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Ballast Degradation Characterized through Triaxial Testing

SUMMARY

Transportation Technology Center, Inc. (TTCI) has supported the development of a large-scale triaxial test device (Figure 1) for testing ballast size aggregate materials at the University of Illinois at Urbana-Champaign (UIUC). This new test equipment uses monotonic compression and repeated load testing to characterize shear strength, resilient modulus, and permanent deformation behavior of railroad ballast materials. The investigation was performed as part of the heavy-axle-load (HAL) Track Substructure research initiative co-sponsored by the Association of American Railroads (AAR) and the Federal Railroad Administration (FRA).

Preliminary test results from the triaxial test device indicated that ballast characteristics could be captured adequately at different levels of degradation. To simulate ballast degradation due to breakage and abrasion, Los Angeles (LA) abrasion tests were used to generate degraded limestone ballast samples.

The laboratory sieve analysis and triaxial tests produced the following results:

- Ballast degradation can cause significant changes in ballast grain size distributions as well as particle shape properties: LA Abrasion Tests produced particles that exhibited considerable breakdown.
- In permanent deformation testing, the heavily degraded ballast specimen with a Selig's Fouling Index (FI) of 40 had the highest permanent deformation compared to the other specimens of new clean ballast and degraded ballast (coarse aggregate fraction) specimen. The specimen with coarse aggregate fraction (particles larger than 3/8 inch) from the degraded ballast yielded higher permanent deformation than the new clean ballast specimen.
- Ballast degradation did not lead to a significant strength loss in the monotonic shear strength tests. On the contrary, under dry sample conditions, the degraded ballast specimens with or without materials finer than 3/8 inch yielded higher strength than the new clean ballast specimen.

The triaxial test setup should provide a better understanding of the factors that affect ballast life-cycle and field performance.

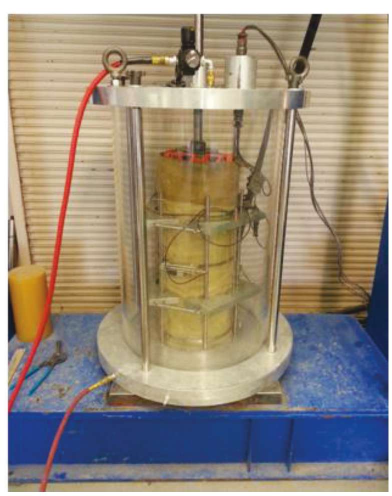


Figure 1. UIUC TX-24 Ballast Triaxial Tester

BACKGROUND

If ballast consists of large aggregate particles with uniform size distribution, it will facilitate load distribution and drainage. Good ballast is an essential component of the track's substructure. As freight tonnage increases, ballast accumulates a larger percentage of fines due to aggregate degradation and contamination by other materials such as lading material, dust, and subgrade soil intrusions. As a result, the shear strength and the load carrying ability of the ballast layer can be affected, especially under wet conditions.

First, the LA abrasion test was performed on ballast to investigate ballast breakdown and to generate ballast fine particles. Then, triaxial tests were performed on specimens of new clean ballast, degraded ballast without fines (material that passed a 3/8-inch sieve), and fully degraded ballast with fines under repeated loading and monotonic compression.

OBJECTIVES

The purpose of this study was to characterize ballast degradation via triaxial testing. The LA abrasion test was used to generate fine materials for testing.

METHODS

The UIUC Triaxial Ballast Tester

Before initiating a test with UIUC's large-scale triaxial test device, an internal load cell with a 20-kip capacity was placed on top of the specimen top platen and three vertical sensors were placed around the cylindrical test sample in 120-degree increments to measure vertical deformation.

The ballast material selected for the laboratory degradation study was crushed limestone, which met AREMA's No. 24 gradation requirements. The test was performed according to AASHTO T 96 or ASTM C 131 to reach the fully fouled condition at a Selig Fouling Index (FI) of 40.

LA Abrasion Test & Image Analysis

The gradations of new clean ballast and degraded ballast (FI=40) specimens (after 1,500 turns of LA abrasion test) are shown in Figure 2. The degraded ballast without fines (FI=0), which represents the coarse fraction (greater than 3/8-inch size) gradation is also shown. After LA abrasion testing, the specimen of the degraded ballast excluded particles smaller than 3/8-inch size.

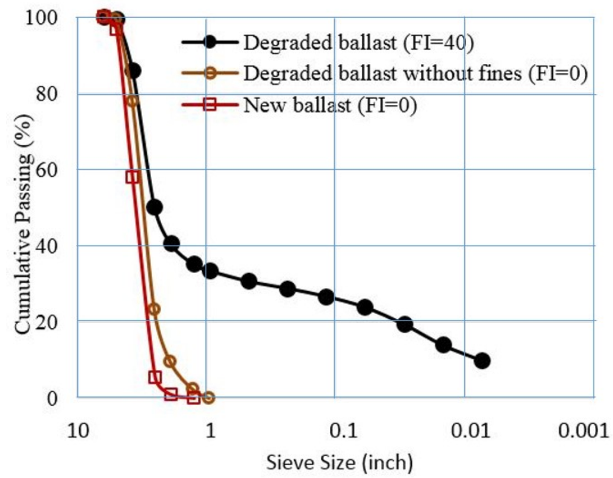
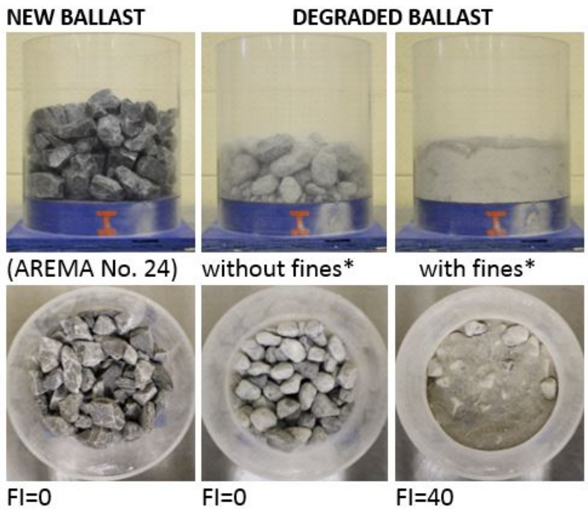


