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RESEARCH RESULTS

FRA OFFICE OF RESEARCH, DEVELOPMENT & TECHNOLOGY

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SETTLEMENT OF FINE-CONTAMINATED BALLAST

SUMMARY

In 2017, the Federal Railroad Administration (FRA) and Transportation Technology Center, Inc. (TTCI) constructed and performed ongoing initial tests on a "Rainy Section" (Figure 1) of track in the Facility of Accelerated Service Testing (FAST) to quantify the drainage, accelerated settlement, and dynamic behavior of fine-contaminated ballast. This test section allows TTCI to control the wetting and drainage of the section in order to simulate various degrees of rain events, in addition to dynamic loading and pulsing of the test section under heavy-axle-load (HAL) train traffic.

The first testing iteration involved using non-plastic sand and silt-sized fines from degraded granite ballast to represent the fine-contaminated ballast that occurs from progressive ballast degradation and not from surface or subgrade infiltration. The ballast had 37.2 percent fine content (i.e., grain size below 4.76 mm), with the fines significantly filling the ballast voids.

Under dry conditions, the ballast section underwent less than 0.1 inch of settlement after 10.5 million gross tons (MGT). Fines accumulated at the surface after wetting and a 6-inch water table developed due to the dynamic loading and increased pore-water pressure. During this process and while still wet, the settlement rates were 5 to 10 times higher than the dry settlement rate. After drying, the post-mud pumping section returned to its pre-wetting settlement rates.

Additionally, the maximum settlement occurred in the center of the test section, suggesting the length of wetted fine-contaminated ballast section influences the settlement magnitude.

The test results showed significant influence from moisture, suggesting that the settlement behavior is highly dependent on (1) the influx of water from precipitation and runoff and (2) the drainage. This indicates that the ability to identify track locations with higher water infiltration rates, reduced drainage, and higher MGT will be beneficial for predicting track settlement in locations with fine-contaminated ballast.

Future tests are anticipated to investigate the influence of drainage and remedial action during the mud-pumping process. Similar tests on different fine materials are also anticipated to investigate how these factors affect the drainage and settlement behavior [1].

This research was completed under a cooperative research initiative between FRA and the Association of American Railroads (AAR) under their Strategic Research Initiatives program.

Figure 1. A water system at the Rainy Section at FAST as a train passes.

BACKGROUND

Fine-contaminated ballast is a condition in which the ballast layer becomes contaminated with fines from ballast degradation, surface infiltration, lading dust, or pumping up from the sub-ballast or subgrade. This condition, especially when wetted, can reduce the ballast performance by limiting drainage and increasing track settlement. These track sections often become a reoccurring maintenance challenge.

OBJECTIVES

This research investigated the settlement of a ballast section with a specific focus on the influence of moisture on ballast contaminated with sand and silt-sized fines produced from ballast degradation.

METHODS

The "Rainy Section" is a 40-foot-long test section located at the Transportation Technology Center in Pueblo, CO, and is comprised of two ballast boxes: a 13-tie test box (Site 1) and a 13-tie control box (Site 2). Using a watering system, the test section can be wetted, while the control section remains dry. This allows for a direct comparison of track behavior of a wetted and non-wetted region. The non-wetted ballast always contains some natural percentage of moisture, termed "field capacity," which can vary according to climatic conditions.

The Rainy Section is made up of 600-MGT degraded granite ballast, having 37.2 percent of fines passing the No. 4 sieve (4.76 mm) and 4.5 percent passing the No. 200 sieve (0.074 mm). This results in a Fouling Index (FI) of 41.7 (37.2 + 4.5) [1]. The fine particles are generally non-plastic sand and silt-sized that represent a highly-degraded granite ballast section.

RESULTS

Top-of-rail (TOR) elevation surveys were taken after each night of testing to measure the rail settlement during the test. The tests involved a loaded freight train, with 39-kip wheel loads and more than 100 cars in the consist, that passed through the Rainy Section about every 4 minutes at 40 mph. The test plan is displayed in Table 1.

Table 1. Table test plan 1: Fall 2017

Night	Date	Nightly MGT	Wetted Laps	Wetted MGT
1	9/26/2017	1.44	2	~0.03
2	10/9/2017	1.44	5	~0.08
3	10/10/2017	1.75	36	~0.54
4	10/11/2017	1.95	37	~0.55
5	10/12/2017	1.93	0	0
6	10/25/2017	2.01	0	0

The raw TOR elevation data is displayed in Figure 2 and shows natural variation in vertical rail surface and gradual degradation of the TOR geometry within the test section. The test section follows a natural topographic slope, explaining the elevation difference between both sides of the Rainy Section.

Figure 3 displays the rail settlement using 0.0 MGT as a reference point and shows that the wetted test section experienced greater settlement than the non-wetted control section and surrounding track. The maximum settlement was about 0.5 inches and is in the middle of the test section.

