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## In Track Tie Plate Performance: Plate Stress and Hold-Down Forces

Richard Reiff and Kari Gonzales

### Summary

A recent evaluation of the performance of a variety of fastening systems on timber ties suggested plate design and/or hold-down conditions may play an important role in system performance.<sup>1</sup> After less than 400 MGT of heavy axle load (HAL) traffic on a 6-degree curve at the Facility for Accelerated Service Testing (FAST), one type of tie plate (rolled) with high strength screw spikes suffered a significant number of failures (44%), while performance evaluations of identical plates and other plate designs with different hold-down components exhibited few or no failures. Under direction of the HAL Research Committee, the effect of failed hold-down components on plate stresses, as well as performance of different tie plate configurations, was evaluated.

Testing was conducted over several nights in Section 25 of the High Tonnage Loop at FAST. Three types of plates, Pandrol Rolled, Pandrol Victor and NorFast, were used to evaluate the influence of hold-down forces on plate stress. Two rosette strain gages were applied to each plate prior to installation in Section 25. Data was collected for 40 laps on each plate under various hold-down patterns. The patterns varied from no screw spikes loose to all screw spikes loose. In addition to the dynamic data collected, static data on a single plate was collected to determine the influence of increasing hold-down torque on the plate stress.

#### Results suggest:

- Two or more loose hold-down screws led to increased plate strains on one plate design.
- A single loose (or missing) hold-down screw had little effect on tie plate strains of other designs.
- One plate design with gage cleats exhibited higher strains than both flat plate designs.
- When torquing hold-down screws at lower torque values, tightening one screw tends to reduce the hold-down force of others.
- Actual hold-down force of a single screw spike varies depending on the tightening sequence:
  - During initial installation, some screw spike positions ended up producing no measurable hold-down force after adjacent spikes were fully tightened.
  - Not until the torque was equal to and above 220 lb-ft did all the screws contribute to holding the plate down.
  - This suggests that when hold-down spikes are at lower torque values, some spikes take more of the uplift load than others, possibly contributing to fatigue failures.
- The tie plate design exhibiting cracking during previous tests<sup>1</sup> produced the lowest strain values of all the plates tested; suggesting the location of high stress may not have been coincident with the strain gages.
- TTCI recommends additional work to develop plate designs that are less susceptible to variable hold down spike torque and to improve training of field installation personnel to ensure proper torque of hold down screws during installation and maintenance.



## INTRODUCTION

Recent results evaluating the performance of a variety of fastening systems on timber ties suggested plate design and/or hold-down conditions may play an important role in system performance.<sup>1</sup> A wood tie and tie fastener system test was conducted at FAST between 2003 and 2007. The focus of the test was determining the gage widening performance of various fastening system designs. The test consisted of a matrix of tie plates and clips installed using a range of high strength and standard screw spikes exposed to HAL traffic in a 6-degree curve at FAST. Although differences in gage widening performance were noted between fastening systems, conclusions could not be drawn on the overall performance of the fastening system because of the high rate of failures of screw spikes and tie plates after 400 MGT of testing. Results from the initial test varied depending on the type of screw spike utilized.

Plates fitted with high strength screw spikes exhibited high screw spike failure rates, while plates fitted with standard screw spike exhibited reduced or no screw spike failures. Since the large number of screw spike failures may have led to tie plate cracking and excessive wide gage, a follow-on test was completed to understand the stress induced in the various fastening systems under several hold-down conditions.

## OBJECTIVES

The current test was conducted to understand the influence of the tie plate hold-down conditions on tie plate stress. Stress data was collected for several of the tie plate designs, providing performance for each of the designs to provide information for optimizing installation and maintenance of hold-down systems for tie plates on timber ties.

