U.S. Department of Transportation
Federal Railroad Administration

RESEARCH RESULTS
FRA OFFICE OF RESEARCH, DEVELOPMENT & TECHNOLOGY

RR 22-31 | **October** 2022

RAINY SECTION AT FAST: PHASE I SUMMARY

SUMMARY

As part of continuing research into mud pumping and fine-filled ballast, the Federal Railroad Administration (FRA) and the Association of American Railroads (AAR) studied how moisture in fine-filled ballast can affect track performance. The goals of this research were to better identify problematic locations and recommend more effective maintenance practices.

Transportation Technology Center, Inc. (TTCI) completed the first phase of testing in June 2019. The objective of Phase I was to quantify how moisture can increase track settlement (up to 15 times that of dry) and reduce the track modulus and drainage capabilities of the ballast section. In cases where the water source is from rainfall, "Rainy Section" testing identified several inches around the tie as the problematic region. Based on this study, mud pumping maintenance and remediation efforts should focus on drainage of this region.

BACKGROUND

Fine-filled ballast is a common substructure problem faced by all railroads, especially when wet conditions are present. Figure 1 shows an example of mud pumping in fine-filled ballast, which can increase track geometry degradation and require more frequent maintenance. Finding better ways to identify locations prone to mud pumping allows for better maintenance planning.

Multiple factors can affect the performance of fine-filled ballast. This includes the levels, source, and distribution of both fines and moisture in the track section [1, 2]. Fine levels above 20 percent by mass are generally considered to be a problem. Once fines reach 40 percent, the fines will fill the majority of ballast voids. The type of fines found in the ballast will depend on the location. Ballast degradation is the main contributor of fines, but fines may also be the result of surface infiltration or pumping from the subgrade when subsurface water is present. Smaller and more plastic fine particles are considered a greater problem than fine particles created by ballast degradation. However, researchers did not consider the effect of fine sizes in this study.

Figure 1. Photograph of mud pumping with standing water

OBJECTIVES

The objective of the initial phase of this long-term study was to quantify the increase in track settlement as well as the reduction in the track modulus and ballast drainage capabilities due to increases in moisture.

METHODS

RAINY SECTION

To investigate the influence of moisture and fouling, FRA and AAR developed a test section at the Facility for Accelerated Service Testing (FAST) in 2016. The Rainy Section is a 20 foot section of track that contains more than 40 percent fines from natural ballast degradation. It has an irrigation and drainage system that allows drainage control and the replication of rainfall in the track. Together, these characteristics mimic a severe fine-filled ballast condition where most of ballast voids are filled by ballast degradation material, and the fines are evenly distributed within the ballast section. Note that results may vary significantly considering different levels, types, and distributions of fines and the moisture source.

PHASE I TESTING

The first phase of testing at the Rainy Section involved characterizing how moisture affected both track performance and the mechanism leading to surface mud pumping. Previous publications [2, 3] reviewed the test results in detail; a high-level overview is presented here.

To evaluate track performance, researchers quantified track settlement, stiffness, and drainage by taking multiple measurements in the Rainy Section. To determine the elevation profile and unloaded settlement rates, researchers collected unloaded top-of-rail elevations (ToRE) after each night of train operations (about 2 million gross tons (MGT)). The team also performed light and heavy tests (10 and 40 ton axle loads) to determine the track modulus at various stages of testing. Moisture sensors were installed at various locations in the Rainy Section to monitor moisture levels.

The various tests conducted on the Rainy Section during Phase I can be divided into groups based on ballast condition: clean; dry and not mud pumped; wet and mud pumped; and dry and mud pumped. After surfacing, the fines were evenly distributed in the ballast section. As the ballast was wetted (i.e., 10 mm/hr of rain for one hour) and experienced train traffic, the fines underneath the ties became saturated and developed a slurry-like consistency. As train operations continued, the pressure exerted by the tie pumped the mud slurry up around the ties and onto the surface of the track. This condition is commonly referred to as mud pumping (see Figure 1). After being allowed to dry, the mud slurry remained at the surface, representing the dry and mud pumped condition.

Figure 2 shows how each of these conditions, along with the clean ballast condition as a baseline, affects track performance in the Rainy Section. The results are presented conceptually due to the variation between the tests and the dependence on specific measurements. However, Figure 2 gives a general idea of the effect of moisture and fine distribution on performance. The results also may vary for different situations.

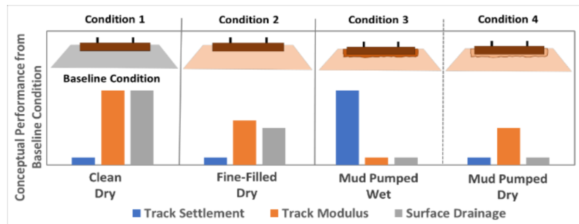

Figure 2. Conceptual performance of four ballast conditions

The Rainy Section results showed:

- **Clean ballast:** This baseline condition typically showed a small track settlement, a track modulus value of about 4,200 lbs/in/in, and a location from which excess water could drain within minutes.
- **Dry, fine-filled ballast:** This condition showed no visual signs of fines on the surface and had similar to slightly higher settlement rates than clean ballast, a slightly lower track modulus (3,500 lbs/in/in), and inhibited drainage, causing excess water to take about one day to drain out.
- **Wet, mud pumped ballast:** This condition had standing water and visual signs of mud at the surface, a settlement rate much greater than the other conditions (up to 15 times greater), a low track modulus (1,500 lbs/in/in), and inhibited drainage, requiring about five days for the excess water to drain.

