Association of
American Railroads

Railway Technology

FAST HEAVY AXLE LOAD
BALLAST TEST RESULTS

REPORT NO. R-914

by

M. Carmen Trevizo

Association of American Railroads
Transportation Technology Center
Pueblo, Colorado

December 1997

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13. Abstract

A ballast experiment was performed at the Federal Railroad Administration's Transportation Technology Center, Facility for Accelerated Service Testing (FAST), Pueblo, Colorado, as part of the original series of tests designed to determine track performance under 39-ton axle loads. Four ballast materials — granite, traprock, limestone and dolomite — were installed in the High Tonnage Loop (HTL) in 1988.

Even though a direct comparison between 33- and 39-ton axle load traffic cannot be made due to differences in ballast types and accumulated tonnage, it appears that degradation of the material in test is more dependent on accumulated tonnage than on increased axle load. The granite and traprock ballast maintained adequate geometry throughout the 750 MGT duration of the test, while the dolomite required an out-of-face surfacing after the first 40 MGT and again after the first 260 MGT, after which it was removed from track. The limestone required surfacing after the first 70 MGT of traffic.

The primary objective of the experiment was to quantify ballast performance based on measurements of track geometry, ballast density, track settlement, and ballast particle degradation. A secondary objective was to quantify the amount of fine material in the ballast generated by track maintenance.

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Executive Summary

Four ballast materials tested in a ballast experiment at the Federal Railroad Administration's Transportation Technology Center, Facility for Accelerated Service Testing (FAST), Pueblo, Colorado, were able to withstand the heavy axle load (HAL) environment at varying accumulated tonnage. Even though a direct comparison between 33- and 39-ton axle load traffic cannot be made due to differences in ballast types and accumulated tonnage, it appears that degradation of the material in test is more dependent on accumulated tonnage than on increased axle load. While the ballast has not exhibited significant distress under HAL, other tests have shown that a fine-grained subgrade can be very sensitive to this increased loading. Therefore, more investigation into the effects of HAL upon subgrade should be performed.

As part of the original series of tests designed to determine track performance under 39-ton axle loads, four ballast materials, which included granite, traprock, limestone and dolomite, were tested under 39-ton axle loads in the High Tonnage Loop (HTL) at FAST. The granite and traprock ballast maintained adequate geometry throughout the 750 MGT duration of the test, while the dolomite required an out-of-face surfacing after the first 40 MGT and again after the first 260 MGT. The limestone required surfacing after the first 70 MGT of traffic.

The primary objective of the experiment was to quantify ballast performance based on measurements of track geometry, ballast density, track settlement, and ballast particle degradation. A secondary objective was to quantify the amount of fine material in the ballast generated by track maintenance.

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1.0 INTRODUCTION/OBJECTIVE

A ballast experiment was performed at the Federal Railroad Administration's Transportation Technology Center (TTC), Facility for Accelerated Service Testing (FAST), Pueblo, Colorado, as part of the original series of tests designed to determine track performance under 39-ton axle loads. Four ballast materials — granite, traprock, limestone and dolomite — were installed in the High Tonnage Loop (HTL) in 1988.

The primary objective of the experiment was to quantify ballast performance based on measurements of track geometry, ballast density, track settlement, and ballast particle degradation. A secondary objective was to quantify the amount of fine material in the ballast generated by track maintenance.

2.0 TEST LAYOUT

Ballast test zones were established in Section 03 of the HTL as shown in Exhibit 1. Section 03 is a 5-degree curve with design superelevation of 4 inches. The FAST train operates at 40 mph, which equates to 1.6 inches of cant deficiency in Section 03. Other than the ballast material, the track structure in the test zones was the same throughout the entire ballast test section and consisted of 136 RE continuous welded rail (CWR) and wood ties with cut spikes and rail anchors. A concrete tie test zone was also located in the curve, but it was not part of the ballast experiment. The limestone and traprock zones were each approximately 560 feet (350 ties) long and the granite and dolomite zones were 715 feet (440 ties) long.