## APPROACH

The approach follows previous evaluations of plate strains in standard tie plates on wood and plastic ties.<sup>2</sup> In the previous test, four rosette strain gages were mounted to the bottom of a conventional tie plate (along the field side of the plate where many fractures had occurred) to measure strains experienced by tie plates installed on wood and plastic ties. Results from the test conducted at FAST showed that the stress in the stiffer (wood) ties were significantly less than when installed on resilient (plastic) ties. In the current test, a pair of strain gage arrays was placed on the bottom of three different tie plate designs at or near where the largest strains were expected to occur. The plate designs included:

- Pandrol Rolled plate with e-clips
- Pandrol Victor plate with e-clips
- NorFast Plate with NorFast clips

In addition, load measuring washers were placed between screw spikes and tie plates of the NorFast plate to determine the effect of varying hold-down conditions, from loose to high torque under static conditions with no train operations. The NorFast plate was selected as its configuration allowed load measuring washers on all four corners without modification to the plate or washer.

During dynamic testing conditions, all plate designs were equipped with 2-4 load washers depending on the plate design.

Figure 1 shows the strain gage array. Figure 2 shows load washers installed on the Pandrol Rolled plate.



Figure 1: Bottom View of NorFast Plate, Showing Strain Gages



Figure 2: Top View of Pandrol Plate, Showing Measuring Load Washers

## DATA COLLECTION

After installation of strain gages, the plates were calibrated statically in the laboratory with a vertical load. Each plate was installed in Section 25 at FAST, 6-degree curve on timber ties, with the orientation shown in Figure 3. The test train at FAST contains 80 cars each loaded to GRL of approximately 315,000 pounds.

For this test, only the high rail of the curve was equipped with an instrumented tie plate. The plates were installed one night prior to data collection to allow the plates to properly bed into the tie. Testing was conducted over four consecutive nights of train operation. The first night, a tie plate from the previous test was used as a control. Following the control night, the Pandrol Rolled, NorFast, and Pandrol Victor plates were tested. Lewis Nut and Bolt manufactured special, 1-inch longer, screw spikes for this test to allow for the load washers to be installed with the NorFast plate during testing.

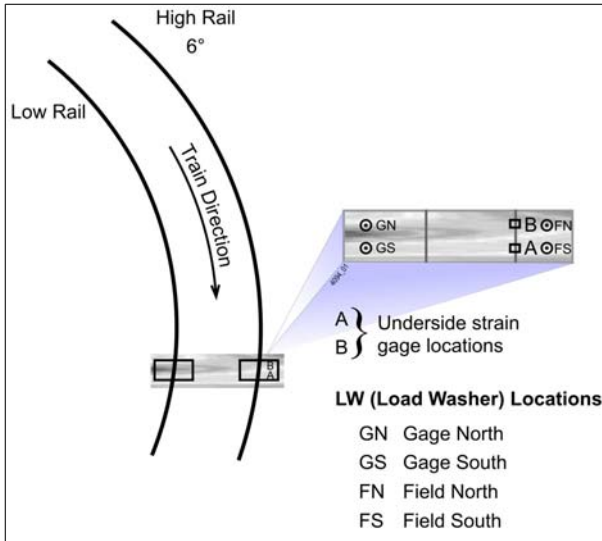


Figure 3: Tie Plate Orientation as Installed In Track

Each night, a set of static data was taken to ensure that the strain gages were installed properly and were not damaged. After the static data was collected, dynamic data was taken for 40 laps with a train operating speed of approximately 40 mph. Every three laps, the screw spike hold-down pattern was varied. The hold-down pattern varied from “all tight” to “multiple loose” to “all loose.” At the end of the test, the screw spikes were returned to the all-tight condition.

In addition to the dynamic testing, static tests were conducted to determine if the tightening sequence and installation torque of the screw spikes influenced the stress in the plate.

**RESULTS**

Data is summarized to show the average tie plate stresses and washer loads generated for five consecutive train passes over the ties.

**Dynamic Tie Plate Stress**

Figure 4 shows maximum principal stress measured under the passage of a train, averaged for three laps. As Figure 3 shows, in the direction of train travel, the strain gage at location B is encountered prior to strain gage at location A. Figure 4 suggests the NorFast plate experienced higher strains than the other plates, and the Pandrol Rolled plate experienced the lowest strain values. Similar trends were observed at strain gage location A. This may have been due to the cleats of the NorFast plate not fully seating into the tie and increasing overall plate bending.

