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# Preliminary Evaluation of Improved Strength Concrete Ties at FAST

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## Summary

Effects of various concrete tie design configurations are being evaluated analytically and experimentally under the Association of American Railroads' Strategic Research Initiatives Program at the Facility for Accelerated Service Testing, Pueblo, Colorado.

Tie design configurations in test are half-frame ties (a larger bearing surface area or "footprint") with under tie pads (elastomeric bearing pad), standard ties at 24-inch spacing, standard ties with under tie pads at 24-inch spacing, and standard ties at 20-inch spacing. The test ties have accumulated 265 million gross tons (MGT) of traffic, mainly under 315,000-pound cars. The following are preliminary test results and observations:

- All of the experimental tie configurations provide benefit in reducing tie-ballast pressures and reducing the rate of track surface degradation. Half-frame ties with under pads have the lowest predicted tie-ballast interface pressures. Half frame and standard ties with under tie pads both have the lowest predicted ballast subgrade interface pressures.
- The experimental results show that half-frame ties have the lowest surface degradation rate, and standard ties at 24-inch spacing have the highest. Current surface degradation rates suggest that track with half-frame ties will have 5 times longer surface life than track with standard ties. The analytical results suggest a similar surface life increase of 6 times higher.
- Ballast degradation is higher under standard concrete tie zones compared to zones with half-frame ties.
  - In the standard tie zone, after 242 MGT, the percentage of particles less than 1/2-inch size increased by 15-20 percent.
  - There is no change in ballast gradation characteristics up to the same tonnage in the half-frame tie zone.
- All test zones remained within FRA track Class 4 limits during the first 265 MGT of testing and required no surfacing. However, with the exception of the half-frame tie and 20-inch spacing zones, all test zones required ballast regulation because of ballast migration.
- The best feature of half-frame ties thus far seems to be their higher resistance to track buckling. During a Single Tie Push Test, which is a measure of track lateral buckling strength, half-frame ties showed more than double the value of standard ties.



**INTRODUCTION**

This *Technology Digest* reviews the effects of different tie design configurations on ballast degradation, surface roughness, and settlement. Modeling results are presented first, followed by the initial in-track test results of the different tie design configurations.

The number of heavy axle loads experienced per year by a typical track in North America have increased significantly over time causing additional stresses on the track. In addition, with the increase in traffic, the track maintenance windows are shrinking. Thus, track designs that help withstand the increased number of heavy axle loads, with minimum maintenance, are desired.<sup>1</sup> This is likely to be achieved by improving the load transfer pattern of ties by changing sizes, shapes, and spacing of prestressed concrete ties.

The ability of ballasted track to hold gage, alignment, and surface is severely tested in high speed rail (HSR) and heavy axle load (HAL) operations. Transportation Technology Center, Inc. (TTCI) is evaluating crosstie design configurations that will improve the durability of track for these applications.

A survey of crosstie usage for joint HSR and HAL track was conducted to benchmark North American practices. For very high speed service, where track surface and alignment must be maintained to very tight tolerances, nonballasted, continuous rail support track is often used. The initial cost and, often, the life cycle costs of this type of track can make it cost prohibitive for many freight operations.

Lower cost, less revolutionary crosstie design may provide the benefits of nonballasted track with the economy of ballasted track. Several such designs are being evaluated under the Association of American Railroads’ Strategic Research Initiatives Program. Most of these alternatives are usable with current maintenance equipment and procedures.

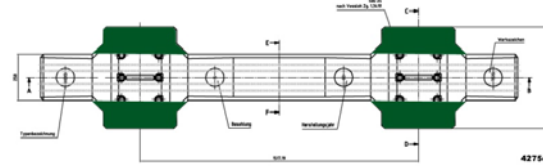
**Analysis of Alternative Designs**

Theoretically ties with larger “footprints” should reduce the ballast pressure and ultimately reduce ballast degradation. Similarly, ties with under tie rubber pads are expected to reduce ballast pressure by increasing the actual contact area at the tie-ballast interface. Reduction in ballast degradation can increase track surface life (i.e., longer ballast tamping or track surfacing cycles).

TTCI conducted a parametric study of the effects of varying tie footprints on ballast and subgrade pressures. This study looked at using conventional ties on shorter spacing, using unconventional tie shapes, such as frame ties (to increase the tie-ballast contact area under the rail), and using a tie-ballast interface pad.

