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DRAINAGE PROPERTIES OF FINE-CONTAMINATED BALLAST

SUMMARY

In 2017, the Federal Railroad Administration (FRA) and Transportation Technology Center, Inc. (TTCI) completed the initial phase of testing on a "Rainy Section" (Figure 1) in the High Tonnage Loop at the Facility for Accelerated Service Testing (FAST) in Pueblo, CO, to measure drainage, settlement, and dynamic behavior of a fine-contaminated ballast section. This test section allows TTCI to control the wetting and drainage of the section, and simulate various rain events.

The first iteration of the testing involved the use of sand-sized and non-plastic, silt-sized fines from granite ballast degradation to represent fine-contaminated ballast that would occur progressively during dynamic ballast degradation and not from surface or subgrade infiltration. This test section at FAST has 37.2 percent fine content (i.e., grain size below No. 4 sieve, 4.76 mm), with the fines filling a significant percentage of the available voids between ballast particles.

Multiple tests were conducted to measure the drainage rate in the Rainy Section after wetting, and the following observations were made:

- For the degraded ballast and unimpeded drainage, the section took approximately 20 hours to drain to pre-wetting conditions. This drainage time depends on the amount of fine-material, type of fine-material, and the drainage routes of the ballast section. Smaller grain sizes (e.g., clays) will generally result in longer drainage time, whereas larger grain sizes (e.g., sands) will generally result in shorter drainage time.
- Mud pumping occurred after 0.5 million gross tons (MGT) when the drainage was blocked and a 6-inch water table developed, resulting in the accumulation of fines in a mud slurry near the surface.

Future drainage tests will involve sampling the ballast at various depths after mud pumping to determine if fine segregation is occurring, and determining the benefits of certain remediation techniques. Also, different fine materials, such as sand, clay, or coal fines, will be used in future testing iterations.

This report is the first of an ongoing study investigating the drainage, settlement, and dynamic behavior of different types of fine-contaminated ballast when exposed to moisture and the benefits of various remediation strategies. The project was conducted by TTCI as part of a cooperative research initiative between FRA and the Association of American Railroads (AAR).

Figure 1. The "Rainy Section" in the High Tonnage Loop at FAST.

BACKGROUND

Fine-contaminated ballast is a condition in which the ballast layer becomes contaminated with fines from various sources [1]. Wetted, fine-contaminated ballast can reduce the ballast performance by limiting drainage, decreasing track stiffness, and increasing track settlement. These track conditions often become a reoccurring maintenance challenge. One issue with predicting the behavior of fine-contaminated ballast is that it is dependent on multiple metrics, such as the degree of fine-contamination, fine material size and plasticity, and moisture.

OBJECTIVES

This research investigates drainage characteristics of a ballast section with a specific focus on (1) the drainage time of ballast contaminated with sand and silt-sized fines from ballast wear degradation and (2) the change in drainage characteristics after mud pumping.

METHODS

FRA and TTCI created a “Rainy Section” to investigate how track behavior is related to fine material and moisture, as well as provide a better understanding of the underlying dynamic mechanisms influencing drainage in fine-contaminated ballast. The Rainy Section has two ballast boxes: a 13-tie (20-foot long) test box (Site 1) and a 13-tie control box (Site 2). Both sites are lined with waterproof and electrically nonconductive material to a depth of 18 inches below the bottom of the tie and are filled with degraded, fine-contaminated ballast. The Rainy Section consists of degraded granite ballast with over 600 MGT of wear, and has a percentage of fines passing the No. 4 sieve (4.76 mm) of 37.2 percent and No. 200 sieve (0.074 mm) of 4.5 percent. This results in a Selig Fouling Index (FI) of 41.7 (37.2 + 4.5). The grain size distribution is shown in Figure 2. Site 1 can be wetted with a watering system while Site 2 remains under in-situ moisture conditions. This allows for a direct comparison of track behavior of a wetted and non-wetted track section.

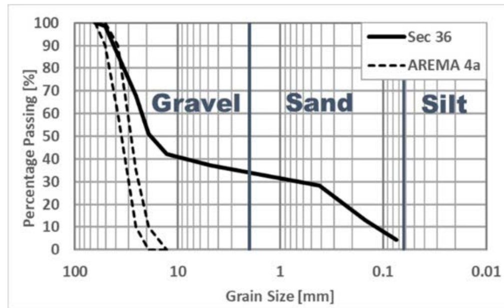

Figure 2. Grain size distribution for Rainy Section ballast.

The moisture in the Rainy Section is controlled by an irrigation and drainage system. The irrigation system has four 10-foot PVC pipes with 20 sprinkler heads to spray water onto the track. The location, type, and magnitude of spray can be controlled. The drainage system collects water along the sides of the Rainy Section and circulates the water back through a filtration and storage system.

Electrical resistivity methods were used to measure moisture in the Rainy Section at a depth of 10 inches below the bottom of the tie. The moisture values were taken at specific increments, and the initial and final values were previously correlated to field capacity (i.e., a fully drained steady-state moisture condition), while the value when a water table developed was correlated to fully saturated conditions using resistivity methods.

