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BALLAST DEGRADATION UNDER HEAVY AXLE LOAD TRAINS AT THE WESTERN MEGA SITE

SUMMARY

Transportation Technology Center, Inc. (TTCI) and the University of Illinois Urbana-Champaign (UIUC), in conjunction with Union Pacific Railroad (UP), investigated ballast performance under 36-ton heavy axle load (HAL) traffic near Ogallala, NE, at the western mega site from 2010–2015. Periodic sampling and laboratory tests were used to monitor ballast degradation and deformation behavior of four mainline-quality ballast materials.

Testing was jointly funded by the Association of American Railroads (AAR), the Federal Railroad Administration (FRA), and UP to quantify the effects of ballast gradations and material types on ballast performance.

In November 2010, new ballast materials from four sources, labeled Types 1 through 4, were installed in a 2-degree curve and tangent test zones, as well as subjected to 220–250 million gross tons (MGT) per year.

Ballast Types 1–4 (Figure 1) were screened after delivery and before installation to remove particles less than 3/8-inch screen size. The Type 5 material was identical to the Type 2 material, but it was installed as delivered without additional screening. Steel boxes separated the ballast types, and samples were collected at six different times over the testing period of 737 MGT. Sieve analyses were performed on the sampled ballast to determine changes in the gradation with tonnage. Permanent deformation trends of the ballast samples were evaluated using a large-scale repeated load triaxial test device. Finally, the ballast sample nonorganic carbon contents from car lading were measured using a carbon, hydrogen, and nitrogen chemical test.

Figure 1. Ballast Box Installation in 2010. Ballast Type Number, Box Number, and Supplier Number Corresponds to the Same Box

In these test zones, ballast degradation rates due to HAL traffic differed substantially among the four mainline-quality ballast types. In general, Types 1 and 2 had lower degradation rates due to material types. However, higher percentages of degradation and organic carbon content in the ballast generally corresponded to higher permanent deformation in laboratory testing, with increasing traffic volume. With additional screening of the Type 2 ballast over the Type 5 control ballast at source gradation, the Type 2 ballast stayed cleaner to the test termination. Finally, for the western mega site, it took 737 MGT to accumulate significant amounts of carbon-based fines in ballast samples.

Testing also revealed that carbon based minerals migrated downwards over time and that the Type 3 deep samples contained the highest organic carbon content of 16 percent. The Type 3 also accumulated the highest laboratory permanent deformation at 10,000 cycles, at the final 732 MGT level.

BACKGROUND

The root causes of ballast degradation and loss of functionality are abrasion and breakdown of ballast particles from repeated wheel loads and maintenance, and infiltration of material from the outside. The American Railway Engineering and Maintenance-of-Way Association (AREMA) recommends several gradations for mainline ballast that can be generally defined as having uniformly graded particle sizes between 2½ and 2¾ inches, and no material smaller than the No. 4 sieve. These gradations have large inter-particle void spaces that facilitate drainage and permit some initial particle breakdown before ballast performance is compromised. Over time, the ballast's drainage capacity and strength is reduced as the percentage of fine material increases and fills the voids.

Ballast performance under 36-ton axle load traffic had been the subject of a major investigation at the western mega site on UP's South Morrill subdivision near Ogallala, NE. This site carries approximately 220 to 250 MGT of traffic annually on Track 2.

OBJECTIVES

To gain additional insight into the field performance of different ballast types and their corresponding life cycles, the relationship between gradation and deformation characteristics was measured by monitoring particle-size degradation as well as the deformation behavior of five mainline quality ballast materials with sieve analysis and repeated load triaxial testing. Coal-dust ballast infiltration was noted, originating from wind-blown material coming off the car hoppers.

METHODS

In November 2010, degradation monitoring began with new ballast materials from four separate sources, which were labeled as Types 1–4 in the test zones. The control ballast was labeled Type 5. Test sections included a 2-degree curve and a tangent location. Table 1 summarizes the ballast types and their mineral compositions.

The ballast types were contained in 14-foot long by 12-foot wide by 12-inch high steel boxes in both test zones, with ballast depth beneath the ties of about 14 inches. The boxes in the curve zone had steel bottoms, and the boxes in the tangent zone had fabric bottoms to isolate the ballast from the subgrade. Eight boxes were used in each section.

Table 1. Ballast Types with Mineral Description

BALLAST	MINERALOGY
Type 1	Orthoclase, feldspar, quartz, hornblende phenocryst
Type 2	Basalt (no minus 3/8-inch material)
Type 3	Quartzite
Type 4	Rhyolite, quartz phenocryst
Type 5 (control)	Basalt (includes minus 3/8-inch material)

The new ballast was sampled before installation in November 2010 and from April 2011 onward until test completion; additional samples were taken at approximately 6-month intervals. Estimated MGT during the intervals was 120, 283, 417, 516, 615, and 737.

Shallow samples were collected at all traffic volumes, from the bottom of the tie to approximately 10 inches below the bottom of the tie, using a narrow backhoe bucket. Deep samples were collected only at 737 MGT (the test conclusion) and were taken from 10 inches below the bottom of the tie to the bottom of the steel box at 14 inches below the bottom of the tie.

