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EFFECTIVENESS OF SPOT TAMPING IN FINE-FILLED BALLAST

SUMMARY

As part of ongoing Federal Railroad Administration (FRA)-funded research examining the behavior of fine-filled ballast when exposed to moisture, Transportation Technology Center, Inc., (TTCI) used the Rainy Section at the Facility for Accelerated Service Testing (FAST) to study the effectiveness of spot tamping in fine-filled ballast. The team conducted this project between 2017 and 2019 as part of a collaborative effort between FRA and the Association of American Railroads (AAR).

The testing conducted in the Rainy Section showed that increasing the lifts or carrying out an overlift can lengthen the maintenance cycle in fine-filled ballast. The team was also able to take a deeper look into the ballast consolidation phase and compare ballast settlement trends with increases in lateral tie strength from tonnage under speed restrictions.

Immediately after tamping, the ballast tended to lose lateral and longitudinal resistance due to the lower ballast mass density [3]. Consequently, railroads often issue speed restrictions to reduce the risk of track misalignment or buckling until the ballast can regain its resistance. Most ballast settlement occurred within the first 0.1 million gross tons (MGT), which agrees with most railroads' typical practices for releasing speed restrictions after ballast maintenance.

BACKGROUND

Spot tamping is a common railroad industry ballast maintenance method used to restore the track surface at a specific location after the track has settled. This involves raising the track to a desired elevation and using vibrating tamping tines to push and compact the ballast underneath the crossties [1]. High initial ballast settlement under train traffic immediately following tamping, called "ballast consolidation," has been observed for decades. This process led to previous innovations, including "Design Lift Tamping" [4] and alternative surfacing methods (e.g., "stoneblowing") [1]. However, these two methods are not commonly used in practice, and spot surfacing continues to be an issue.

The effectiveness of tamping can vary based on the ballast condition, tamping method used (e.g., production versus spot versus hand tamper), and the tamper operator. While practices vary by railroad, they often involve adding ballast and then tamping until the required elevation is achieved. However, the ballast settlement immediately following tamping may cause the track to lose most of its surface in the first few MGT. This, in turn, reduces the effectiveness of the maintenance practice and may result in repeated tamping at problematic sections. Maintaining surface following spot tamping is even more challenging in fine-filled ballast, especially when the ballast is wet.

OBJECTIVES

The team sought to explore the effectiveness of spot tamping in fine-filled ballast as part of a larger project that studied the effect of moisture and maintenance in fine-filled ballast at the FAST Rainy Section [2].

METHODS

The FAST Rainy Section consists of fine-filled ballast that (1) results from natural fine degradation with a fine percentage of about 40 percent, (2) fills most of the voids within the ballast, and (3) can inhibit drainage. It is important to note that the Rainy Section requires regular spot tamping for surface maintenance. FRA initiated this study after a previous Rainy Section spot tamping test (Test 1 in Table 1) due to significant settlement that occurred after the first night of train operations (around 2 MGT). This regular maintenance allows researchers to evaluate the effectiveness of lift height, adding ballast, and moisture. Table 1 lists the tamping tests the team performed at the Rainy Section.

Table 1. Tamping variables

Test	Lift Height	Ballast Added	Wet or Dry
1	0.52 in.	No	Dry
2	0.51 in.	Yes	Dry
3	1.47 in.	Yes	Dry
4	0.07 in.*	Yes	Wet

* *The low lift height in the wet situation was from difficulty lifting and preserving the desired elevation during tamping.*

Lift height and track settlement were measured using top-of-rail elevations, or ToRE, which is an unloaded method of measuring rail elevation that does not account for track deflection under train operations. This method gives relevant insight into lift heights and settlement. The tie settlement of the center tie was also measured using bending beams.