One of the more innovative designs evaluated was a half-frame tie. Figure 1 shows the plan view of the tie. The areas shaded green show the “dog-ears” that extend under the rail from each rail seat. This additional area provides a bigger footprint in both the vertical and lateral planes. This should lower ballast pressures and extend track surfacing cycles.

However, this design could require modifications to the tampers currently used to fully achieve the optimal benefits of the design and production rates currently seen with standard ties.



**Figure 1. Half-frame Ties in Test at FAST**

Modeling of the five crosstie configurations, listed below, was conducted to evaluate load distribution and track surface life.

1. Base Case – standard concrete crosstie
2. Base Case 20 in. – standard tie on a closer spacing
3. Half Frame – Half-frame crosstie
4. Base Case w/Pads – a standard tie with a bottom elastomeric pad
5. Half Frame w/Pads – half-frame tie with a bottom elastomeric pad

Figure 2 shows the results of an elastic layer model of ballast and subgrade pressures at different locations along the tie. All of the proposed cases can reduce ballast and subgrade stresses. The modeling results show that the ties with bottom pads may be more effective than increasing the tie footprint. Lower pressures reduce ballast degradation and create even settlement patterns.

The ballast pressure data was used to model track surface degradation using ballast degradation and surfacing models developed by Chrismer and Selig.<sup>2</sup> Results in Table 1 suggest that a significant improvement in track surface life can be obtained using the half-frame ties with bottom pads. The model predicts a 660 percent increase in track surface life. The model also predicts 300 and 240 percent increase in service life of standard ties with rubber pads and half-frame ties without under tie pads, respectively. For weak subgrades, the half-frame ties are likely to provide a larger increase in surface life (on a percentage basis). However, all ties are

expected to provide a relatively short surface life on this type of foundation.

The increase in track surface life on capacity constrained HSR and HAL corridors may justify a substantial initial cost premium. A full economic analysis will be done after long term testing of the five configurations under HAL traffic.

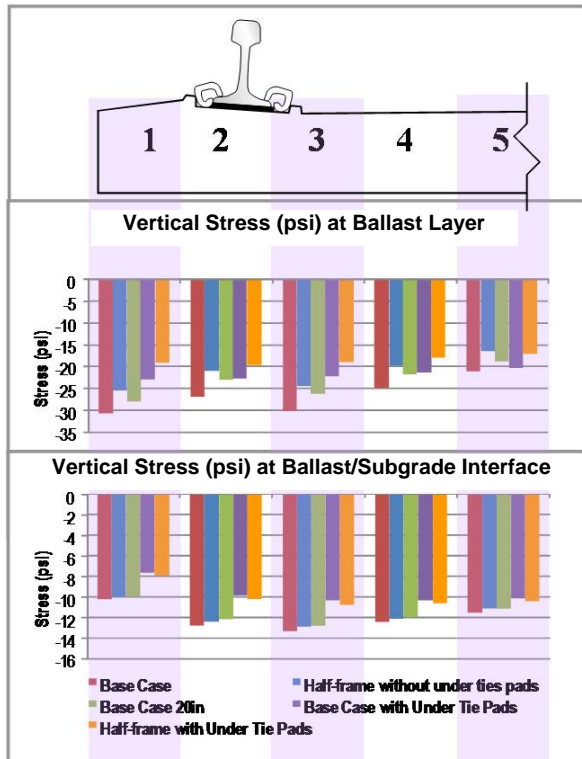


Figure 2. Predicted Ballast Pressures for Various Crosstie Configurations

Table 1. Predicted Track Surface Life for Various Crosstie Configurations

Predicted Surface Life	Base	Half Frame	Base @ 20 in.	Base w/pads	Half Frame w/pads
MGT	195	468	273	585	1,287
Normalized	1.0	2.4	1.4	3.0	6.6

**Performance Evaluation under HAL Traffic**

Five crosstie configurations, as described below, were installed in the 5-degree curved track on the High Tonnage Loop at the Facility for Accelerated Service Testing. There are five approximately 100-tie each/200-foot-long zones. There is a transition zone before the first zone and at end of the last zone.

- Transition zone** – 30 ties at 24-inch spacing, with e-clips.
- Zone 1a** – 95 half-frame SSL ties with Vossloh fastener system, Getzner soft rail pads and 4 clips per tie.
- Zone 1b** – 95 half-frame SSL ties with Vossloh fastener system, Getzner soft rail pads and 6 clips per tie (2 gage clips per rail seat).
- Zone 2** – 100 conventional scalloped ties – control zone 24-inch spacing with Pandrol® ‘e’clips and Safelok fasteners.

