists of a plate, a pad, two insulators, and two clips on the gage and field sides of the rail.

A rail clip, when engaged on the base of the rail, provides gage restraint through toe load (hold-down force). On the other hand, an insulator provides gage restraint through its lateral resistance against the base of the rail.

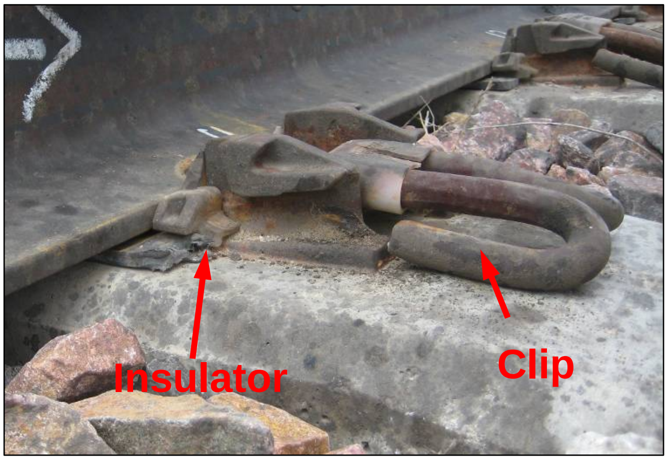

Figure 1. Example of Rail Fastener for Concrete Tie Track (Note that the clip shown is not engaged on the rail)

For concrete tie track under heavy axle load (HAL) operations, railroads and the Federal Railroad Administration (FRA) are concerned about several issues from both safety and maintenance perspectives, including missing or broken fasteners, rail seat abrasion, pad wear, loss of toe load, improper fastener configuration, and excessive lateral rail movement. A previous study conducted by Transportation Technology Center, Inc. (TTCI) in cooperation with the Union Pacific Railroad (UP) addressed some of the toe load concerns through research conducted at the western mega site.[2] This *Technology Digest* (TD) addresses the missing or broken fasteners issue.

Under HAL train operations it is inevitable that some rail fastener components, such as clips and insulators, will break or become loose over time (Figure 2 shows an example). As such, there are questions concerning how track integrity or gage restraining capability by rail fasteners may be compromised as a result of failed or missing fasteners and how different parts of a fastener system can affect gage restraint (gage strength). Answers to these questions provided by actual field testing and measurements may help railroads develop and optimize their track maintenance practices.

Track and Test Methods

In 2009-2010, TTCI completed an investigation of the effects of missing fasteners on gage restraint or gage strength. Tests were conducted at Facility for Accelerated Service Testing (FAST) and in revenue service.

Figure 2. Example of Missing Fasteners in Revenue Service

At FAST, the concrete tie track that was tested uses a Fastclip type of fastener system (Figure 1) and is part of a section of tangent track. At the revenue service western mega site located near Ogallala, Nebraska, the concrete tie track uses a SAFELOK® clip type of fastener system (Figure 2). Tests were conducted on both tangent and curve track locations. At FAST and in revenue service, all the tracks tested are classified as FRA Class 4 and are designed for HAL train operations.

Figure 3 shows a light track loading fixture (LTLF) used to measure gage strength. At each test location, a gage widening force of 9,000 pounds was applied to the gage face 5/8 inch from the top of the railhead. Lateral rail deflections were measured at the head and base of both rails. For the given gage widening test load, higher deflections correspond to lower gage strength.

Testing with the LTLF does not consider the hold-down moment produced by vertical wheel forces. Therefore, a test using TTCI's Track Loading Vehicle (TLV) was conducted at FAST to verify the findings obtained using the LTLF. With the TLV, gage widening was measured under 33,000 pounds of vertical wheel load and 18,000 pounds of lateral wheel load (gage spreading load) while the TLV moved along the track.

Figure 3. LTLF for Gage Strength

For each test section selected, clips and/or insulators were removed from both rails one by one to simulate missing or broken fastener conditions. Gage strength was measured for the baseline or "as found" condition and after the fasteners were removed. Missing clip conditions were created in three different phases:

- Phase 1 – Field side rail clips removed on both rails
- Phase 2 – Gage side clips removed on both rails
- Phase 3 – Field and gage side clips removed on both rails

After each phase, all the rail clips were reinstalled before the next phase began.

With the LTLF, the gage spreading load was applied at the same location (center of the test zone) each time as the clips were removed sequentially, away from this location. Rail deflections were measured at this location as well.

For each test zone, clips were removed sequentially from a maximum of nine consecutive ties (a maximum of 18 clips).

To investigate the effects of missing insulators on gage restraint, the same three-phase test procedure was used, but both clips and insulators were removed.