Figure 2. Gradation Curves of Ballast Materials

The study also related gradation information to ballast layer functional characteristics and the governing mechanisms that impact ballast layer structural and drainage behavior. Approximately 22 pounds of ballast material obtained before and after 1,500 turns in LA abrasion tests was poured into the 10-inch tall acrylic chamber with a 10-inch diameter for the triaxial test. Figure 3 presents side and top views of ballast aggregates taken before and after degradation with their corresponding FI values. As FI approached 40, nearly all the voids created by the large particles were filled with fine particles.



*fines refer to particle sizes passing 3/8-inch sieve

Figure 3. Side and top views of ballast aggregate packing

Triaxial Testing

A realistic dynamic pulse (similar to field train loading) with 0.4-second load duration and 0.6-second rest period was selected to evaluate permanent deformation characteristics of the ballast materials obtained before and after LA abrasion tests. The peak deviator stress repeatedly applied on the specimen was 24 psi (166 kPa) and the confining pressure was 8 psi (55 kPa).

A typical loading strain rate of 1 percent per minute was used, which corresponded to 0.1016 mm per second. All test specimens were monotonically loaded up to 10 percent axial strain at a confining pressure of 10 psi (69 kPa).

RESULTS

Figure 4 presents the results of the permanent deformation tests on the new clean ballast and degraded limestone ballast after 10,000 load cycles. The fully degraded ballast specimen (with fines), for which the FI was 40, clearly resulted in the highest permanent axial strain value of 1.32 percent. The degraded ballast specimen with coarse aggregates (without fines) had a permanent axial strain value of 0.92 percent, whereas the new clean ballast specimen had a permanent axial strain value of 0.62 percent.

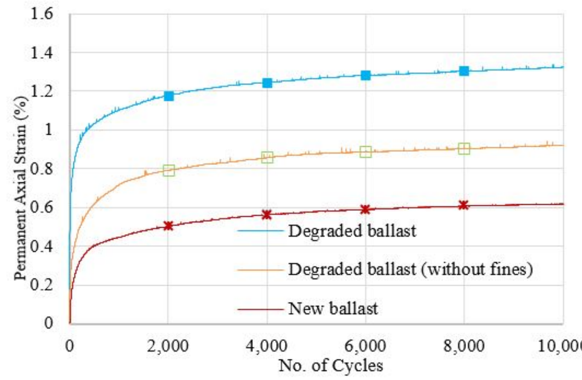


Figure 4. Side and top views of ballast aggregate packing

Figure 5 shows the results of the monotonic shear strength tests on the new clean ballast and cylindrical specimens of degraded limestone ballast for up to 10 percent axial strain. Interestingly, when dry fouled ballast specimens were compared to the new clean ballast material, particle degradation did not lead to significant strength loss in the dry-fouled ballast. On the contrary, both the fully degraded ballast with fines and the degraded ballast without fines (coarse aggregate) yielded higher strength than the new clean ballast specimen under dry sample testing conditions.

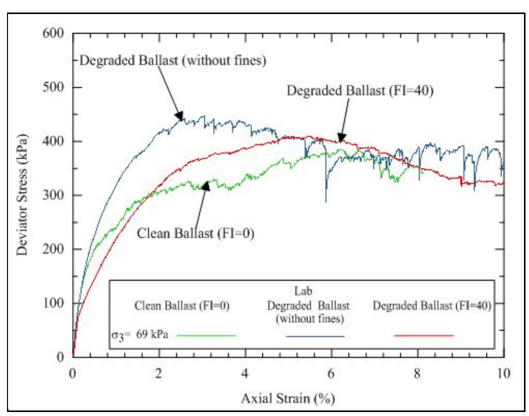


Figure 5. Deviator Stress and Axial Strain for New, Dry, Clean Ballast and Degraded Ballast

Comparing the gradations of the three ballast materials, the degraded ballast without fines was more "well" graded than the new clean ballast material. The smaller particles in the fully degraded ballast matrix helped to achieve higher density and better packing.

CONCLUSIONS

The ballast degradation tests produced the following results:

- As LA abrasion tests caused degradation in ballast, the particles tended to become smaller in size and significant amounts of fines (particles smaller than 3/8 inch) were generated. Particles that did not break became more rounded and smoother in texture.
- When the FI approached 40 (fully degraded ballast with fines), nearly all the voids were filled with fines, which resulted in loss of contact between large particles in the degraded ballast aggregate skeleton.
- Fully degraded ballast with fines (FI=40) yielded the highest permanent deformation, followed by the degraded ballast with no fines, and the new clean ballast resulted in the lowest deformation. On the contrary, the degraded ballast with or without fines yielded higher strength than the new clean ballast specimens when tested under dry conditions.

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KEYWORDS

Ballast degradation, triaxial testing, LA abrasion test