**Zone 3** – 100 CXT ties with factory installed under tie pads – 24-inch spacing with Pandrol Safelok fasteners

**Zone 4** – 100 used conventional ties with field installed Getzner under-tie pads – 24-inch spacing.

**Zone 5** – 100 conventional scalloped ties – 20-inch spacing

**Transition zone** – 30 ties at 24-inch spacing, with Safelok clips

The test ties have accumulated 265 MGT to date. No ballast surfacing was performed on any of the zones. The only significant maintenance issue is the rectification of ballast migration from high to low rail in zones 2, 3, and 4. Three clips of dog-bone ties broke, and approximately 24 percent of the dog-bone ties developed hair line cracks on the top of center tie.

**Ballast Degradation**

After 225 MGT, the ballast gradation of samples collected from under half-frame ties was similar to the ballast gradation at 0 MGT, suggesting that there was no significant ballast degradation under half-frame ties. However, the percentage of ballast passing a 1/2-inch sieve (and smaller size sieves) increased by 15-20 percent in the other tests zones. This suggests that half-frame ties induce lower pressure (due to a wider footprint) in ballast causing less ballast degradation. Another reason may be the higher weight of half-frame ties. Standard ties are lighter and may move up and down (pumping action) under wheels causing increased ballast degradation.

Results from the standard tie sections suggest that ballast degradation under ties with or without tie pads was similar. The model predicted that standard ties with under tie pads would have ballast pressure similar to half-frame ties. If that is correct, then ties with under pads should have ballast degradation similar to the half-frame ties. Long-term testing will verify if the model may have overestimated the benefits of ties with under pads.

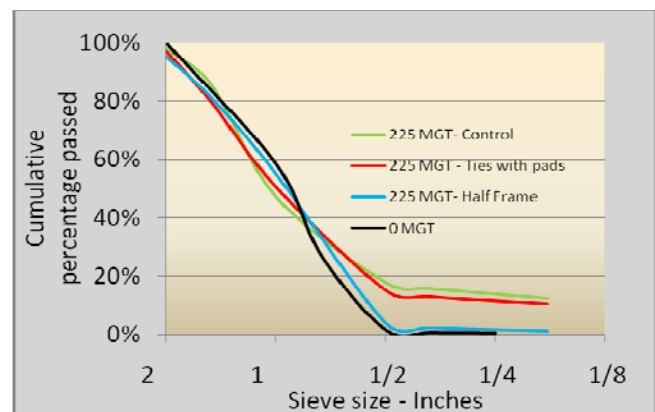


Figure 3. Ballast Gradation at 0 and 225 MGT

**Vertical Track Modulus**

Six ties in each zone were loaded using a heavy car (wheel load of 39,000 lbs) and a light car (wheel load of 8,000 lbs), and vertical track deflections were measured. The load from the light car was applied to get track slack out of the measurement. Table 2 shows that zones 3 and 4 have the highest deflections. This is most likely due to the soft under tie

pads. Zone 4 has standard ties at 20-inch spacing, which has increased the overall track stiffness. Track deflections in zones 1 and 2 are nearly similar, when first installed. Zone 2 has stiffened with tonnage.

Table 2. Loaded Vertical Track Deflection (in.)

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
0 MGT	.081	.079	.095	.115	.040
142 MGT	.087	.055	.115	.135	.042

**Track Surface**

Figure 4 shows track surface data collected for all test zones on the low rail using TTCI’s Track Geometry Car. Maximum values of dips and bumps appear to be similar for all zones, with the exception of the transitions between sections. However, the frequency of dip and bump cycles is lower in Zone 1 as compared to the other zones. Isolated higher data spikes at transition zones were removed for subsequent standard deviation calculations.

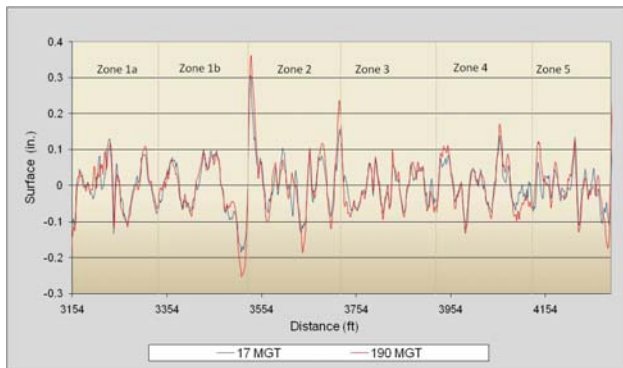


Figure 4. Vertical Track Alignment (Surface)

Static standard deviation of vertical track surface is used to represent the track quality, as the top graph in Figure 5 shows. Moving window standard deviations show similar trends. For all practical purposes, the trend is linear with tonnage. Zone 2 has the highest surface roughness, whereas zones 3 and 5 have the lowest among all five zones. However, the rate of change of surface roughness is lowest for Zone 1 and highest for Zone 2. On the basis of this data, predictions for the next required surfacing operation were made (see bottom graph of Figure 5).

