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IMPACT OF SHOULDER CLEANING ON BALLAST DRAINAGE

SUMMARY

The Federal Railroad Administration (FRA) and the Association of American Railroads (AAR) jointly supported Transportation Technology Center, Inc., (TTCI) to investigate the influence of shoulder ballast cleaning (SBC) on the performance of fine-filled ballast. Repeated vehicle loadings degrade ballast particles over time and can eventually allow enough degraded ballast fines to accumulate around the tie ends to block drainage. This blocked drainage can then produce mud pumping and rapid track geometry degradation and can also accelerate track component degradation.

SBC is a ballast maintenance technique that focuses on opening the drainage paths around the tie ends by replacing degraded shoulder ballast with new, clean ballast (see Figure 1). Despite being commonly used to address fouled ballast locations (i.e., ballast defects), information on the ability of SBC to improve drainage is mostly anecdotal.

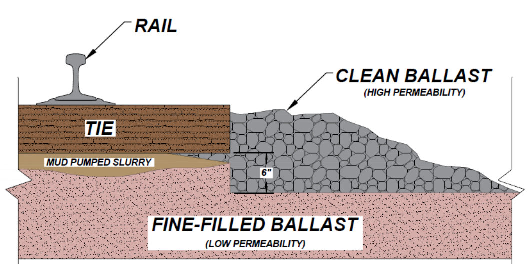

Figure 1. Diagram of the shoulder ballast cleaned section with scarifier

Testing was conducted between 2021 and 2022 at the "Rainy Section," a degraded ballast test section at the Facility for Accelerated Service Testing (FAST) in Pueblo, CO. The test section is 20 feet long and has a Selig's Fouling Index (FI) of 40, indicating most of the ballast voids are filled with fines. In addition, the section uses an irrigation system to control the wetting of the ballast.

Research findings indicate better shoulder drainage resulting from shoulder cleaning can improve drainage capacity, reduce surface mud pumping, and reduce track settlement in certain situations.

BACKGROUND

This research built upon Phase I of a study at the Rainy Section, which involved wet ballast exhibiting poor drainage and comparing wet versus dry track performance [1, 2]. Phase II testing involved performing spot SBC and comparing the performance of SBC with the results of the poorly drained ballast from Phase I. The SBC section was monitored from March 2021 to April 2022, after accumulating 61.1 million gross tons (MGT). The spot SBC was done by manually stripping the shoulders from the tie end outward to a depth of about 6 inches below the bottom of the tie. A scarifier was replicated to further open drainage paths underneath the tie, and new American Railway Engineering and Maintenance-of-Way Association (AREMA) No. 4 ballast replaced the shoulders.

OBJECTIVES

The objective of this research was to compare the drainage performance after SBC (Phase II) to the baseline no-maintenance condition (Phase I).

METHODS

During Phase II, researchers conducted three wetting tests to simulate heavy rainfall events. Test 1 occurred on April 14th, 2021 (16.8 MGT accumulated); Test 2 occurred on May 19th, 2021 (27.7 MGT accumulated); and Test 3 occurred on April 20th, 2022 (61.1 MGT accumulated). Each test involved rain intensities of about 0.4 inch/hour for a 2-hour period, accumulating about 0.8 inch per wetting test. This high rain intensity is considered a “heavy rain” event based on publicly available rainfall charts [3] and was identical to the ballast wetting in Phase I.

Over the test period, Pueblo experienced slightly higher than average amounts of natural precipitation. Combining natural and artificial wetting from the three tests, 19.65 inches of precipitation were accumulated against a 14.35-inch average. The rainfall also varied considerably from month to month. For Tests 1 and 3, the combined natural and artificial rainfall in both April 2021 and 2022 (~1.3 inches) was slightly drier than the 1.5-inch average. Test 2, however, occurred during a very wet period in May 2021, when the area experienced a combined 5.75 inches of natural and artificial rainfall compared to the 1.5-inch average. The varying amount of precipitation in Pueblo allowed the research team to use the tests as proxies for various climate conditions.

