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Ballast Degradation Test at FAST

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Summary

The Transportation Technology Center, Inc. (TTCI) has evaluated the effects of mineral dust impingement on track stability on the High Tonnage Loop (HTL) at the Facility for Accelerated Service Testing (FAST) from 2009–2013. Degradation of track geometry in response to various percentages of fine material (fines) in ballast was investigated. Research showed that the design variables did not have as much effect on track stability as was expected. The addition of moisture, initial percentages of fines present, and type of crosstie produced small differences in track stability and stiffness. Results indicate that a onetime major spill event of certain fine-grained materials in revenue service may not warrant major track cleaning efforts. Low density fines can be transported out of a ballast section that has good drainage during high rainfall events, resulting in minimal retention of fines.

Wood and concrete crosstie sections were used in this test, and fines percentage levels were “clean” (no fines introduced), 15 percent fines, and 25 percent fines in both sections.

The test parameters included settlement associated with accumulation of tonnage (MGT) on the HTL track sections; surveys were conducted approximately every 10 to 30 MGT. The Track Loading Vehicle was used to measure pre-test ballast stiffness and track stiffness for each section. Water was introduced into the ballast during specific phases of testing, with the hydrated sections receiving approximately 0.5 to 1 inch of water per week while the accumulated loading proceeded as planned.

After analysis, it was decided that the simulation at FAST did not represent revenue service conditions closely enough, and TTCI planned different approach for a future test in order to produce significant results. Factors such as periodic and significant influx of fines into the top of the ballast test section are critical, because fine material retains moisture more readily than coarser material. In addition, it was noted that fines with a relatively low density are transported out of the ballast section by turbulent flow during high intensity wetting events. This retains ballast stability under loading and wetting events. Finally, the lower ballast section must have a condition of fines packing in between the ballast particles, such that saturated conditions produced by continual wetting and the vibration of a passing train cause a pore water pressure increase and loss of contact between ballast particles. Together, these conditions would be expected to produce the degradation of track geometry that has been observed in revenue service conditions.

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INTRODUCTION

Ballast gains inherent stability from several factors: Angularity of ballast particles produces an interlocking effect that increases the internal friction angle of the mass; inter-particle friction between ballast faces adds to the internal friction angle and mass stability; and finally, the high permeability of new ballast induces quick drainage from induced internal moisture to outside the track boundaries.

Ballast wear can reduce each of these factors, as grain-to-grain dynamic movement under load can cause polishing of ballast faces, particle breakage, accumulation of fines in the ballast mass, and reduced drainage. Infiltration of dust from the ballast top surface can contribute to instability, since it may have lower density, lower frictional value, lower strength, higher field capacity for moisture retention, and lower mass hydraulic conductivity.

BALLAST SECTION DEGRADATION TEST

From 2009–2013, TTCI performed an evaluation of the effects of dust infiltration on track stability on the HTL. The introduction of clean, 15 percent, and 25 percent (of total voids) fines into the ballast mass was done in order to observe and compare track instability, lubricating effects of water, and dynamic effects on ballast mass. The various test sections were produced by blending each proportion after the materials were separated out from undercutter fines (Figure 1) obtained from revenue service sources.

Figure 1. Construction of the Test Zone Ballast Blends

The test zone in Sections 36 and 37 was divided into the following 85 crosstie (138 feet) subsections, as Figure 2 shows:

1. Section 36 Ties 200–285: Wood crosstie control with 12-inch screened ballast layer
2. Section 36 Ties 286–370: 15 percent fines below wood crossties
3. Section 36 Ties 371–455: 25 percent fines below wood crossties
4. Section 36 Ties 456–540: 25 percent fines below concrete crossties
5. Section 36 Tie 541–Section 37 Tie 025: Concrete crosstie control with 12-inch screened ballast below crossties

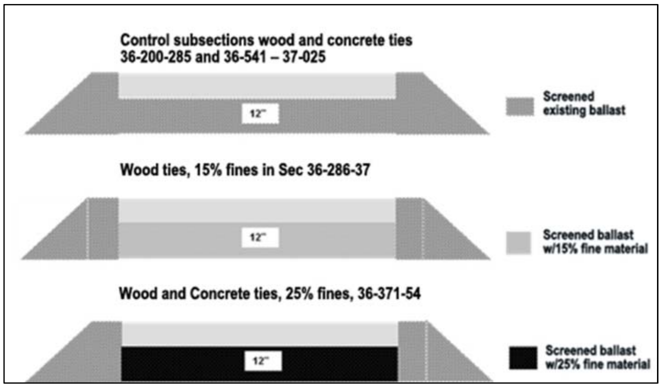

Figure 2. Test Zone Ballast Subsections

Figure 3 shows the initial gradations were designed to be heavily out-of-specifications for the AREMA 24 maximum (for the fines portion) in order to simulate limited ballast degradation and to be able to test the stability of various gradational percentages. The gradational design was intended to produce instability in the subgrade that could be observed, tested, and modeled.