Test Results at FAST

A pilot test was conducted at FAST before testing began in revenue service. For the pilot test, only clips were removed using the procedure described above, but the effects of missing insulators on gage restraint were not investigated.

Figure 4 shows the FAST test results, i.e., gage widening plotted against the number of rail clips removed. Note that gage widening is the sum of the lateral deflections from both rails, and 0 on the x-axis corresponds to the baseline condition.

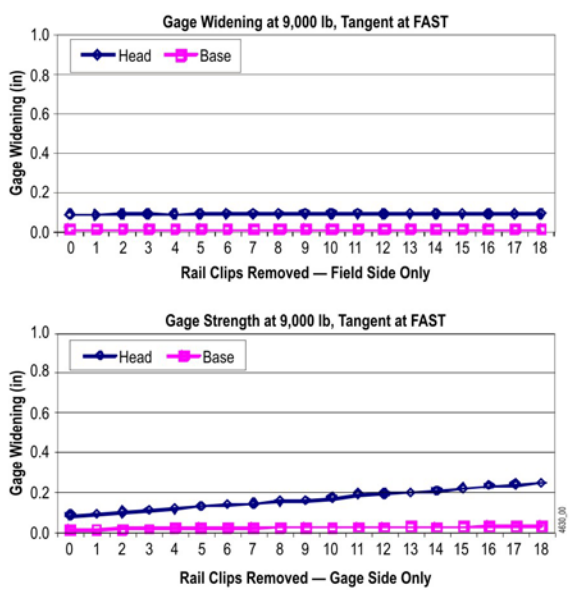

Figure 4. Gage Widening as a Result of Missing Rail Clips

The top graph shows the test results when the field side clips were removed, and the bottom graph shows the test results when the gage side clips were removed. Removal of the field side clips from up to nine ties had little effect on gage strength, but removal of the gage side clips had a more significant effect. As each additional individual gage side clip was removed, gage widening increased under the 9,000-pound gage widening force.

The results indicate that clips provide gage restraint primarily through their capability of preventing rail roll. When rail roll occurs, it rolls toward the field side of the rail with respect to the field side edge of the base of the rail. As such, toe load provided by clips on the gage side of the rail plays a much bigger role in preventing gage widening than clips on the field side of the rail.

The test was also conducted to determine the effect of removing both gage side and field side clips. The trends are similar to those shown in the bottom graph of Figure 4, with a maximum railhead gage widening measured at 0.35 inch. The test with the TLV was also conducted at FAST, but was done after the revenue service testing was completed. Results obtained from the TLV test are presented later in the TD.

Results in Revenue Service

The revenue service test sites were located at the western mega site on the heavy haul coal route near Ogallala, Nebraska. Tangent track at milepost (MP) 50.56 and a 2-degree curve at MP 50.35 were tested in two different seasons: one in warm weather (September 2009) and another in cold weather (January 2010).

Similar to test results obtained at FAST, the revenue service test showed that missing clips (up to nine consecutive ties) on the field side of the rail had less effect on gage strength than missing clips on the gage side of the rail. However, missing insulators on the field side of the rail had more effect on gage restraint than missing insulators on the gage side of the rail. Apparently, insulators provide gage restraint through their lateral resistance to the base of rail. As such, the field side insulators, rather than those on the gage side, are mobilized when gage widening occurs.

Figure 5 is a summary of the revenue service test results (2-degree curve, warm weather) concerning gage widening as a result of (1) missing clips on the field side of the rail, the gage side of the rail, and both the field and gage sides of the rail (three charts on the left) and (2) missing clips and insulators on the field side of the rail, the gage side of the rail, and both the field and gage sides of the rail (three charts on the right). Results are given for the baseline, missing fasteners for five consecutive ties, and missing fasteners for nine consecutive ties. The results support what was discussed above concerning the different effects of clips and insulators, depending on whether they are missing on the field side or gage side of the rail.

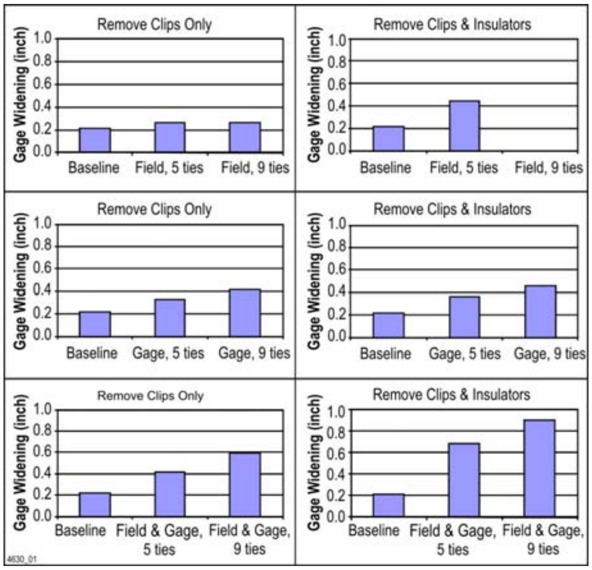

Figure 5. Effects of Missing Clips and/or Insulators on a 2-degree Curve in Warm Weather