Data also shows the effect on the overall plate stress when various screw spikes were intentionally loosened, intended to simulate the effect on tie plate stress from missing or broken hold-down spikes. Results suggest that the Pandrol Victor and Pandrol Rolled plates experienced no significant change in bottom of plate stresses generated by loose or tight hold-down screws, whereas the NorFast plate did experience an increase in strain when the gage side hold-down screws were loose (train passes 13-18). This data represents stresses generated

for a limited number of trains; no long-term effects were tested. Also, during the course of data collection, tie plates and ties remained normal to the curve, no skewing was observed.

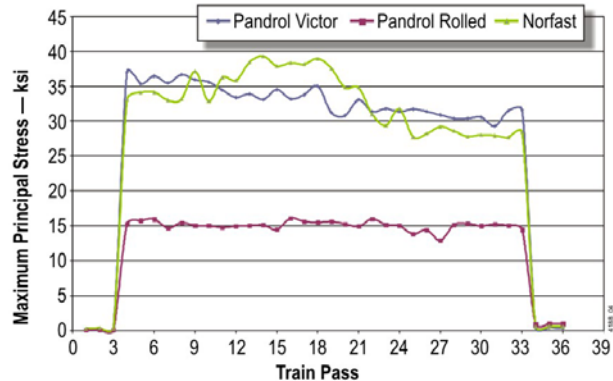


Figure 4: Maximum Principal Stress under Tie Plate, Gage B

**Static Screw Spike Hold Down Forces**

Figure 5 displays the effect of tightening sequence of screw spikes on the NorFast plate stresses for different load washer locations: field north (LWFN), field south (LWFS), gage north (LWGN), and gage south (LWGS). This data represents static hold-down forces that might be introduced only during installation or maintenance; no train operation was conducted during these measurements. Data is presented in four groups. Each group represents the final hold-down force generated after each of the four spike locations reached a specific torque. For this comparison, the torque was increased as follows:

- Group 1 – 180 lb-ft (interval 0-4)
- Group 2 – 200 lb-ft (interval 6-10)
- Group 3 – 220 lb-ft (interval 12-16)
- Group 4 – 240 lb-ft (interval 18-22)

Note that for each torque group, the spikes were tightened in a rotating pattern. For the first two groups (up to 200 lb-ft), some screw spike positions produced no measurable hold-down force. Only when the torque was equal to and above 220 lb-ft did all the screws contribute to holding the plate down. This suggests that when hold-down spikes are at lower torque values, some spikes take more of the uplift load than others, possibly contributing to fatigue failures.

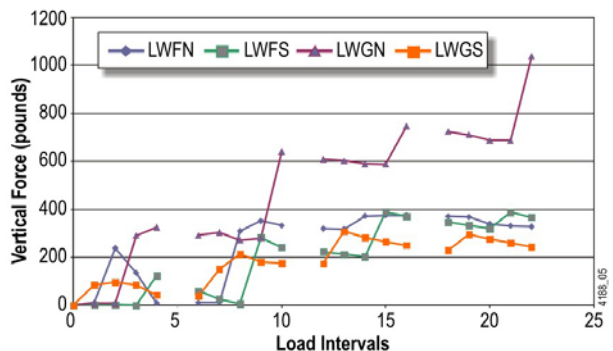
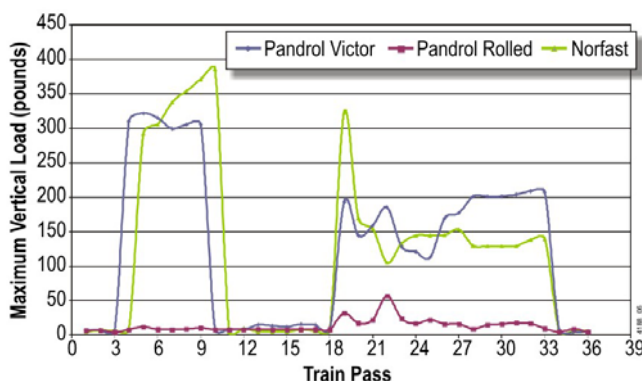