- **Dry, mud pumped ballast:** This condition had visual signs of mud at the surface, similar settlement rates to the dry fine- filled ballast condition, a lower track modulus (3,000 lbs/in/in), and inhibited drainage, requiring about five days to drain out the excess water.

MUD PUMPING MECHANISM

The overall objective of fine-filled ballast research is to better identify potential problem regions and quantify the benefits of various maintenance and remediation methods. A thorough understanding of mud pumping and its causes is necessary to this research.

Rainy Section Mud Pumping

Mud pumping at the Rainy Section follows a specific process (see Figure 3).

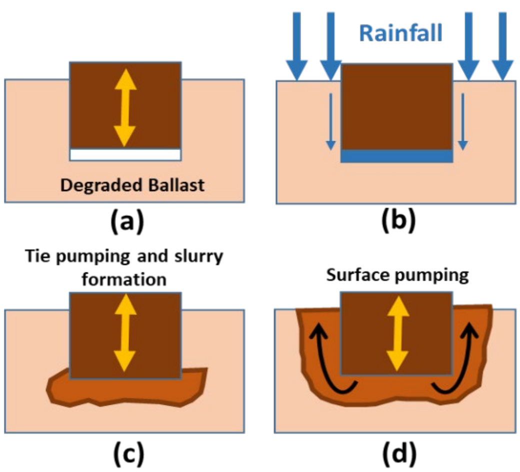

Figure 3. Step-by-step of mud pumping in Rainy Section (blue = rain, light brown = fine contaminated ballast, rust = slurry, brown = tie, yellow = tie pumping due to train operation)

From the (a) dry initial condition, (b) rainfall (blue color) begins to wet the surface and upper ballast layer and ponds underneath the ties. After the simulated rainfall increased the moisture levels underneath the ties to a sufficient level and train traffic caused the ties to move vertically, (c) the fines and water form a mud slurry. This slurry is very soft and mobile (rust color). Excess water is anticipated to pond underneath the tie. Continued train traffic causes the tie to move vertically, and this pushes the mud slurry away from the tie while pulling surrounding fines into the voids generated. This likely causes the slurry to move downward and outward, but the easiest escape path is actually upward around the tie and eventually, the slurry coats the tie and surface (d).

The final cross-section is shown in Figure 4.

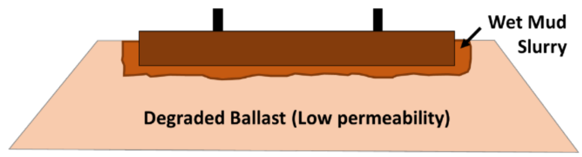

Figure 4. Cross-section of Rainy Section with surficial mud pumping

Multiple tests were run to determine the depth of the wet region (slurry). These tests involved moisture sensors, trenches, and geoendoscopes (video devices that can look downward into the ballast). The results from all three methods agreed that the wet region in the Rainy Section only extends several inches immediately below the bottom of the tie. The fact that the wet region is so shallow suggests that the problem is mainly surficial and does not extend deep into the ballast section.

General

The Rainy Section only represents a single scenario, but degradation of the main ballast condition and mud pumping can occur in other ballast and subgrade situations as well.

Results indicate the three requirements for mud pumping are: (1) fine-filled ballast, (2) a water source, and (3) tie pumping. These are explained as follows:

- **Fine-filled ballast:** Fines are an obvious precursor for mud pumping, but the influence of the fine level and type is significant. There should be a minimum fine level threshold that is needed for the slurry to form, and different fine types will likely affect how the slurry acts.
- **Water source:** The water source plays a significant role in mud pumping. In the Rainy Section, the

water source is artificial rainfall that accumulates at the surface because the low permeability of the ballast inhibits drainage.

- **Tie pumping:** The tie moving vertically during train passage not only helps produce the slurry but also pushes it upward to the surface around the ties. This movement indicates that the severity of mud pumping could be dependent on the amount of tie motion.

CONCLUSIONS

Phase I testing quantified how moisture can increase ballast settlement (up to 15 times that of dry) and reduce the track modulus and drainage capabilities of the ballast section. In cases where the water source is rainfall, Rainy Section testing identified the problematic region of several inches around the tie. Drainage of these region by shoulder cleaning, shallow undercutting, or lifting should be the focus of mud pumping maintenance and remediation.

REFERENCES

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ACKNOWLEDGEMENTS

TTCI conducted this research as part of the cooperative HAL revenue service research program between FRA and AAR. TTCI team members included Dr. Steve Wilk and Dr. Dingqing Li.

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KEYWORDS

Ballast, mud pumping, settlement, track modulus, drainage