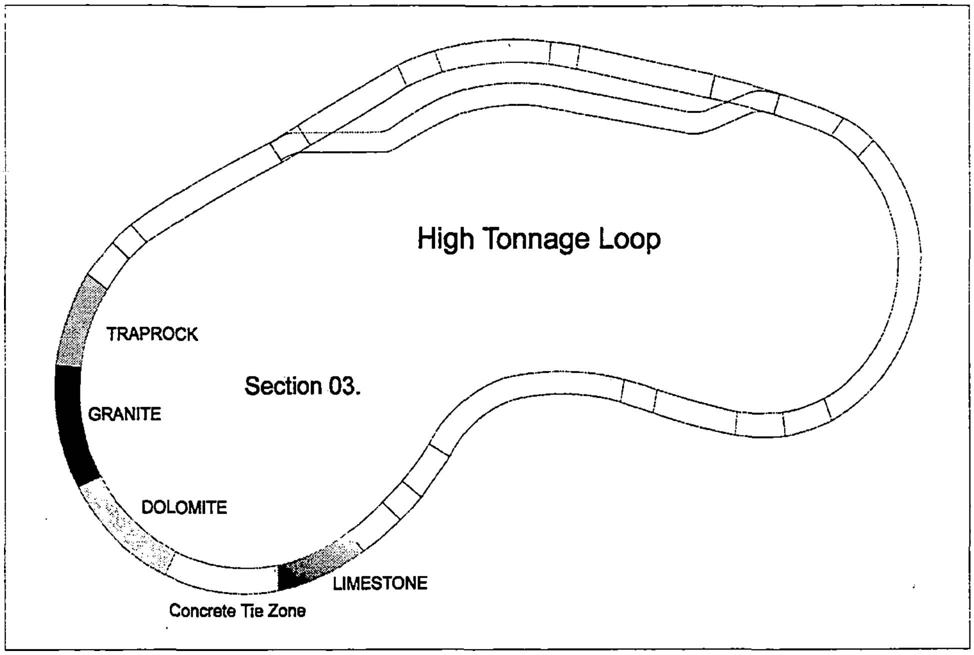

Exhibit 1. Ballast Test Zone Locations

Each of the four ballast material test zones was divided into subsections including two transition subsections, one geometry subsection, one sampling subsection, and one continuity subsection as shown in Exhibit 2. The transition subsections were approximately 81 feet long and were located on the ends of each zone. The geometry subsection was 162 feet long, and was located between the continuity subsection and a transition subsection. The ballast sampling subsection was 162 feet long in the traprock and limestone zones, and 300 feet long in the granite and dolomite zones. The continuity subsection 81-feet long and was used as a divider between the geometry and ballast sampling subsections in each test ballast.

Ballast bins were installed in transition subsections of the granite and dolomite test zones to exclude the potential ballast fouling sources of wind-blown fines or subgrade intrusion. This provided a means to measure only the ballast degradation from traffic loading and from tamper damage.

The ballast gradation specification recommended by the AREA ballast committee and requested by the Association of American Railroads for the ballast experiment was AREA No. 24. However, upon gradation analysis, TTC engineers found that the gradations of the four donated ballasts varied somewhat. The gradation for the granite and limestone ballasts was a modified AREA No. 3, while the traprock gradation was AREA No. 4, and the dolomite was an AREA No. 24.