RESULTS

Initial tests of the Rainy Section involved wetting the test section and observing the time for the section to freely drain back to initial conditions. The tests assumed no dynamic influences on drainage impedance.

Figure 3 presents the moisture content during wetting in fall 2017 and shows a rapid increase in moisture during wetting, starting from about

16.8 percent and reaching full saturation at about 18.1 percent. The remainder of the curve shows that the section drained halfway in about 2.5 hours and required about 20 hours to reach field capacity.

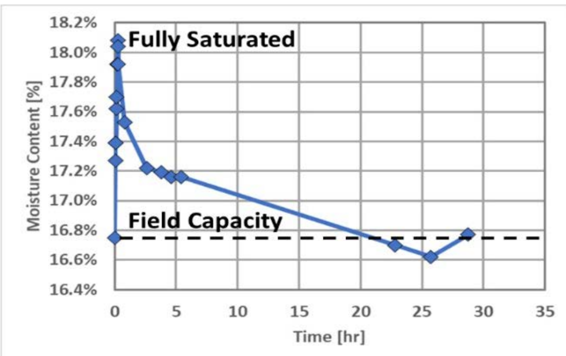

Figure 3: Moisture content from wetting and drainage of the Rainy Section

During a later test involving running a 100+ car consist with 39-kip wheel loads over the test section at 40 mph, the drainage valves were closed to maintain a standing water table. Within 36 train passes, which is equivalent to approximately 0.5 MGT, mud pumping was observed with fines accumulating on the ballast surface, ties, and rails. The section was allowed to drain and the next night another 37 train passes (approximately 0.5 MGT) was accrued while the Rainy Section was fully saturated. This led to even more mud pumping with standing water remaining on the surface.

The mud pumping process is believed to occur from the dynamic loading of the trains increasing the porewater pressure of the standing water in the lower ballast. The water and fines move outward and upward toward the ballast surface with each dynamic wheel pulse. After the pulse is finished, a lower pressure fluid response carries finer material back into the perimeter zone of the tie. This repetitive process leads to the development of a low-permeability zone near the ballast/fines interface.

Figure 4 shows the track surface when the Rainy Section was fully saturated and mud pumping was observed. The development of a fines "mudcake" near the fine/coarse-grained particle boundary could also slow the drainage of the coarser sand beneath it, because of the higher suction potential of this mudcake as it dries out.

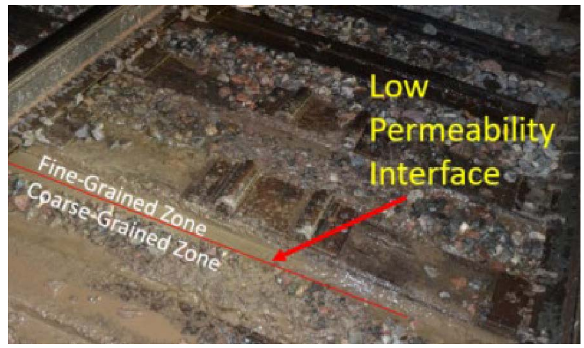

Figure 4: Photograph of mud pumping in the Rainy Section

An interesting note is that, after the standing water in the lower ballast drained, the water on the ballast surface remained. While the resistivity rods were too deep to measure this observation, it appeared that the accumulation of silt-sized fines impeded drainage of the upper ballast layer, creating a condition similar to a perched water table (i.e., higher moisture as depth decreases). This is a notable finding because successfully draining the lower ballast layer may not result in the immediate draining of the upper ballast layer since the surface water is blocked by the accumulated fines near the surface.

CONCLUSIONS

Initial tests involving wetting and draining of the Rainy Section have led to the following observations:

- It takes about 20 hours to drain a 40-foot long ballast section with about 40 percent silt-sized fine particles with no blockage of drainage routes. This value is site-specific and will depend on the amount and type of fine material along with drainage impedances. In general, smaller fine sizes (e.g., clay) will result in longer drainage times than larger fine sizes (e.g., sands).

- Mud pumping causes the development of a low-permeability zone near the ballast surface, impeding drainage of surface water.

FUTURE ACTION

Monitoring of the Rainy Section is anticipated to continue and involve further testing of different remedial actions and fine-material conditions. Upcoming tests will aid in better understanding how the mud-pumping process affects the fine materials and the degree to which they segregate by filling the Rainy Section with different materials to observe drainage, pumping, and overall track behavior.

TTCI plans to obtain ballast samples with depth after mud pumping. This will hopefully give insight into the degree of segregation of fine particles after pumping. Fine percentages of 45 percent in the upper layer and 35 percent in the lower layer would have different drainage implications than 60 percent in the upper layer and 20 percent in the lower layer because the ability to drain the surface water will decrease as the fine level increases.

REFERENCES

[1] Li, D. Hyslip, J., Sussmann T., and Chrismer, S., Railway Geotechnics, Boca Raton, FL: CRC Press, 2016.

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KEYWORDS

Ballast, fines, drainage, mud pumping, track