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Settlement of Fine-Contaminated Ballast

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Summary

Transportation Technology Center, Inc. (TTCI) constructed and performed initial tests on a “Rainy Section” in the High Tonnage Loop (HTL) at the Facility for Accelerated Service Testing (FAST) to quantify drainage, settlement, and dynamic behavior of fine-contaminated ballast. This test section allows TTCI to control the wetting and drainage of the section and simulate various rain events, in addition to dynamic loading and pulsing of the test section under heavy axle load (HAL) traffic.

The first testing iteration involved using sand-sized and non-plastic silt-sized fines from degraded granite ballast to represent fine-contaminated ballast that occurs naturally from ballast degradation and not from surface or subgrade infiltration. The ballast has 37.2 percent fine content (grain size below No. 4 sieve, 4.76 mm), with the fines significantly filling the ballast voids.

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

Observations from the first test are listed below. These specific values should be considered site-specific, as the exact results will vary depending on fine percentage, fine material, moisture, drainage, train loading, train tonnage, and train velocity.

- Under dry conditions, a section of ballast with a fine percentage of 37 percent from naturally degraded ballast underwent less than 0.1 inch of rail settlement after 10.5 MGT.
- If wetted and a water table develops due to blocked drainage, mud pumping occurred and settlements rates increased five to 10 times the dry settlement rate.
- The maximum settlement occurred in the center of the test section suggesting the length of the wetted fine-contaminated ballast contributes to settlement magnitude.
- Under wet conditions, the settlement was progressive and did not show rapid deterioration.
- After drying, the settlement returned to its pre-wetting rate.

Future tests will investigate the influence of drainage and train speed during the mud pumping process. Similar tests on different remediation and fine materials will investigate how these factors affect the drainage and settlement behavior. An overall objective is to determine successful remediation techniques addressing fine-contaminated ballast.

This *Technology Digest* is second in a series of an ongoing study investigating the behavior of fine-contaminated ballast when exposed to moisture. The project was conducted by TTCI under the AAR Strategic Research Initiatives Program, with joint funding from the Federal Railroad Administration.



INTRODUCTION

Fine-contaminated ballast is a condition in which the ballast layer becomes contaminated with fines from various sources.¹ This condition, especially when wetted, can reduce the ballast performance by limiting drainage, decreasing track stiffness, and increasing track settlement. These track regions often become a reoccurring maintenance challenge. One issue with predicting the behavior of fine-contaminated ballast is that it is often dependent on the percentage of fines, fine material size and plasticity, and moisture.

To investigate the behavior of a fine-contaminated ballast, TTCI created a “Rainy Section” in Section 36 of FAST to better understand how track settlement is related to fine material and moisture along with better understanding the underlying mechanisms producing accelerated rates of settlement in fine-contaminated ballast. This *Technology Digest* is the second of a continuing series and focuses on settlement of the Rainy Section when contaminated with silt-sized fine particles from ballast degradation and the change in drainage behavior after mud pumping. The first part of the series focused on drainage.²

RAINY SECTION

The Rainy Section is a 40-foot-long portion of FAST Section 36 that has two test boxes: a 13-tie test site (Site 1) and a 13-tie control site (Site 2). Using a watering system,² the test section can be wetted while the control section remains dry. This allows for a direct comparison of track behavior of a wetted region and a non-wetted region.

The Rainy Section consists of 600 MGT degraded ballast granite, and has added fines passing the No. 4 sieve (4.76 mm) to 37.2 percent and the No. 200 sieve (0.074 mm) to 4.5 percent. This results in a Fouling Index (FI)¹ of 41.7 (37.2 + 4.5). The fine particles are generally sand-sized and non-plastic silt-sized and the result of granitic ballast degradation with minor eolian (windblown) sand, so they represent a naturally degraded granite ballast section. A grain-size distribution is presented in Figure 1.

Fall 2017 Testing

The first round of testing in the fall of 2017 focused on gradually increasing the number of train passes to ensure the settlement could be controlled and predicted. Therefore, the testing involved wetting the section during the last few train passes of each night, letting the section drain overnight, and then gradually increasing the number of train passes under wet conditions until an understanding of the behavior was obtained. Figure 2 is a photograph of a passing train during wetting.