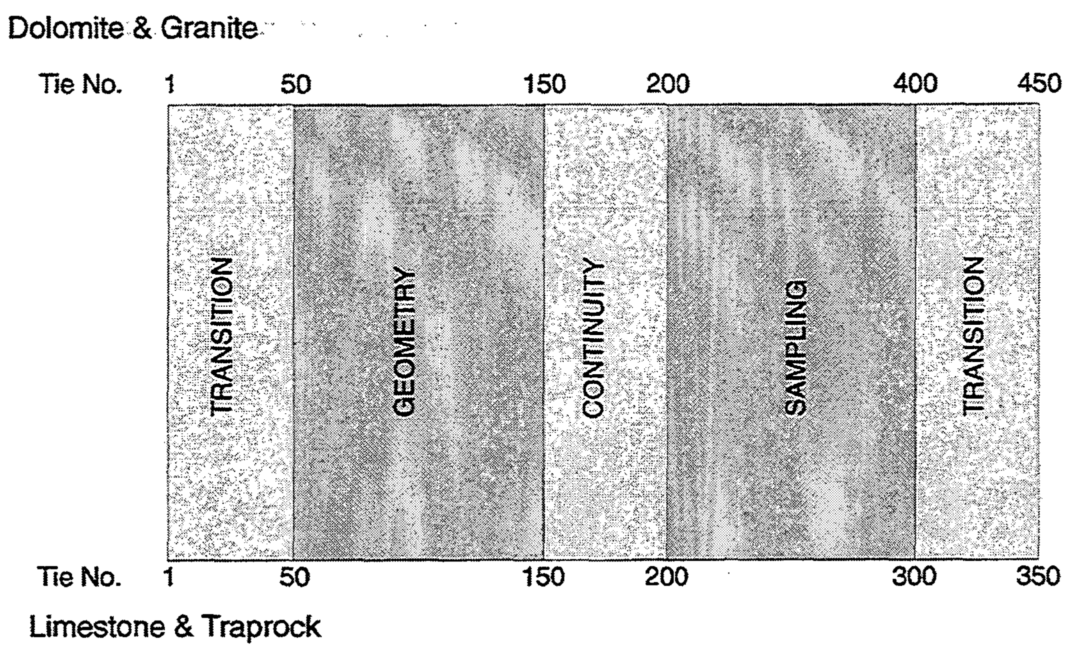

Exhibit 2. Test Zone Layout

3.0 MEASUREMENTS

Ballast degradation, track geometry retention, and vertical track modulus measurements were made at predetermined MGT cycles (subsection 3.7) for each of the test ballasts.

3.1 TRACK GEOMETRY

Measurements taken to monitor track geometry retention included loaded and unloaded profile elevations, and track geometry car measurements (e.g., alinement, cross level, profile).

3.1.1 Loaded Track Profile Elevation

Consecutive loaded track profile measurements provided a determination of track settlement with accumulated tonnage under a loaded car. This was accomplished by reading the elevation of a short survey rod permanently attached to the A-end of a coal car which provides a static 39-ton axle load. The vertical track deflection was recorded when the wheel set was located directly above each of the selected ties.

Because the static track deflection measurements are obtained from 39-ton axle loading, the deflection is a better approximation to that produced by the FAST/HAL train (39-ton axle loads moving at 40 mph) than that measured with the FAST EM80 geometry measurement car, which only applies a 15-ton axle load at 10 mph.

Track irregularities such as joints, battered welds, and profile deviations often appear as more distinct features in data collected with the loaded, rather than with unloaded, track profile measurement.

3.1.2 Unloaded Track Profile Elevation

The unloaded profile measurement was accomplished by reading top of tie elevations on five selected ties in the geometry subsection of each test ballast. Tie elevations were taken next to each rail on the field side. Tacks were installed on the ties to ensure that measurement was always taken on the same location of the tie and on a non-wearing surface.

3.2 <u>Ballast Density</u>

Ballast density measurements were taken just inside each rail (gage side) using a nuclear density gage on five tie locations. The selected ties were prepared by drilling through a 3-inch hole as shown in Exhibit 3. Hollow steel pipes were then placed in the holes, down to the ballast/subgrade interface, to provide access for the nuclear probe.

The depth density-moisture gage, which measures sub-surface density using a probe containing a gamma source and a gamma detector, was used on all ballast density measurements. To avoid back scatter when taking the readings, the probe was lowered through the steel pipe 3 inches above the ballast/subgrade interface.

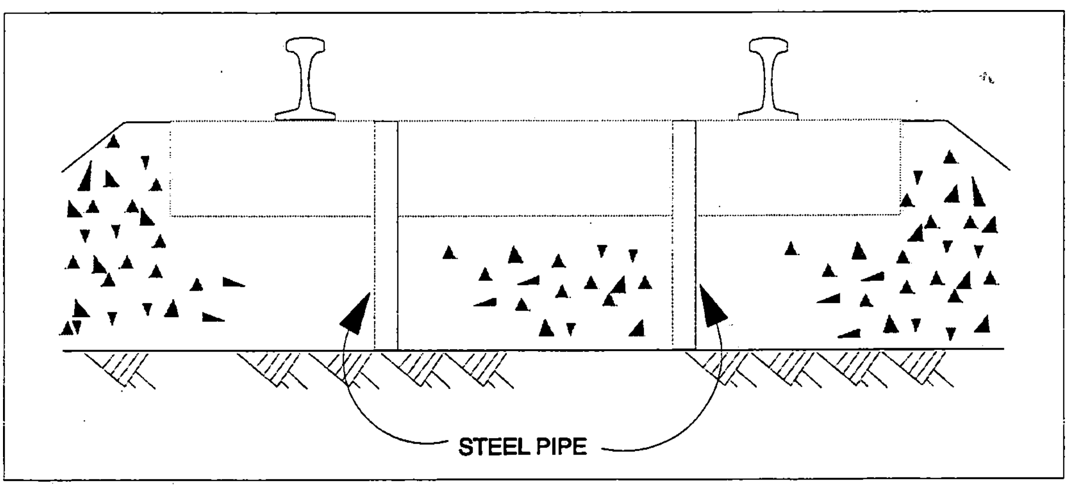

Exhibit 3. Typical Density Measurement Layout

3.3 <u>VERTICAL TRACK MODULUS</u>

Vertical track modulus is calculated by using the measured vertical track deflection under pre-determined loads. The deflection used in the calculation is the difference between that produced by a light load (10 kips) and a heavy load (39 kips).