RESULTS

The first performance indicator used was visual observation of surface mud pumping. Avoiding mud pumping is important because it is often a visual indicator of degraded ballast, can imply poor drainage, and is often used to justify ballast defects. Figure 2 shows surface mud pumping and water ponding from previous Phase I testing. However, no surface mud pumping was observed after each of the three Phase II tests. Figure 3 shows the section after Test 1. While the surface fines were moist, they did not result in the slurry formation that was commonly found in Phase I. The track was visually similar after Tests 2 and 3.

The lack of mud pumping suggests improved performance and indicates the drainage paths remained open over the year-long test. These observations suggest SBC can provide improved drainage to prevent mud pumping.

Drainage was another performance indicator evaluated during this test. Excess water from rainfall should drain through and away from the track, ideally keeping the track drier. Drainage was calculated by monitoring moisture levels at the track center in the crib (Figure 3). Moisture sensors were installed 1 inch below the surface and measured water trapped in the track center. For this study, ballast with 10 percent moisture or less was considered “dry,” ballast with 15 percent moisture or more was considered “saturated,” and ballast with 10 to 15 percent moisture transitioned from dry to wet. To assess drainage, researchers used the metric of “days to reach below 15 percent.” This metric is simple and imperfect, but still represents complicated behavior well.

Figure 2. Photograph of mud pumping from no maintenance situation

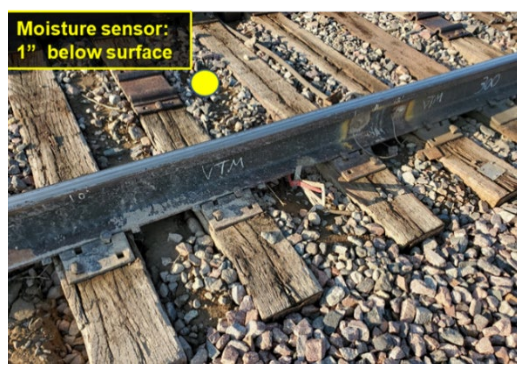

Figure 3. Photograph of SBC situation

Figure 4 shows the drop in moisture levels after wetting for two previous Phase I tests (Tests A and B) in red, the two drier SBC tests (Tests 1 and 3) in brown, and the wetter SBC test (Test 2) in blue. The results show that in Phase I testing, it took upward of five days for moisture to drop below 15 percent. This result agrees with the visual observations of mud pumping and surface water ponding for days after wetting. In Phase II, Tests 1 and 3 showed the quickest drainage, taking about 3 to 6 hours. The pre-wetting moisture readings were dry at 6 and 8 percent, suggesting that although some moisture infiltrated the fines, much of the moisture drained through surface runoff. The location was also allowed to dry fully between rain events. Test 2 took longer to drain (~2 days), but the pre-wetting moisture reading was already at about 14.3 percent, and it took about two days for the ballast fines to return to their pre-wetting moisture levels. A natural rainfall event also occurred 3 days after the wetting test, causing the location to remain wet and suggesting that for Test 2, the high number of natural rainfall events along with artificial wetting caused the section to remain in a very wet state without drying in between rain events. The higher settlement rate in Test 2 also means that although the moisture did not form a slurry, it was likely able to penetrate deeper than in Tests 1 and 3.