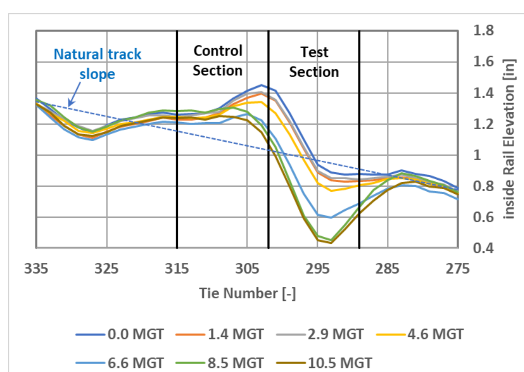

Figure 2: Rail elevation of control and test sections

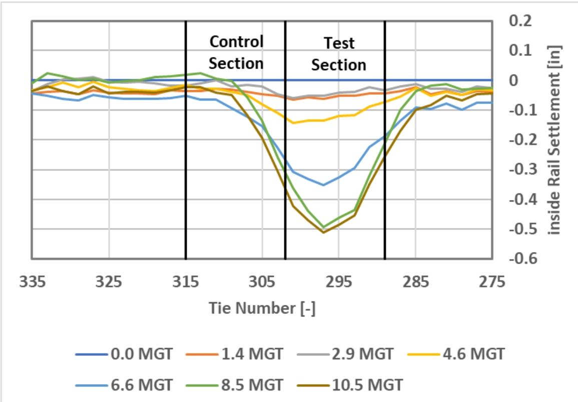

Figure 3: Settlement of control and test sections

Figure 4 takes four inside rail locations along the track (Tie 297, orange squares), control section (Tie 307, gray triangles), and surrounding track (Tie 283, blue diamonds and Tie 327, yellow circles) and plots the TOR settlement with increasing MGT. The test section results showed minimal settlement for the first two nights of testing and then about 0.08 inch after the third night of testing. This means after wetting the test section and developing a 6-inch water table, the influence of 36 train passes (~0.5 MGT) resulted in 0.08 inch of maximum settlement in the test section. The following night of runs resulted in settlement of about 0.22 inches. This is likely greater than the previous night because the mud pumping prevented drainage of the surface moisture so the upper ballast was likely near-saturated prior to the application of water for the last 37 laps (~0.5 MGT) [1]. No water was applied during the fifth night of testing, but settlement did occur because of the inability to fully drain the surface moisture. The entire section was dried by the sixth night and minimal settlement was observed.

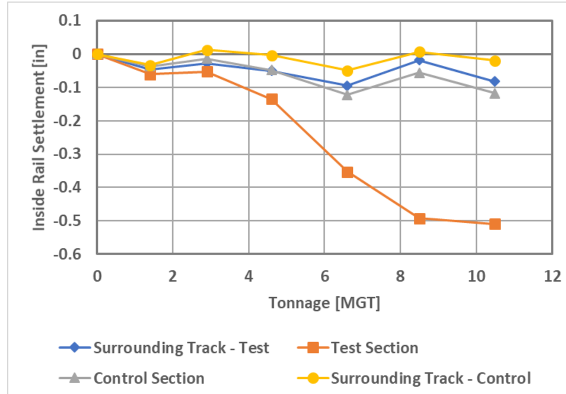

Figure 4: Rail settlement of inside rail with MGT

This change in settlement rate from various wetting and drainage conditions shows the influence of moisture on track performance. When the track system was saturated, the settlement rate increased and simultaneously produced mud pumping. The mud pumping changed the drainage condition and extended the time the track was saturated, which lengthened the time the settlement rates were increased. This cycle can produce conditions that are difficult to drain and maintain track geometry.

CONCLUSIONS

The results showed:

- Under dry conditions, a section of ballast with a fine percentage of 37 percent from naturally degraded ballast undergoes less than 0.1 inch of track settlement after 10.5 MGT.
- If wetted and a water table develops due to blocked drainage, mud pumping occurred and settlements rates increased 5 to 10 times the dry settlement rate.
- Fines pumping and accumulation into the upper ballast further decreases ballast matrix hydraulic permeability.
- The maximum settlement occurred in the center of the test section suggesting the length of the wetted fine-contaminated ballast influences the settlement magnitude. A longer test section may have resulted in more settlement.

- Under wet conditions, the settlement was progressive and did not show rapid deterioration.
- After drying, the settlement returned to its pre-wetting rate.

This test showed that moisture was a contributing factor to the settlement of ballast contaminated with fines from ballast-wear degradation and the settlement behavior are influenced by water infiltration and drainage. Ballast with a continual water source or inability to drain will behave differently than a dry section or a section that can drain prior to dynamic loading.

FUTURE ACTION

Future testing will investigate how different rain events wet the track section and how different track conditions (i.e., dry, wet and mud pumped, dry and mud pumped) relate to track modulus. These factors will be correlated to track settlement. Additional tests will also be completed on different fine materials to investigate how fine size and plasticity affects the drainage and settlement behavior.

REFERENCES

[1] Drainage Properties of Fine-Contaminated Ballast. *Research Result*. RR 19-01. February 2019.

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KEYWORDS

Ballast, fines, drainage, mud pumping, settlement