The deflection is measured on a magnetic scale that is attached to the rail directly over the measured tie. The 605 car, a modified locomotive frame that applies single-point loading on both rails to simulate a single axle loading, is used to apply loads ranging from 0 to 40,000 pounds in increments of 10,000 pounds. Vertical displacement of the rail is measured and recorded at each of the load levels.

3.4 EM80 CAR — TRACK GEOMETRY MEASUREMENTS

Track geometry retention was monitored with data collected using the EM80 track geometry measurement car. The EM80 measures gage, track profile, cross level, and alinement. Data is collected dynamically at a speed of 10 mph, under an axle load of 15 tons.

3.5 BALLAST GRADATION ANALYSIS

Gradation analyses were performed to monitor the particle breakdown with accumulated tonnage and tamping. Two sampling methods were used: (1) sampling ballast from in track by excavating a portion of ballast from under the tie in the rail-tie area, and (2) sampling from ballast bins which were placed in track as shown in Exhibit 4.

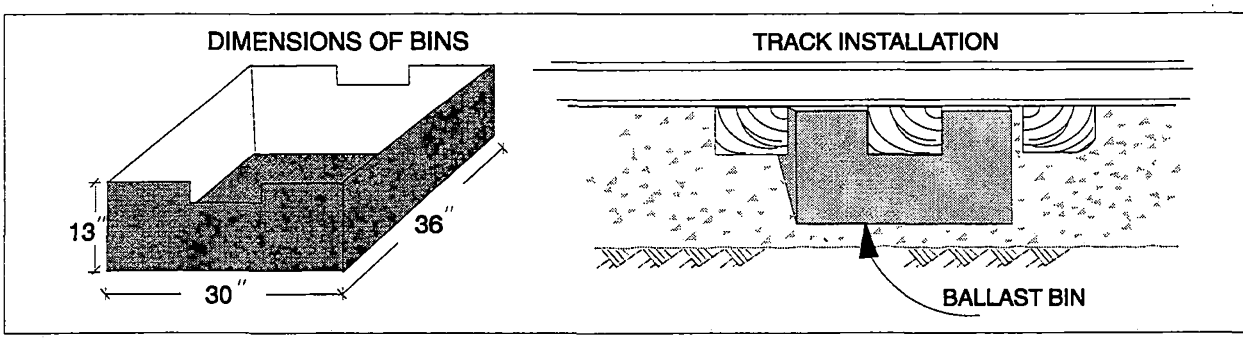

Exhibit 4. Ballast Bin Track Installation

3.5.1 Gradations from Ballast Samples

Ballast samples were retrieved in accordance with the current FAST S-008 methodology. Samples were retrieved during the designated MGT schedule, and before and after out-of-face surfacing. Initially, ballast samples were retrieved at each measurement cycle from five random ties. However, after the first 160 MGT of HAL traffic, the sample size was reduced to four ties due to the reduced track sampling area as a result of another test in the same area. The samples were retrieved from the rail seat and crib area of both rails to capture any difference in ballast degradation between high and low rails.

3.5.2 Gradations from Ballast Bins

To isolate the actual physical degradation of the ballast particles from contamination of subgrade or wind-blown material, ballast bins were installed in the granite and dolomite transition test zones. Ten bins were installed in one of the transition zones on the granite and dolomite test zones.

The sides of the bins, shown in Exhibit 4 , were made of sheet metal. A geotextile material was used for the bottom of the bins. The geotextile was used to keep the ballast samples drained, while retaining most of the ballast particle breakdown. The use of the geotextile, on the bottom of the bin, did not alter the vertical support condition of the contained ballast. After the ballast was placed in the bins, the bins were covered with a sheet metal cover to prevent outside contamination.

All of the 20 bins were filled with a known gradation and installed directly under the tie-rail bearing area. The ballast gradation in each bin had less than 0.5 percent passing the 1/4 sieve. Of the 10 bins in either the granite and dolomite materials, 5 were tamped at predetermined cycles. The ballast in the other five bins received only one tamping application (just after placement).

