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Revenue Service Track Substructure Investigation

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Summary

In August 2009, Transportation Technology Center, Inc. examined the track substructure at three Norfolk Southern mainline sites to determine the root causes of localized mud-fouled ballast deterioration. The inspections were performed as part of the Improved Track Substructure Strategic Research Initiative (SRI) and were jointly funded by the Federal Railroad Administration and Association of American Railroads.

The inspections revealed excess water in the ballast layer as the basic problem at all locations. Although well-defined ditches were located next to and below the elevation of the track, the very low permeability of the fouled shoulder ballast and clay subgrade effectively blocked lateral drainage from the ballast section to the ditch.

The inspections were carried out by digging cross trenches to a depth of 3 to 4 feet below the ties. At least one trench was dug where mud was visible on the surface of the ballast (referred to as a mud spot) and one was dug where mud was not visible (non-mud spots) at each site. In addition to the presence of excess water in the ballast, the inspections showed:

- A top layer of ballast at all locations that was 6 to 12 inches deep and consisted of loose to medium-dense granular material that was wet and highly fouled with a viscous mud slurry. The existence of mud slurry was found at both mud and non-mud spots. However, it appears to become visible at the surface only when the volume and viscosity of the slurry, along with the hydraulic pressures generated under traffic, are sufficient to pump it up around the tie ends.
- A second ballast layer at all locations that extended to a depth of 12 to 18 inches below the top layer, denser than the top layer, wet and highly fouled, but without the mud slurry.
- There was no significant visual difference between ballast layer conditions at mud spots and nearby non-mud spots in terms of water content and the degree and type of fouling. The similarity in conditions indicates that mud spots can rapidly develop on track that visually appears to have a clean and well functioning ballast section.

The sites inspected were selected from a number of locations visited in May 2009, where muddy ballast had been identified as a chronic problem by local maintenance forces. In 2010, the next phase of the SRI, TTCI will design and test remediation methods at the same locations.

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INTRODUCTION

In 2009, Transportation Technology Center, Inc. (TTCI) began work on a new Strategic Research Initiative aimed at improving performance of the track substructure. The project is jointly funded by the Association of American Railroads and the Federal Railroad Administration and overall objectives include:

- Determining the effects of current axle loads and train speeds on track substructure performance
- Measuring the impact of poorly performing substructure on track component life cycles
- Developing guidelines for substructure diagnostics, remedy, design, and construction

One issue being investigated is the problem of ballast fouling and localized mud spots. Ballast that is highly fouled suffers loss of strength and increased deformation, as well as a reduced capacity for drainage and effective distribution of wheel loads. Input from a survey sent out in early 2009 indicated that dealing with mud spots is an industry-wide problem requiring significant effort and resources. Therefore, it was decided that guidelines for remediation and prevention of muddy ballast would be an immediate goal of the research, and defining the origin and root cause of the condition would be the necessary first step.

PHASE 1 PRELIMINARY INSPECTION

In May 2009, cursory inspections were performed at Norfolk Southern (NS) mainline locations in Alabama, Kentucky, West Virginia, and Ohio, where muddy ballast had been identified as an ongoing problem by local maintenance forces. The purpose of the Phase 1 inspections was to get a general idea of conditions and select two or three sites for more thorough investigation during the second phase of the project. Selection criteria included: (1) conditions considered to be fairly representative of other North American sites, (2) favorable site access, and (3) minimum annual tonnage of 30 million gross tons (MGT).

The following sites with chronic mud spot problems requiring ongoing maintenance efforts were selected for the Phase 2 investigation conducted in August 2009:

- Site 1 (55 MGT annual traffic) — Double track with reoccurring mud spots of moderate severity in a shallow cut area (Figure 1). There was a well-defined ditch about 12 feet from the south rail ballast shoulder.
- Site 2 (46 MGT annual traffic) — Double track with a number of severe and reoccurring mud spots creating rough track geometry on Track 1 (Figure 2). A well-defined ditch was located about 20 feet from Track 1. The adjacent Track 2 showed no sign of mud or rough track.
- Site 3 (73 MGT annual traffic) — Single track with numerous mud spots over several miles.