FIELD TEST RESULTS

Figure 2 shows the general trend of accumulation of material finer than 3/8 inch. Different ballast types with the mineral compositions listed in Table 1 showed different rates of degradation as traffic accumulated. Fluctuations of results can be attributed to field sampling error.

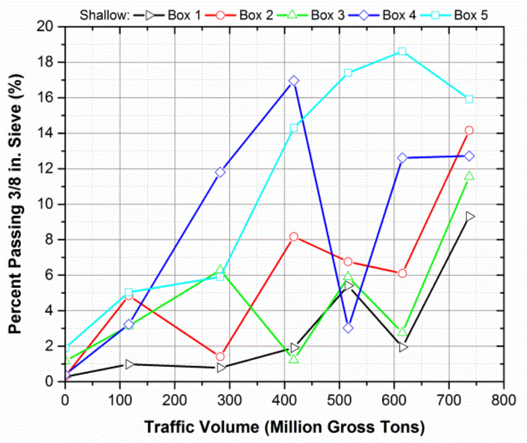

Figure 2. Accumulation of Materials Finer than 3/8 Inch with Traffic

Types 2 and 5 are basalt that came from the same source (see Table 1), though the Type 2 materials underwent an additional screening process to remove material finer than 3/8 inch when installed. Figure 2 indicates that the degradation was generally much higher for Type 5 than for Type 2. Additionally, the final field measurement of Type 2 (and Type 5 with the same mineral type) showed the highest degradation among the four types monitored. Previous results from Mill Abrasion (MA) testing also showed that the Type 2 material had the highest MA value, which means it has the highest potential for abrasion degradation. On the other hand, the Type 1 ballast exhibited the smallest gradual increase in the percentage of minus 3/8-inch material over time, both in terms of general trends and the final measurement. Note that the significant drop of ballast degradation result for Type 4 at 516 MGT was most likely caused by field sampling error.

TRIAXIAL TESTING RESULTS

Due to the short 14-foot distance in the field from one ballast type to another, accumulation of permanent deformation was evaluated as the field settlement potential of the track ballast using the UIUC Triaxial Ballast Tester (TX-24) (Figure 3 insert). This laboratory test was done under controlled, repeatable conditions that supplemented track settlement measurements in the field. It involved a cylindrical ballast specimen being subjected to a number of repeated load pulses along its longitudinal (vertical) axis and simultaneously subjected to a constant 8 psi confining pressure.

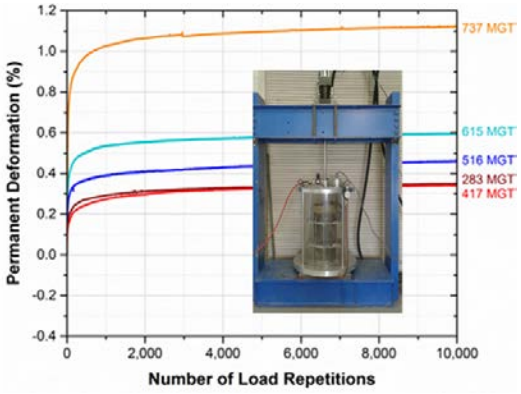

Figure 3. Permanent Deformation and Sieve Results for Type 1, with UIUC Triaxial Ballast Tester

Deformation was measured along all three principal axes, and both the resilient (elastic recoverable) and permanent deformations of the specimen were measured during each load cycle. Figure 3 shows the Type 1 ballast permanent deformation test results for 10,000 load cycles at 283, 417, 516, 615, and 737 MGT. The Type 1 ballast accumulated the lowest permanent deformation over time among all ballast types. As MGT increased, the deformation for all ballast types also increased, as Figure 3 shows.

Inorganic carbon was sampled from the base of each ballast box at 737 MGT, and it was noted in varying proportions at each location. However, only minute amounts were observed in samples taken from underneath the ties during the previous sampling intervals.

CONCLUSIONS

The following conclusions were reached:

- Ballast degradation rates differed substantially among the four ballast types. In general, Types 1 and 3 had lower degradation rates.
- With increasing MGT, higher percentages of degradation and organic carbon content resulted in a higher laboratory permanent deformation.
- The Type 2 ballast stayed cleaner, with additional screening, compared to the Type 5 control ballast at source gradation.
- For the western mega site, it took 737 MGT to accumulate the significant amounts of carbon-based fines that were observed in ballast sampling.

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CONTACT

Luis Maal
On-Site Resident Engineer Program Manager
Federal Railroad Administration
Office of Research and Development
55500 DOT Road
Pueblo, CO 81001
(719) 584-0551
luis.maal@dot.gov

Second Contact

Gary Carr
Chief – Track Division
Federal Railroad Administration
Office of Research, Development and Technology
1200 New Jersey Avenue, SE
Washington, DC 20590
(202) 493-6354
gary.carr@dot.gov

KEYWORDS

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