Figure 5: Hold-Down Load with Various Screw Spike Torque Values

### Dynamic Screw Spike Hold Down Forces

The effect of train operation over plates with broken or missing screw spikes was suggested as a contributing factor to accelerating other spike failures experienced during the previous test.<sup>1</sup> To determine the effect of one or more loose hold-down screws on tie plate strains and screw spike forces, the train was operated while various combinations of screw spikes were tightened or loosened. This test was performed using all three plate designs. The test sequence for each plate was similar, first starting with all spikes fully tight before operating the train, using a torque wrench to ensure full tightness. Spike forces as measured by load washers were collected while normal train operations at FAST were conducted. During this time, the field-side spikes were loosened, and then retightened, followed by the gage-side spikes. After a range of loose- and tight-spike conditions were created, all spikes were retightened in the field; however, train operations precluded the use of torque wrenches of power equipment.

As an example, Figure 6 shows data for the hold-down screw located on the north, field-side of the tie plate. The three lines represent the hold-down forces measured for each plate under the various loose-spike conditions shown.



**Figure 6: Maximum Dynamic Vertical Load Applied to Load Washers with Various Screw Spikes Loose and Retightened**

Data in Figure 6 is similar for all four positions evaluated. Note that the first all-tight condition generated higher hold-down forces than the final all-tight spike condition for two plates, which is similar in performance for other spikes. This suggests that field tightening (without the use of a torque wrench) did not replicate the original hold-down force, and/or repeated tightening and loosening of screw spikes (without the use of any type of plugging agent) gradually reduces total available hold-down force.

### DISCUSSION

During the previous wood tie fastener test, the Pandrol Rolled plate with high strength screw spikes experienced a high rate of fracture.<sup>1</sup> During the same period, however, identical Pandrol Rolled plates with standard screw spikes, and Pandrol Victor and NorFast plates exhibited no failures. The Pandrol Rolled plates, due to the sharp corner at the rail seat, under

some conditions, may be subjected to higher stresses. However, data shown in Figure 6 does not support this suggestion. During these evaluations, the Pandrol Rolled plate exhibited the lowest stresses of all plates, at least along the line where fractures had previously occurred.

### CONCLUSIONS

Results suggest:

- Two or more loose hold-down screws lead to increased plate strains on the NorFast plate.
- A single loose (or missing) hold-down screw had little effect on tie plate strains of the other plates.
- One plate design with gage cleats exhibited higher strains than flat plates.
- When tightening hold-down screws at lower values of torque, tightening one screw tends to reduce the hold-down force of others.
- The actual hold-down force of a single screw spike varies depending on tightening sequence:
  - During initial installation, some screw spike positions produced no measurable hold-down force after adjunct spikes were fully tightened.
  - Not until the torque was equal to and above 220 lb-ft did all the screws contribute to holding the plate down.
  - This suggests that when hold-down spikes are at lower torque values, some spikes take more of the up lift load than others, possibly contributing to fatigue failures.
- The tie plate design exhibiting cracking during previous tests produced the lowest strain values of all the plates tested, suggesting the actual location of high stress may not have been coincident with the strain gages.

### RECOMMENDATIONS

Data suggests loose or missing screw spikes can lead to increased tie plate strains and/or higher loads on adjacent screw spikes. This increases the importance for proper installation training, fully and equally setting of torque. Alternative plate and spike designs less susceptible to variances in hold-down torque should be investigated.

### REFERENCES

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2. Gonzales, Kari et al. February 2008. "Evaluation of Tie Plate Cracking on Composite Ties." *Technology Digest* TD-08-009, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, CO.

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