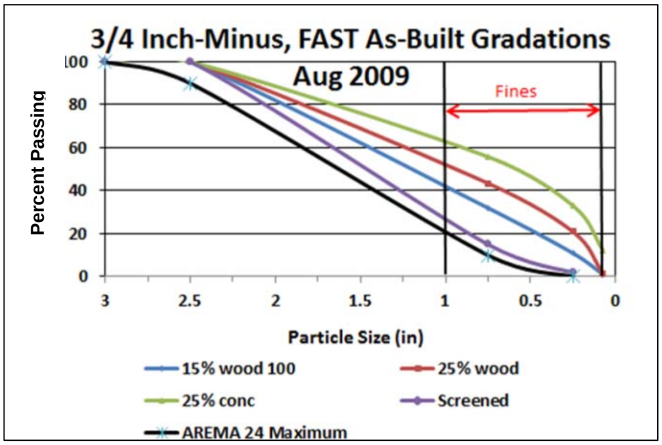

Figure 3. Ballast As-Built Gradations

PERFORMANCE MEASUREMENTS

Performance metrics during testing were accumulated settlement, track settlement surveys, and track stiffness. Analysis included comparisons of the track stiffness for the various gradational percentages under the wood and concrete sections, as well as effects of the introduction of moisture into the ballast mass. Ballast samples were collected at regular intervals to monitor changes in gradation.

Accumulated Settlement

To determine accumulated settlement, sampling of the ballast was performed in spring and fall of each year, with final sampling done in May 2013. Grain size analysis was performed on the ballast samples in general accordance with the ASTM C136-06 method. The ballast gradations generally did not indicate unexpected levels of fines or accelerated accumulation of ballast fines during that time. The final sampling revealed fines gradations that were grouped into a tighter mean than the as-built gradations. This was likely due to low density fines undergoing hydraulic or wind transport out of the ballast into the right-of-way over time.

It appears that much of the less dense fines placed in the original gradational site may have migrated downward and possibly outward from the track centerline, particularly in the first few weeks and months after placement. This could have happened during tamping, initial wetting events, and accumulation of initial track MGT.

It was also observed that subsequent ballast sampling events did not display the expected coloration that would normally be present with the infiltration levels of various fines (Figure 4).

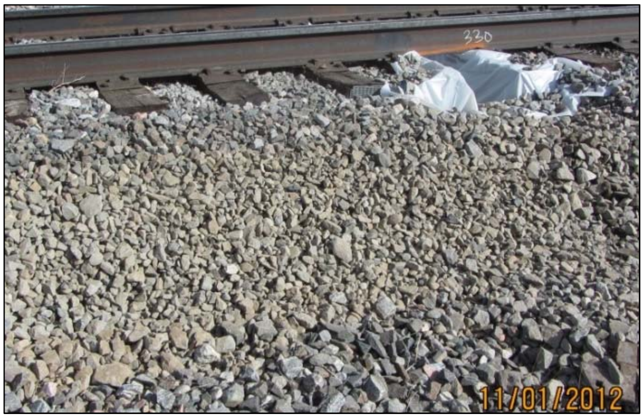

Figure 4. Excavated Ballast face at 180 MGT shows few fines and little discoloration under the 15% Fines Wood Tie Section

Figure 5 shows the gradation of the fines in the final sampling event. Gradations were performed down to the No. 4 sieve, resulting in a "tail" of fines continuing outward, which represents pan fine material. Further analysis would have smoothed the tail downward, but would not have revealed additional usable data for this project.

In comparing the fine material gradations from the initial and the May 2013 conditions, the fine material fraction has decreased noticeably since the beginning of the test, as fines were transported out of the ballast mass, and evidence of crushing is seen in the control ballast gradations.