Figure 6 shows a comparison of the test results for the tangent and 2-degree curve track in warm weather conditions, and for the 2-degree curve track in cold weather conditions. The results were obtained when the clips and insulators were removed one by one on both the gage and field sides of the rail for up to nine consecutive ties (a total of 36 clips and insulators). When all nine ties had their clips and insulators removed, the maximum gage spreading measured 0.97 inch. Changes in temperature did not cause significant differences in the results. It appeared that the effect of missing fasteners was more significant for the tangent track than for the 2-degree curve track.

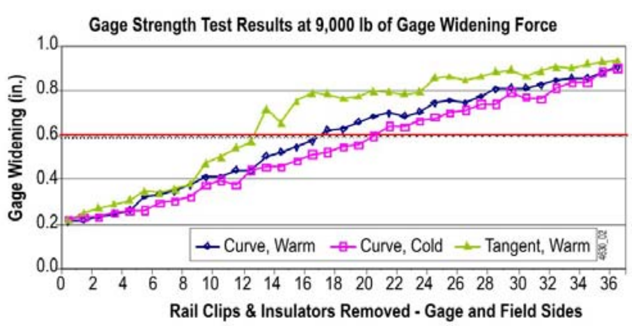

Figure 6. Comparison of Gage Widening Test Results under Different Track and Weather Conditions

TLV Test Results

In April 2010, a TLV test was conducted at FAST to determine if the findings obtained using the LTLF were valid, because a test using the LTLF does not consider the effect of vertical wheel loads on gage restraint. Figure 7 shows a summary of the TLV test results under three scenarios: (1) only clips removed on the gage side of the rail, (2) only clips removed on the field side of the rail, and (3) clips and insulators removed on both the gage and field sides of the rail.

Figure 7 shows the results obtained in the TLV test were similar to those presented in Figures 4 through 6; the TLV test verified the findings obtained using the LTLF.

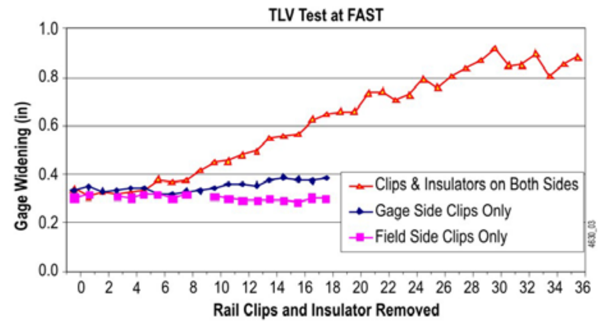

Figure 7. TLV Test Results

ALLOWABLE MISSING OR BROKEN FASTENERS

It is unlikely that all fastener components (clip and insulator) would fail on both the gage and field sides of the rail at the same time. To determine how many fasteners can be allowed to fail before compromising track strength and track integrity, a magnitude of 0.6 inch was estimated to be the gage widening limit at the 9,000-pound gage widening force produced by the LTLF. This estimate was based on FRA Track Safety Standards (Part 213, Subpart A to F) that specifies: (1) the maximum gage widening limit ratio under GRMS (gage restraint measurement system) is 1.0 inch, from which the gage widening limit at 9,000 pounds can be estimated to be (1.0 x 9,000/16,000) = 0.6 inch; (2) the gage widening limit is 5/8 inch (0.625 inch) under a 4,000-pound gage widening force using the LTLF when the force is applied at the web of the rail.

By comparing the 0.6 inch estimated gage widening limit to the test results obtained at FAST and in revenue service (e.g., Figure 6), the following conclusions can be drawn:

- In the case where only clips or insulators were missing, it took eight consecutive ties to reduce gage restraint below the allowable limit;
- When both clips and insulators were missing, it took only three consecutive ties to reduce gage restraint below the allowable limit.

Acknowledgements

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References

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2. Li, D., R. Jimenez, and E. Kohake. March 2009. “Revenue Service Test of Rail Anchors on Concrete Tie Track at Western Mega Site.” *Technology Digest* TD-09-007, AAR/TTCI, Pueblo, Colo.