Figure 1. Site 1 Mud Spot



Figure 2. Mud Spot at Site 2 on Track 1 Only

PHASE 2 DETAILED SITE INVESTIGATIONS

The inspections were carried out by digging cross trenches across the track to a depth of 3 to 4 feet below the ties. The substructure layers were measured and sketched, and the layer material was identified in general accordance with the ASTM Visual-Manual soil identification procedure D2488. Samples of material from the layers were collected for further laboratory tests. At each location, at least one trench was dug where mud was visible on the surface of the ballast, and one was dug where mud was not visible.

Site 1

Three cross trenches were dug at Site 1. One trench was dug at the mud spot shown in Figure 1 and labeled XT-1, and two others were dug at nearby locations where mud was not visible on the surface and labeled XT-2 and XT-3. The substructure layer conditions at all three trenches were similar, including:

- A top granular layer consisting of loose to medium-dense aggregate that was wet and fouled primarily with mud slurry.
- A second granular layer, denser than the top layer, very wet and fouled, but without the mud slurry.
- Subgrade of moist plastic clay, grey in appearance and moderately stiff at the surface, becoming increasingly stiff a few inches below the subgrade surface.

The only difference in the appearance of the three trenches was that the mud slurry in the top layer had pumped through the shoulder ballast at XT-1 to form a mud spot (Figure 3).

As Figure 4 shows, the granular layers at all three trenches were very wet and the bottom of the trench filled rapidly with water seeping from the exposed faces of the layers. The amount of water indicated substantial moisture was being retained in the upper ballast layer.



Figure 4. Water Collecting in the Bottom of XT-2 Trench

Site 2

Two cross trenches were dug at Site 2 — one at a mud spot labeled XT-5 and the other at a non-mud spot labeled XT-4. The conditions at these trenches were somewhat similar to Site 1, as Figure 5 shows, and are described as follows:

- The mud spot had a top layer less than 12 inches deep that was wet and fouled with mud slurry material.
- It had a second layer, denser than the top layer, also wet and fouled, but without the slurry. Water also collected at the bottom of the trench as at Site 1.
- A hardpan layer, consisting of cemented limestone and slag, was located between the second granular layer and the subgrade. The subgrade that was visible at the edge of the hardpan was moist clay.