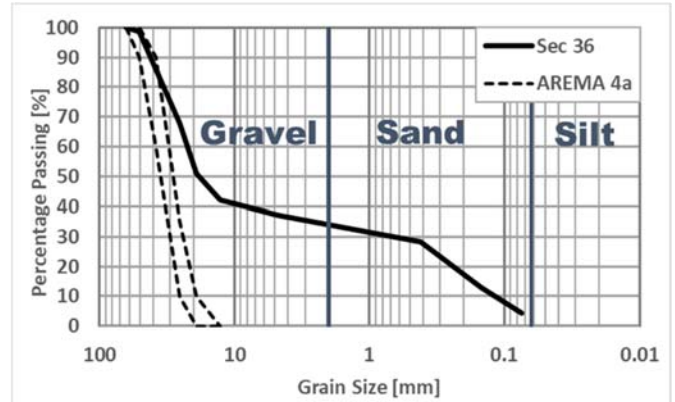


Figure 1. Grain Size Distribution for Rainy Section Ballast



Figure 2. Water System during Train Passage

The fall 2017 test involved six nights of testing for a total of 10.5 MGT. The test plan is displayed in Table 1.

Table 1. Fall 2017 Test Plan

Night	Date	Total MGT	Wetted Laps	Wetted MGT
1	9/26/2017	1.44	2	~0.03
2	10/09/2017	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 drainage valves were turned off on the third and fourth nights of testing, and a 6-inch water table developed. This represents a more extreme condition in which the drainage path is blocked either from fine materials, abutments, or other material.

After the third night of testing, a mud pumping condition was observed in which fine particles appeared to accumulate near the track surface and prevent surface drainage (see Figure 3). Drainage valves were opened to drain any standing water in the lower ballast layer, but surface water remained, so the test section could not fully

drain for the fourth and fifth days of testing. This is discussed in more detail in TD-18-010.² On the sixth day of testing, the entire section was dried.



Figure 3. Mud Pumping after 4th night (10/11/2017)

Top-of-Rail Settlement Measurements

To measure the rail settlement during the course of the test, top-of-rail (TOR) surveys were taken after each night of FAST runs. The elevation and settlement over the course of test for the inside rail is displayed in Figure 4. The raw elevation data is displayed in Figure 4 and shows natural variation in vertical rail surface and gradual degradation of surface in the test section. Section 36 has a natural slope, explaining the elevation difference between both sides of the Rainy Section.

The Figure 5 rail settlement used 0.0 MGT as a reference point and clearly shows the wetted test section experienced greater settlement than the non-wetted control section and surrounding track. The maximum settlement was ~0.5 inch and was located in the middle of the test section.

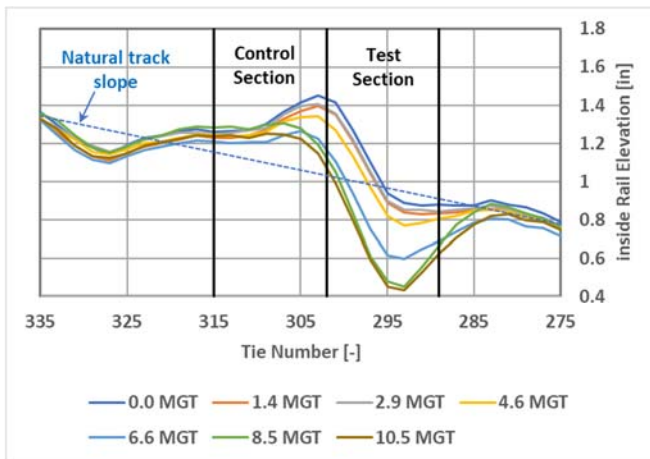


Figure 4. Rail Elevation with Distance

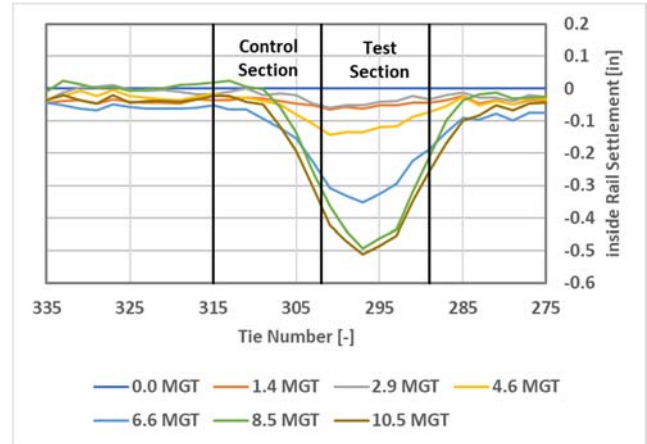


Figure 5. Ballast Settlement with Distance

Figures 6 and 7 show four locations in the test section (Tie 297, orange squares), control section (Tie 307, gray triangles), and surrounding track (Tie 283, blue diamonds and Tie 327, yellow circles) and the TOR settlement in these locations with increasing MGT. Figure 6 shows settlement results for the inside rail and Figure 7 shows results for the outside rail.