3.6 LABORATORY TESTS

There were several laboratory tests performed at the start of the ballast experiment on the four ballast materials: Soundness of Aggregate (magnesium & sodium sulfate), Los Angeles Abrasion, Clay Lumps, Friable Particles, Scratch Hardness of Coarse Aggregates, Unit Weight of Aggregate, Sieve Gradation Analysis, Particle Shape Indices (Elongation and Flakiness Index) Test, and CIGGT Shape Factor Test. The appendix lists the test results.

3.6.1 Soundness of Aggregate Test (magnesium & sodium sulfate)

The Soundness of Aggregate Test helps determine the resistance of aggregates to disintegration by saturated solutions of sodium sulfate or magnesium sulfate. This test provides information on the soundness of aggregates subject to weathering. Test Designation AASHTO T104.

3.6.2 Los Angeles Abrasion Test

The Los Angeles (LA) Abrasion Test is the most widely specified test for evaluating the resistance of the coarse aggregate to degradation by abrasion and impact. A ballast sample of a specified gradation is placed in a steel drum with 12 steel charges. The drum is rotated for 1,000 revolutions and a steel shelf within the drum lifts and drops the ballast sample. This tumbling action and the impacts of the charges cause the more brittle particles to shatter; surface wear and abrasion as the particles rub against one another and against the steel charges also result from this. Test Designation ASTM C535, Grading 3.

3.6.3 Clay Lumps and Friable Particles Test

The test determines the amount of weak and undesirable lumps of clay and friable (easily pulverized) particles present in the ballast. Test Designation ASTM C 142 - 78.

3.6.4 Scratch Hardness of Coarse Aggregates Test

The Scratch Hardness of Coarse Aggregates Test is used to quantify the hardness of the aggregate particles on a relative scale. Test Designation ASTM C 851 and ASTM C 235.

3.6.5 Unit Weight of Aggregate Test

The Unit Weight of Aggregate Test determines the weight of ballast material per unit volume under a limited compaction effort. (Test Designation ASTM C 29.)

3.6.6 Sieve Gradation Analysis

The Sieve Gradation Analysis determines the particle size distribution of the fine and coarse ballast sizes by sieving. Test Designation ASTM C 136 and ASTM C 117.

3.6.7 Particle Shape Indices (Elongation and Flakiness Index)

The British Standard test defines an elongated particle as one with a length to width ratio greater than 1.8. The elongation index is the percentage by weight of elongated particles in a sample. This British Standard defines a flaky (or flat) particle as one with a ratio of thickness to width less than 0.6. As with the elongation test, the flakiness index is the percentage by weight of flaky particles in a sample. Test Designation British Standard 812.

3.6.8 CIGGT Shape Factor

The CIGGT Shape Factor Test (performed by W. W. Boxely Company) is described by the Canadian Institute of Guided Ground Transport as a ratio of the longest dimension to the least width. The test is performed by selecting a representative sample of about 100 coarse ballast particles that are retained on a specified grading sieve designated to have 50-70 percent passing. Using a pair of calipers, each particle is measured to the nearest millimeter to determine its longest dimension and its least width.

3.7 MEASUREMENT SCHEDULE

Exhibit 5 lists the schedule of measurements taken during the experiment.

Exhibit 5. List of Schedule Measurements

MEASUREMENT	LOCATION	FREQUENCY
Loaded Track Profile	Geometry Zone	0, 2.4, 7.2, 20.8, 40, 60.8, 100, 130, and 160 MGT. And whenever maintenance is performed.
Unloaded Track Profile	Geometry Zone	0, 2.4, 7.2, 20.8, 40, 60.8, 100, 130, and 160 MGT. And whenever maintenance is performed.
Vertical Track Modulus	Geometry Zone	0, 2.4, 7.2, 20.8, 40, 60.8, 100, 130, and 160 MGT. And whenever maintenance is performed.
Ballast Samples	Sampling Zone	**Limestone & Traprock** 0, 2.4, 7.2, 20.8, 40, 60.8, 100, 130, and 160 MGT. And whenever maintenance is performed. **Granite & Dolomite** 0, 0.8, 2.4, 7.2, 20.8, 40, 60.8, 100, 130, and 160 MGT. And whenever maintenance is performed.
Ballast Bins	Transition Zone	0, 7.2, 40, 60.8, 100, and 160 MGT.
Laboratory Tests		At start of test.