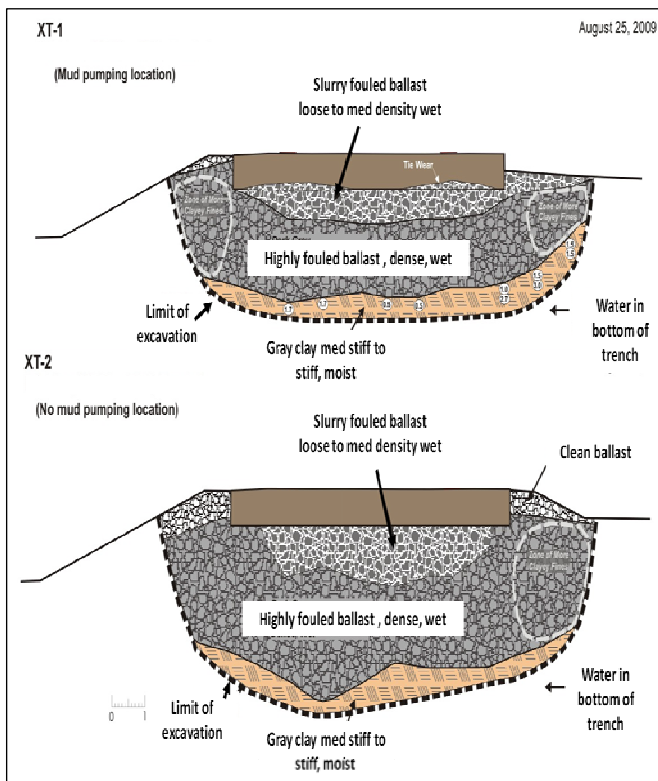


Figure 3. XT-1 and XT-2 Cross Sections

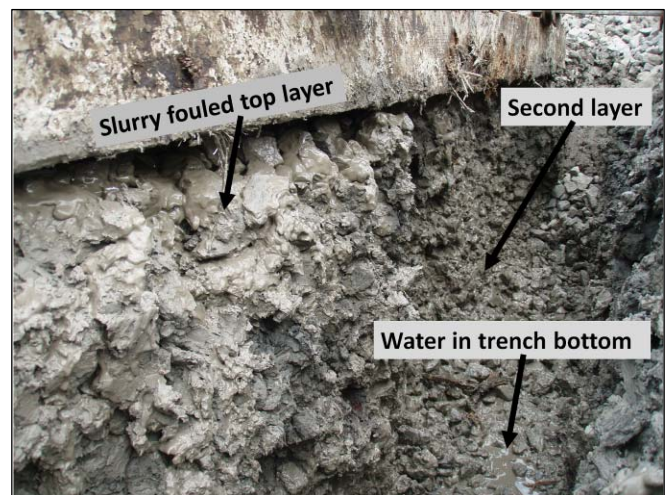


Figure 5. Granular Layer Conditions at the Site 2 XT-5 Trench

Site 3

Two cross trenches were dug at Site 3 labeled XT-6 and XT-7. As at the other sites, the granular layers were very wet with water collecting on the bottom of the trench, along with slurry-fouled top layer and a denser, highly fouled second layer. However, there was a third layer of medium-dense granular limestone gravel subballast sitting on a hardpan layer (Figure 6). There was a free-water surface within 2 feet of the bottom of tie. This site was slightly different from the other two in that there was a lot more water present, and the slurry tended to pump through the ballast shoulder near the toe, as Figure 7 shows, rather than pumping up around the ties.

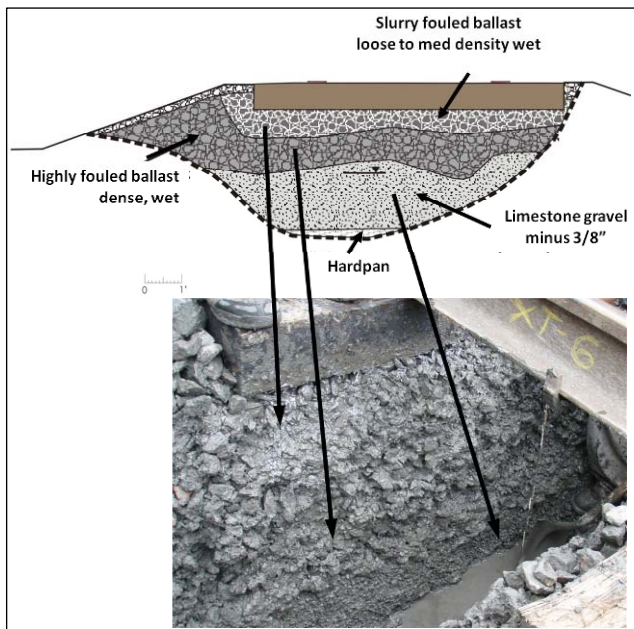


Figure 6. XT-6 Trench at Site 3



Figure 7. Mud Pumping through Ballast Shoulder at Site 3

CONCLUSIONS

The root cause of ballast deterioration and mud pumping at the three sites investigated was found to be water trapped in the ballast granular layers. External drainage at the sites, i.e., longitudinal ditches and drains, appeared to be adequate to remove water from the right-of-way; however, the internal drainage of the ballast section was inadequate to drain water laterally to the ditches.

Track relies on gravity drainage to remove water. At the sites investigated the relatively low permeability of the subgrade material and highly fouled lower ballast layers surrounding the upper ballast material prevented the water from draining.

The presence of water is highly detrimental to substructure behavior, particularly ballast performance. Water trapped in the voids between ballast particles facilitates ballast particle abrasion and breakdown, which culminates in the formation of slurry and subsequent mud pumping. The water also reduces the strength of the ballast layer, which in turn accelerates geometry degradation and tamping cycles. Tamping further contributes to breakdown of the ballast and mud formation.

Drainage is often cited as a fundamental requirement for acceptable track performance, but can be difficult to achieve. Maintenance activities such as cribbing to remove fouled ballast between ties, surfacing, and production ballast undercutting/cleaning (depths of 12 inches or less) are commonly used to deal with muddy ballast conditions. However, in cases such as those documented in this *Technology Digest*, the typical intervention methods do not completely restore adequate permeability of the ballast section, and more extensive work is required to provide a lateral drainage path out of the ballast shoulders.

FUTURE WORK

The next phase of this study will involve designing and testing drainage remediation methods such as lateral and edge drains, hot mixed asphalt underlayment, impermeable membranes, and urethane grout.

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