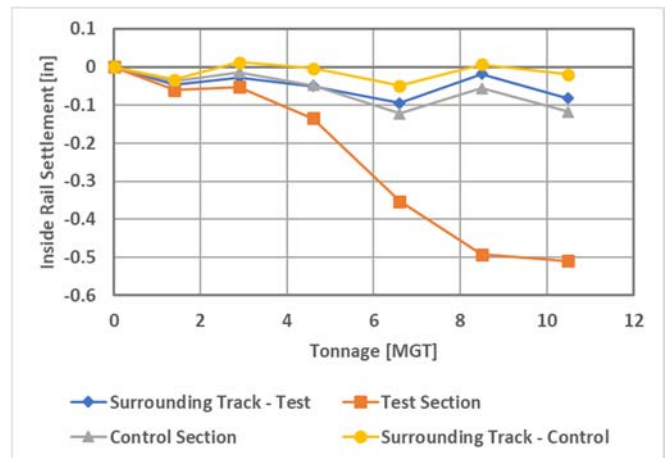


Figure 6. Ballast Settlement with MGT for inside rail

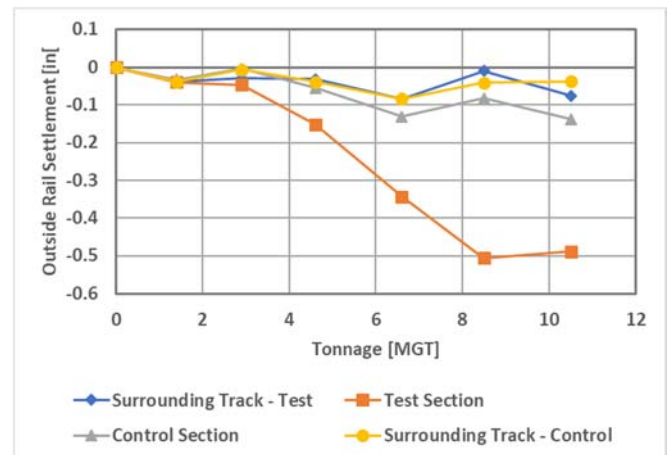


Figure 7. Ballast Settlement with MGT for outside rail

The results show minimal settlement for the first two nights of testing and then ~0.08 inch after the third night of testing. This means after wetting the test section and developing a 6-inch water table, the passing of 36 trains (~0.5 MGT) resulted in 0.08 inch of maximum settlement in the test section. The following night of FAST train runs resulted in settlement of ~0.22 inch. 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 and settled prior to the application of water for the last 37 laps. No water was applied 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.

Stringline and Dynamic Measurements

After the fourth night of testing, 62-foot stringline measurements were taken to assess the unloaded track profile. While a dip was visually noticed, the stringline measurement only showed a vertical surface deviation of 0.125 inch to 0.25 inch. This value is dependent on the elevation of the surrounding track.

Dynamic measurements were taken with a Voidmeter (see Figure 8) to determine the maximum rail deflection during train passage. After the fifth night, a maximum rail deflection of 0.625 inch was observed. This correlates the loaded vertical surface deviation of ~0.75 inch to 0.875 inch and is below the 2-inch limit for Class 4 track, which is the design standard for FAST.



Figure 8. Photograph of Voidmeter

Discussion of Results

The results show:

- Under dry conditions, a section of ballast with a fine percentage of 37 percent from naturally degraded ballast underwent less than 0.1 inch of rail settlement after 10.5 MGT.
- If wetted and a water table develops due to blocked drainage, mud pumping occurred and settlements rates increased five to 10 times the dry settlement rate.
- Fines accumulation in the upper ballast 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 contributes to settlement magnitude.
- 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 shows that moisture is a contributing factor to the settlement of ballast contaminated with fines from natural ballast degradation, and the settlement behavior is dependent on precipitation events or other means of water infiltration and drainage. This means the same ballast with a continual water source or inability to drain behaves differently than a dry section or a section that is able to drain prior to passage of hundreds of trains.

Future tests will investigate the dynamic behavior during mud pumping, the influence of drainage, and train speed during the mud pumping process. The influence of different fine materials will be used in similar tests to investigate how fine size and plasticity affects the drainage and settlement behavior of ballast. Additionally, the benefits of remediation techniques will be investigated as improved maintenance of fine-contaminated ballast is one of the end objectives of this test.

REFERENCES

1. Li, D., J. Hyslip, T. Sussmann, and S. Chrismer. 2016. *Railway Geotechnics*. CRC Press. Boca Raton, FL.
2. Basye, C., Y. Gao, and S. Wilk. May 2018. "Drainage Properties of Fine Contaminated Ballast." *Technology Digest*. TD-18-010. AAR/TTCl. Pueblo, CO.

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