4.0 IMPLEMENTATION

Before the ballast was installed, the existing ballast and subballast in the test zones in Section 03 were excavated by undercutting down to the subgrade interface. The skeletal track was in place when a dolomitic sub-ballast material was installed. The rails and ties were not removed prior to the installation of the sub-ballast to avoid any adverse influence on the rails and weld test that was in place at this location four years before the start of the ballast test. The sub-ballast was installed with an average depth of 8 inches under all of the ballast test zones.

The ballast materials were then installed to an average depth of about 18 inches below bottom of tie on the low rail. The ballast depth was dictated by the surrounding track sections. Because only part of the curve was undercut, the track elevation in the undercut area had to be raised to the elevations of the adjoining track zones, keeping the experiments in the undercut area and the adjacent areas undisturbed.

After 15 MGT of HAL, an investigation was conducted to evaluate the sub-ballast layer condition. Seven trenches were excavated to provide access to the sub-ballast, so that density measurements, water content, proctor tests, ballast, and sub-ballast depth measurements could be obtained. The trenches were located in the transition zones to avoid disturbing the geometry retention and ballast sampling zones.

The ballast depth measured across the seven trenches varied from 19 to 21 inches. The small switch undercutter used allowed this variation. Although a full-size undercutter would have produced a more controlled and uniform depth excavation, only a switch under cutter was available.

Because the sub-ballast material was installed to a uniform thickness, the difference in excavation depth created by the under cutter had to be compensated by the varied ballast depth to achieve the desired top of rail elevation. Exhibit 6 shows the average ballast depth measured in the four ballast sections.

The measured sub-ballast depth varied from 7 inches to 9 inches. A total of 49 sub-ballast density readings were obtained throughout the seven trenches. The sub-ballast layer was considered to be uniformly compacted since the coefficient of variation from the density readings was less than the 10 percent. The coefficient of variation was calculated by dividing the standard deviation by the mean density of the 49 density readings.

Once the test began, the geometry zone of each ballast section was monitored for track geometry retention loss. If and when a zone within any of the individual ballast test sections fell below FRA Class 4 track geometry specifications, that entire ballast material section was tamped. Track geometry measurements were taken before and after surfacing.

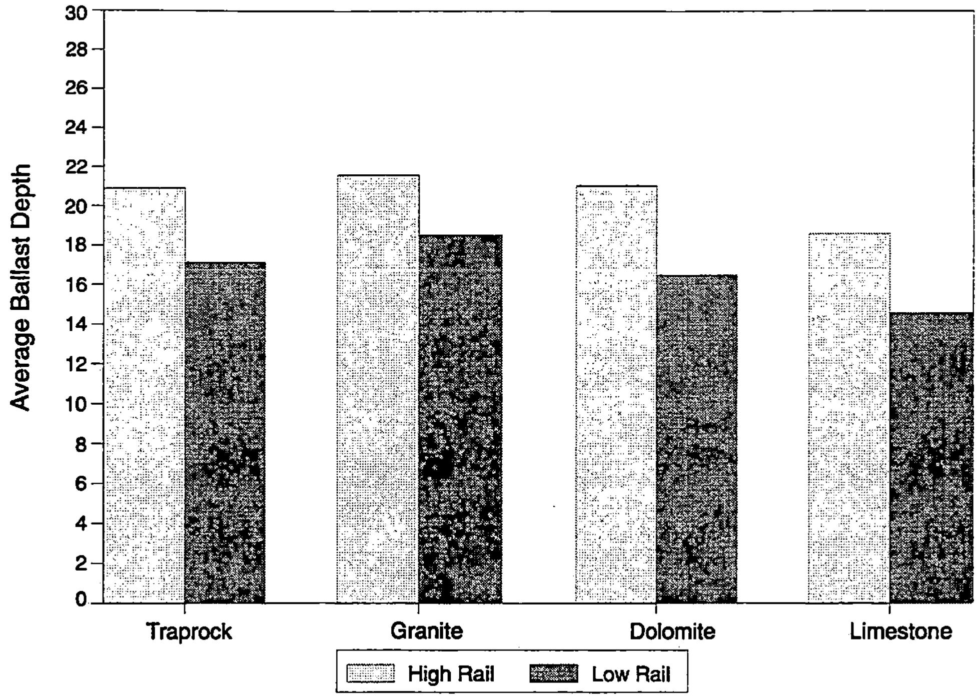

Exhibit 6. Average Ballast Depth — Section 03

The geometry measurement frequency listed in the previous section was followed as recommended by the AREA ballast committee.

Results from the experiments after the first 160 MGT of HAL traffic indicated that rail and tie changes and replacements were necessary in selected areas of the curve in Section 03, the ballast test sections. After the changes were made, the track over the granite and part of the dolomite areas required surfacing. However, the entire track length through the four ballast materials were surfaced so that the tamping-induced ballast degradation would be consistent.