Researchers calculated the lift height as the average rail elevation lift of both rails at the same tie. “Ballast Added” refers to whether ballast was added during the tamping process. While typical railroad maintenance would use clean ballast, the team used more fine-filled material (Fouling Index (FI) = 40) to avoid compromising the other aspects of the Rainy Section test. The wet-versus-dry variable compares whether the fine-filled ballast was noticeably wet or dry (typical railroad experience suggests tamping fine-filled ballast while it is wet is ineffective). The fourth test’s small lift height of 0.07 inch resulted from issues the tamper had in lifting the track to the desired elevation and preserving that elevation during the tamping process.

RESULTS

Figure 1 highlights the settlement of the entire test section after Test 1, which shows the ToRE for (1) pre-tamping, (2) post-tamping, and (3) after the first 2 MGT. The results show that the initial 2 MGT settlement profile almost reverts to the pre-tamping elevation profile. This indicated the majority of the lift height was lost.

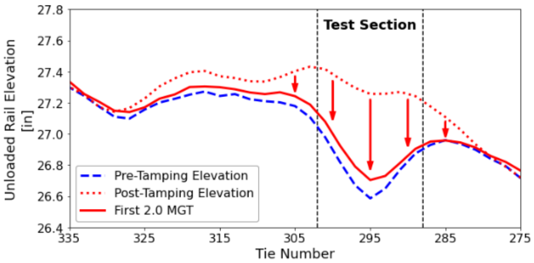

Figure 1. Rail settlement of entire test section after tamping

Figure 2 shows the results from a bending beam measurement on a single tie in the center of the Rainy Section. The tie experienced about 1 inch of settlement during the first 2 MGT and emphasized the majority of settlement occurred in the initial 0.1 MGT and then stabilized afterward. This 1 inch tie settlement after 2 MGT (Figure 2) is greater than the 0.65 inch rail settlement (Figure 1) because of loose spikes and other slack within the fastening system. In the literature [1], this ballast consolidation phase mainly involves settlement from recompacting the ballast particles into a more condensed state. After the ballast settlement stabilizes, the ballast experiences a post-consolidation phase in which the ballast settlement rate slows.

The ballast densification results are also relevant for lateral track resistance. After surfacing, the railroads require speed restrictions for about 0.1 MGT while the ballast is in a loose state. The results in Figure 2 show most of the ballast densification occurs within the first 0.1 MGT. These results support previous work [3] showing that once the ballast consolidates or settles to a more compact state, its vertical, lateral, and longitudinal resistance will approach pre-tamping levels. Therefore, these results agree with existing practice that speed restriction be lifted after the initial 0.1 MGT.

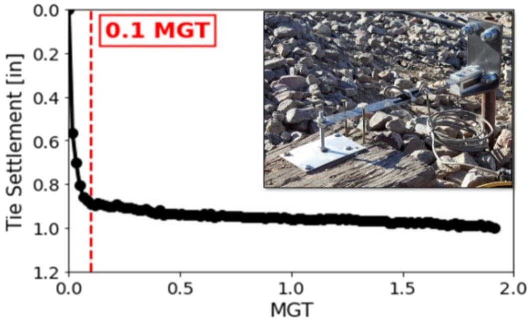

Figure 2. Bending beam at center tie in section measured tie settlement during initial 2 MGT

Figure 3 and Figure 4 present the results of each of the tamping tests. In Figure 3, the x-axis represents the lift height and the y-axis represents the initial 2 MGT settlement from the ToRE measurements. Two MGT is the first ToRE measurement that can be used due to the nature of FAST operations, but is still close enough to 0.1 MGT. The best-fit line from an FRA-funded revenue service data set, currently unpublished, is included for context [5]. In Figure 4, the x-axis represents the percentage of lift height remaining after 2 MGT. Researchers calculated these values by dividing the y-axis value by the x-axis value in Figure 3.

The two figures highlight different aspects of the results. Figure 3 suggests that all four tamping tests produced about 0.4 inch of settlement in the initial 2 MGT. This result is surprising, as the initial settlement is often dependent on the lift height, as observed in previous studies (see dotted line in Figure 3) [6]. The 0.4 inch of initial settlement for all tests may be coincidental when accounting for lift height and the tamping procedures. Test 1 (blue diamond) and Test 2 (red square) match the anticipated initial settlement, with Test 2 having a slightly greater residual lift (the remaining lift after the initial settlement). The large overlift (Test 3, gray, Figure 3) had a higher residual lift than typical practice, so it performed better than anticipated. At the same time, the wet section (Test 4, purple, Figure 3) has a lower residual than typical practice.