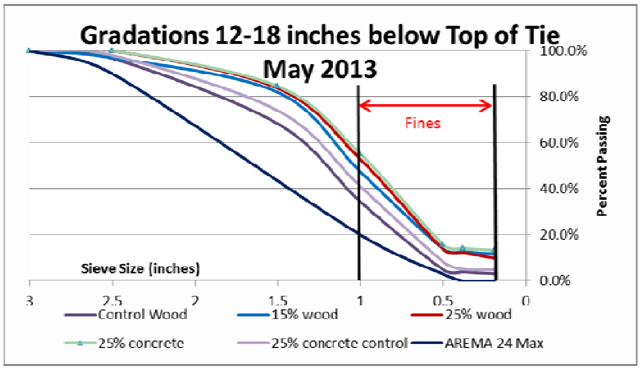

Figure 5. Final Ballast Gradations

Track Settlement Surveys

Track optical surveys were performed every 10 MGT on Section 36. As Figure 6 shows, average track settlement was significant up to approximately 30 MGT, with about 1.25 inches of settlement. After 30 MGT, the track stabilized considerably, with an average of approximately 1 additional inch of settlement for the next 170 MGT.

Approximately 0.5 to 1.0 inch of water was added weekly to the test track sections during various phases of the testing. It was observed that hydration of the ballast and subgrade had slight effect on the settlement or stability of the subgrade in these test sections.

Differential settlement over time was also recorded, as Figure 6 shows, but it did not indicate a cause for additional scrutiny since differential variation was minimal between the various test configurations.