To accommodate an experiment of rail seat abrasion in concrete ties, the existing concrete tie area in Section 03 was extended after 250 MGT of traffic had accumulated in the ballast test. This change eliminated the dolomite ballast test zone and reduced the limestone ballast test zone. The decision, made by the FAST Steering Committee, took into account the daily maintenance that was required in the dolomite ballast during the most recent 10 MGT of HAL traffic. The limestone test section continued with the original geometry retention zone undisturbed; however, the tie sampling was eliminated. The ballast sampling continued in the transition zone adjacent to the geometry zone and was also extended 10 ties into the spiral zone of Section 04.

The few ties left undisturbed in the ballast sampling zone of the granite and traprock test zones were reserved to be sampled at the end of ballast life. The tie sampling areas had been depleted soon after the start of the test, due to the high initial sample frequency, and to the need for frequent spot maintenance at the rail joints. Although the rail in this area was, rail breaks were common and, until a field weld was installed, rail joints were used as a CWR temporary fix.

As HAL traffic tonnage reached 300 MGT, the majority of the rail in Section 03 was experiencing an increase in rail fatigue defects. Rail breaks were occurring often and the welding crew was unable to repair them immediately. The number of rail joints and the length left in track increased tremendously. The adverse effect of these joints on the individual ballast performance could not be quantified. The ballast experiment measurements were stopped for a time by the FAST Steering Committee.

After 360 MGT of HAL traffic, rails with fatigue defects were replaced, thus eliminating all joints in the test zones. The entire curve in this section was surfaced after the installation of the new rails and ballast measurements resumed.

5.0 RESULTS

By the end of the test more than 750 MGT of HAL traffic had accumulated over the granite, limestone, and traprock ballast sections. The increase in axle load seems to have little or no influence on the performance of the ballast. Ballast life and geometry retention appear to be more influenced by accumulated tonnage, maintenance practices, high dynamic forces, and ballast particle shape. Geometry retention varied with ballast type and accumulated tonnage.

5.1 GEOMETRY RETENTION

The granite and traprock ballast have not required any out-of-face surfacing after 750 MGT of traffic. The limestone ballast was surfaced out-of-face after 70 MGT of traffic due to loss of cross level, and after 255 MGT due to a track buckle in the test zone. The dolomite ballast required surfacing out-of-face twice (at 40 and 255 MGT) due to loss of cross level. It was removed from test after 255 MGT.

5.2 LOADED TRACK PROFILE ELEVATIONS

Track settlement with tonnage (Exhibits 7 and 8) was obtained from the loaded track profile measurements for the four ballast sections. It appears that the largest settlement rate occurred during the first 3 MGT of traffic in all four ballast test zones. As expected, the largest settlement rates follow any surfacing maintenance of the track. As shown in Exhibit 7, there was a difference in settlement rate and total settlement between the ballast materials. Both the settlement rate and total settlement were lower for the granite and traprock ballast materials compared to those of the dolomite and limestone for 0 to 160 MGT. However, after the surfacing maintenance at 160 MGT applied to all four ballast sections, these settlement rate and total settlement trends reversed.