Figure 4 shows the differences in the percentage of surface height remaining after 2 MGT relative to the lift height. Tests 1 and 2 indicates most of the surface change is lost for small lifts (~0.5 inch) but adding ballast material during the tamping process can have a positive effect. Test 3 suggests that a higher lift will result in a greater percentage of surface change remaining after initial settlement (Figure 4) and therefore have more residual lift.

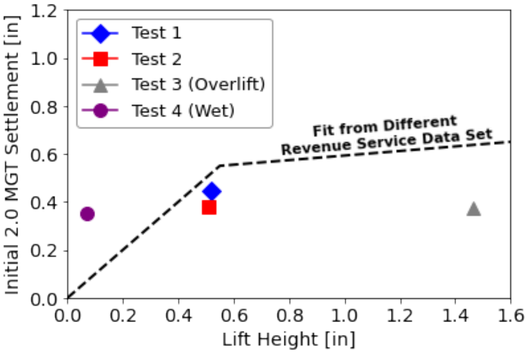

Figure 3. Lift height versus initial 2 MGT settlement

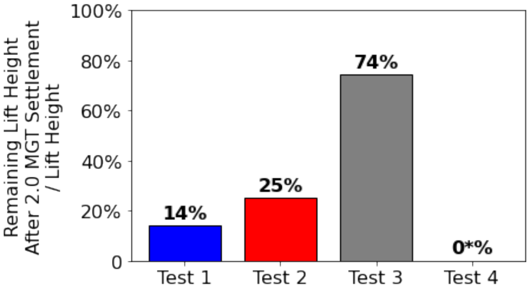

Figure 4. Percentage of lift height remaining after Initial 2.0 MGT settlement (*Test 4 calculations produced a negative number but is kept at 0% to highlight the entire lift was lost)

Railroads can use overlifts as a tamping design practice to increase track geometry life, therefore lengthen maintenance cycles [4]. An overlift will produce a hump in the middle of the previous depression after surfacing. The desired end goal is flat geometry after the initial settlement (0.1 MGT) has occurred. In Test 3, the surfacing resulted in an initial hump of 0.8 inch using a 62 foot chord, as shown in Figure 5. After the first 2 MGT, train operations reduced the surface hump to 0.5 inch – a loss of 0.3 inch of profile. This hump during Test 3 may have been too large for revenue service because of undesirable train dynamics, but it extended the maintenance cycle of the test section and extends the time before the surface degradation approaches track geometry exceptions. This suggests the benefit of spot tamping is greatest from balancing a "high-as-possible" tamp lift height while not creating vehicle dynamic issues from an overly humped track.

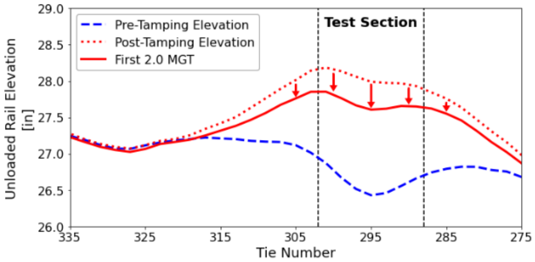

Figure 5. Rail settlement after tamping with an overlift

Test 4 also shows the difficulty of preserving track geometry when the fine-filled ballast is wet. This difficulty suggests that railroads should avoid tamping when fine-filled ballast is wet unless absolutely necessary.

CONCLUSION

Test results from this study show that higher lifts and carrying out an overlift can lengthen the maintenance cycle in fine-filled ballast, and that tamping wet fine-filled ballast is ineffective. This reduces the risk of rapid surface degradation that could result in track geometry exceptions.

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KEYWORDS

Ballast, spot tamping, ballast settlement, overlift