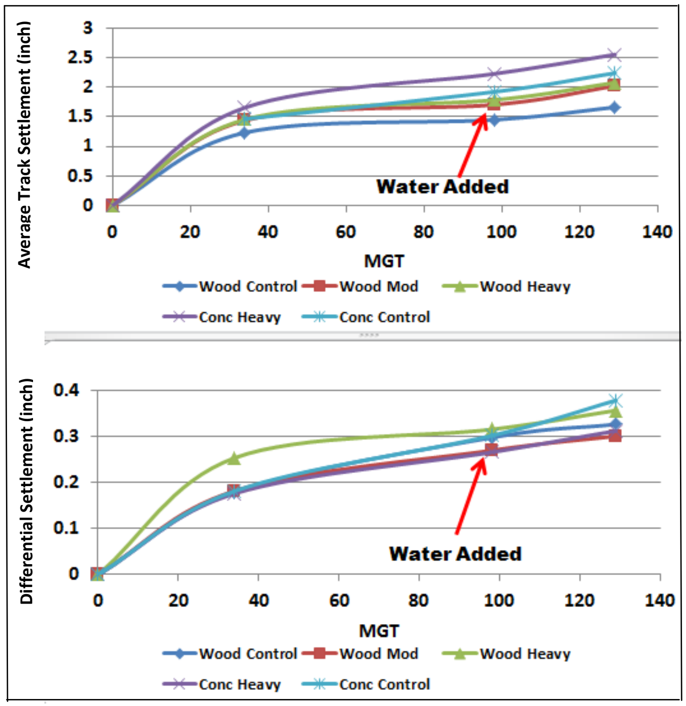

Figure 6. Average 2012 Track Settlement and Differential Settlement

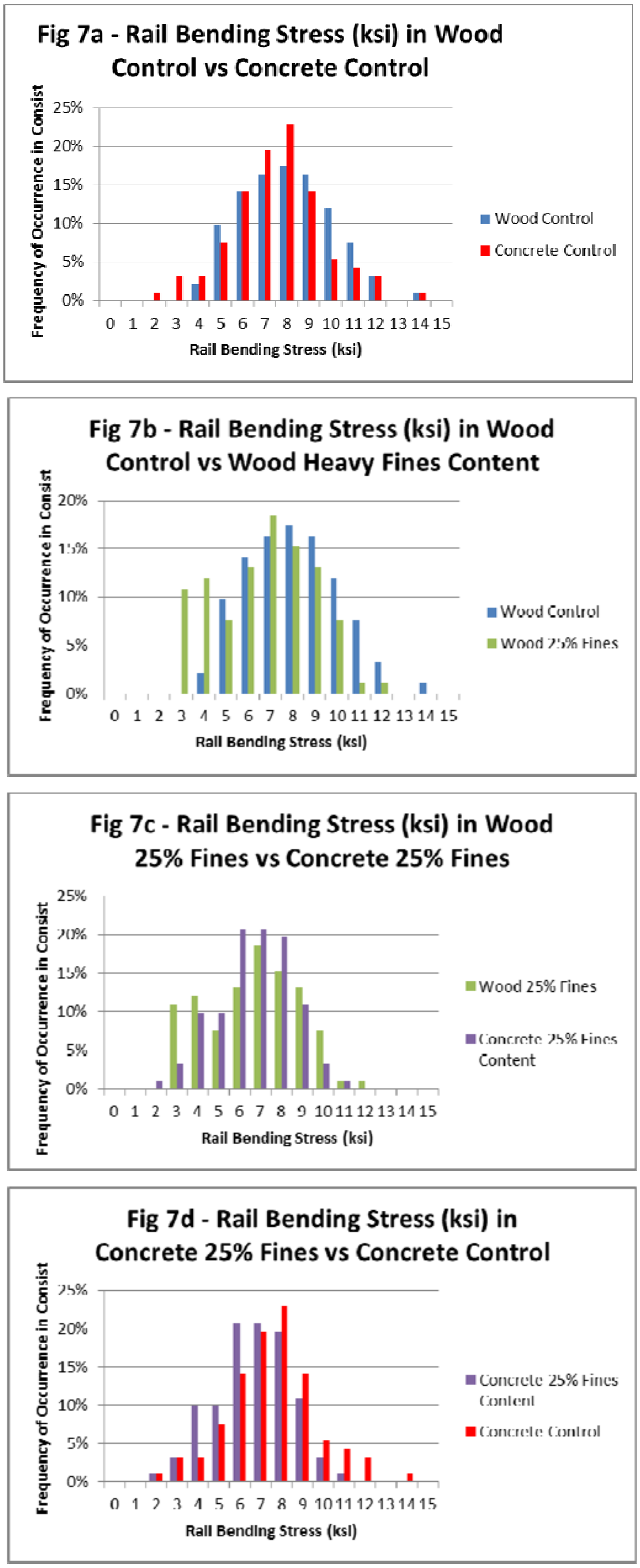

Figure 7. Rail Bending Stress During Consist Passage

Track Stiffness

Measurements were recorded several times during the data collection phase to test and confirm track stiffness in the test sections. It was assumed that concrete ties would bend less than wood ties as the train passed over them; hence, rail bending stress would be less in the rail strain gages in concrete tie areas. It was also assumed that ballast loaded with mineral fines would offer less support (hence, greater rail bending stress) than ballast with no fines.

Figure 7 shows comparisons that indicate rail bending stress was not significantly different between wood tie and concrete tie sections. Figure 7a shows average rail bending stress was 8 ksi, about the same in concrete tie sections as in wood tie sections, although concrete tie data was more tightly grouped. Results lead to the tentative conclusion that concrete ties offer slightly less variability in support, compared to wood ties.

Figure 7b shows the wood tie section with 25 percent heavy fines versus control measurements does not indicate a stress difference great enough to offer conclusive results.

Figure 7c shows average rail bending stress was almost identical in wood tie versus concrete tie sections with 25 percent fines, although the concrete ties offered a slightly more tightly grouped data set, possibly indicating less variation in concrete tie structural variability.

Figure 7d shows rail bending stress in the concrete tie control versus 25 percent fines had nearly identical peak occurrence and stress maximums, although the control data was grouped more tightly, possibly indicating less variation in control support variability.

Some of the results shown in the plots may be due to the fact that subsequent gradations revealed that the controls had more fines and the test sections had fewer fines than assumed when the measurements were made. In each testing event 2011 and 2012, similar results were observed, and no apparent correlation could be established.

Conclusion and Way Forward

Although this test did not accomplish the creation of an unstable and testable set of ballast (with fines) sections at FAST, the data obtained has aided researchers in understanding that these levels of initial fines can still result in a stable track, even under moist conditions. Consequently, it may be concluded that a onetime major spill event of certain fine-grained ballast materials in revenue service may not warrant major track cleaning efforts. Low density fines can be transported out of a ballast section that has good drainage during high rainfall events, resulting in minimal retention of fines.

Additional testing planned for 2014 will more likely approximate field conditions with a new testing regime. Plans are being developed to initiate a 100 percent (of available voids) fines test section, with high moisture content. Major metrics will be continually monitored and renewed to maintain the initial test parameters.