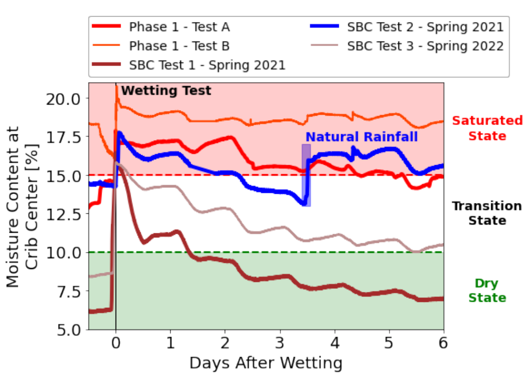

Figure 4. Change in moisture content at crib center after wetting

A third performance indicator assessed was settlement. Researchers used top-of-rail survey elevations (ToRE) to establish the track settlement, which indicates track deformation. When localized in a dip, as in this test, settlement has a strong relationship with surface profile roughness. Figure 5 shows the track settlement at the center of the dip after tamping, which was done immediately after SBC. Ballast compaction, common after tamping, caused the initial 0.5 inch of settlement. The three shaded regions in Figure 5 show the wetting tests and the settlement rate within those shaded regions can be calculated. For reference, Phase I testing showed about 0.003 in/MGT when dry and 0.08 in/MGT when wet. Tests 1 and 3 again showed minimal settlement with rates at 0.012 in/MGT. These settlement rate values match well with the Phase I dry settlement (no wetting). Test 2 showed much greater settlement rates with about 0.091 in/MGT, like the wet settlement rate in Phase I.

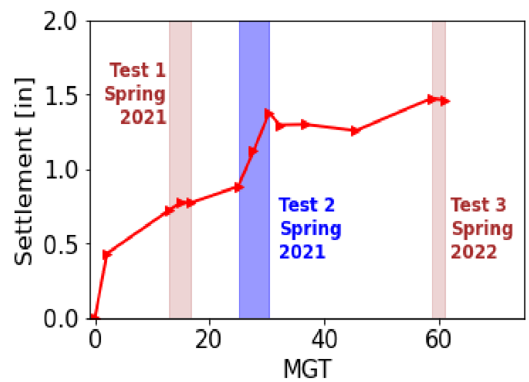

Figure 5. Settlement during surfacing cycle from Spring 2021 to Spring 2022

Table 1 summarizes the qualitative performance of SBC by rainfall event. When no shoulder cleaning takes place, any moisture can become trapped underneath the tie and induce mud pumping. SBC did not produce mud pumping in areas where the shoulder ballast was cleaned. However, the SBC section did experience higher settlement rates after repetitive rainfall events because the fines underneath the tie were able to soften. Figure 6 shows a diagram of the two rainfall climates and the effect of drainage.

Table 1. Qualitative summary of shoulder ballast cleaned performance

Shoulder Cleaned	Rainfall Climate	Surface Mud Pumped	Settlement
No	Either	Yes	High
Yes	Repetitive	No	High
Yes	Sporadic	No	Low

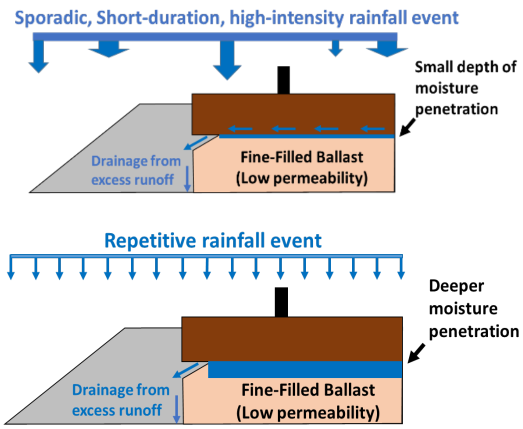

Figure 6. Diagrams of rainfall events and moisture penetration

CONCLUSIONS

The results show that shoulder drainage due to shoulder cleaning prevented surface mud pumping and improved drainage. This improved drainage partially addressed, but did not eliminate, track susceptibility to high track settlement rate.

The settlement results suggest the effectiveness of SBC varies with climate. SBC will reduce track geometry degradation in arid environments that experience sporadic rainstorms, as excess water drains out of the shoulders instead of collecting underneath the tie and producing mud pumping. For wetter climates, locations may still experience greater settlement rates if the fines wet to a near-saturated state. However, the location will still drain more quickly with the clean shoulder, thereby preventing surface mud pumping.

REFERENCES

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CONTACT

Jay Baillargeon
Program Manager
Federal Railroad Administration
Office of Research and Development
55500 DOT Road
Pueblo, CO 81001
(719) 584-7155
jay.baillargeon@dot.gov

Stephen (Sean) Woody
Chief, Track Research Division
Federal Railroad Administration
Office of Research and Development
1200 New Jersey Avenue SE
Washington, DC 20590
(202) 573-3252
sean.woody@dot.gov

KEYWORDS

Mud pumping, settlement, degraded ballast