If, for example, 0.1 standard deviation triggers a surfacing operation, then Zone 2 (standard ties) will likely be surfaced at about 400 MGT and Zone 1 (half-frame ties with pads) at approximately 2,000 MGT. Thus, Zone 1 has 5 times higher service life for this operation than Zone 2. This is very close to the predicted 6 times increase using analytical models. These preliminary field results can be used in an economic analysis by comparing the roughness degradation rates. If one assumes that the track with each tie design is built to the same levels of quality, then track surface life improvement is the inverse of the ratio of the degradation rates. Further, the surface life will depend on the initial roughness and the maintenance limit. For higher track classes, the payback period will be shorter because of a lower roughness limit.

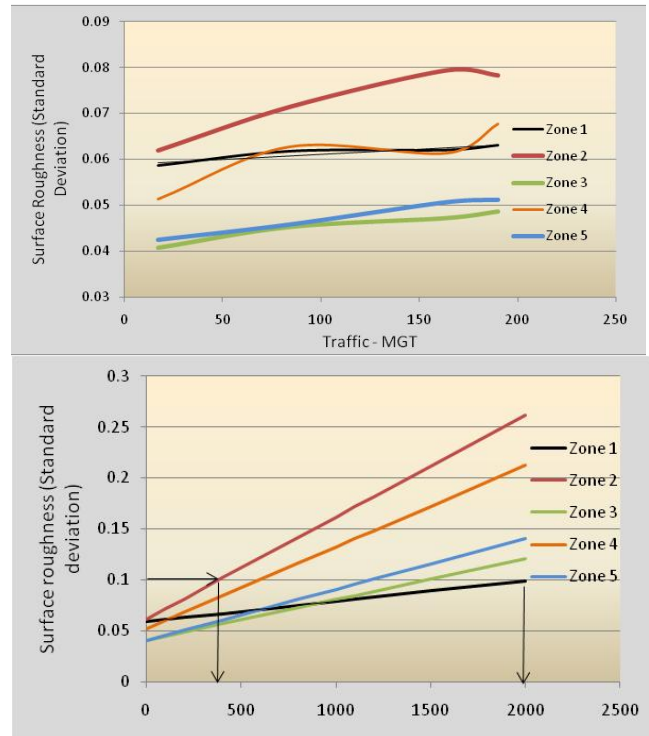


Figure 5. (Top) Data collected at FAST (Bottom) Prediction for Surfacing

Other track geometry measures (e.g., gage, cross level, horizontal alignment, and curvature) have not shown any considerable difference between the five test zones.

**Lateral Track Strength**

A series of lateral strength tests were conducted. As Table 3 shows, at 2 MGT, the standard tie showed a single tie push (STP) value of 3,800 pounds. After 150 MGT, the value increased to 5,000 pounds, showing that ballast compaction around the tie with traffic increased in lateral strength. At the same tonnages, the STP value for half-frame ties exceeded the capacity of the STP value of 10,000 pounds.

Table 3. Single Tie Push Values

Tie Type/Tonnage	2 MGT	150 MGT
Standard Tie (24-inch spacing)	3,800 lb	5,000 lb
Half-frame Tie	10,000 lb*	10,000 lb*

\*STP value capacity exceeded

STP test values are a measure of track strength against lateral track buckling. Thus far, the best feature of half-frame ties seems to be their lateral strength against track buckling.

**REFERENCE**

1. AAR, Railinc, and TTCI. October 2008. “Railroad Industry Priority Technology Goals and Directions for the Next 20 Years.” Research Report R-993. AAR/TTCI. Pueblo, Colo.
2. Chrismer, Steven and Ernest Selig. July 1994. “Mechanics-Based Model to Predict Ballast Related Maintenance Timing and Costs.” Research Report R-863. AAR/TTCI. Pueblo, Colo.

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