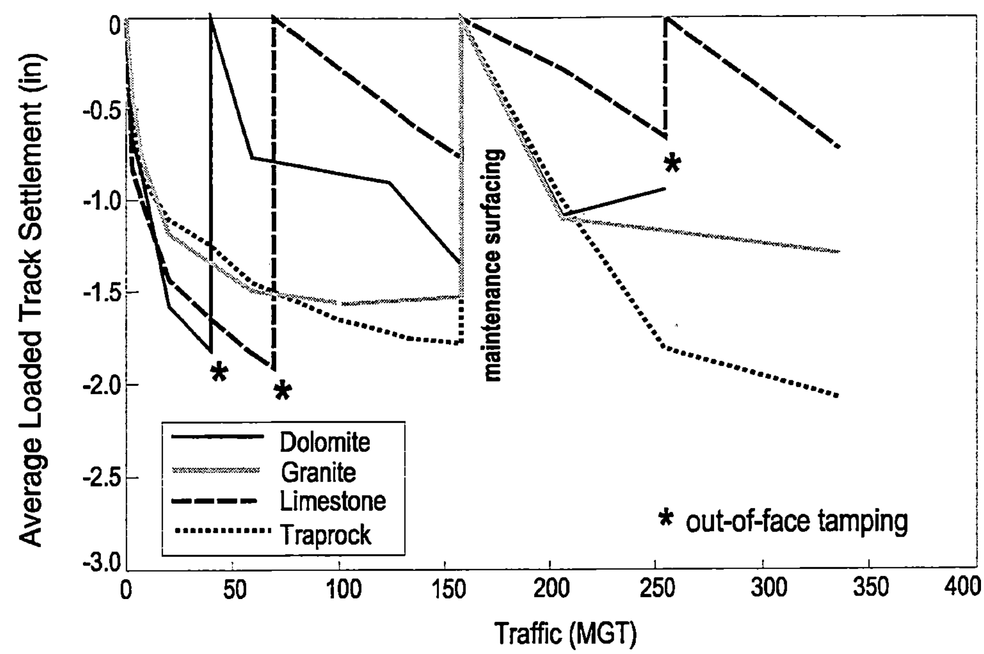

Exhibit 7. Track Settlement from Loaded Survey — High Rail

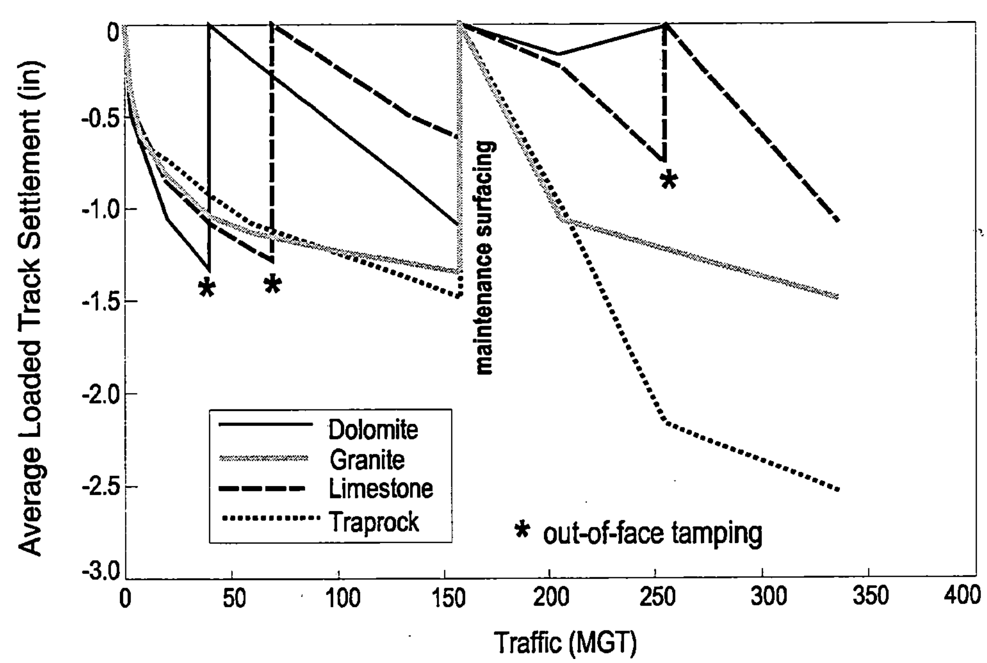

Exhibit 8. Track Settlement from Loaded Survey — Low Rail

5.3 UNLOADED TRACK PROFILE ELEVATIONS

The track profile elevations from the unloaded top of rail surveys shown in Exhibits 9 and 10 reflect the same settlement trend shown with the loaded track profile. An initial large settlement rate occurs after ballast installation and after any surfacing cycles, leveling off with tonnage. The unloaded track profiles also show the differential settlement between the high and low rail, resulting in loss of cross level for the dolomite and limestone ballast.

5.4 BALLAST DENSITY

Changes in ballast-density measurements from the initial (post tamping, 0 MGT) readings are shown in Exhibits 11 and 12. Ballast compaction under traffic loading produced an increase in ballast density with tonnage for all ballast materials following the two surfacing operations. The loosening effect that tamping often has on ballast can be seen by the decrease in density with the second tamping.

The main factors which can influence ballast density are ballast particle shape, specific gravity, gradation, and compaction. Although differences in these properties between the four ballast materials could cause a large change in density, there is little relative difference indicated in Exhibits 11 and 12 between ballast materials. Because the average post tamp, pre-traffic ballast density is about 110 pcf, the amount of increase with tonnage ranged only from 5 percent to 10 percent. This amount of variation does not, by itself, indicate a significant difference in ballast performance.

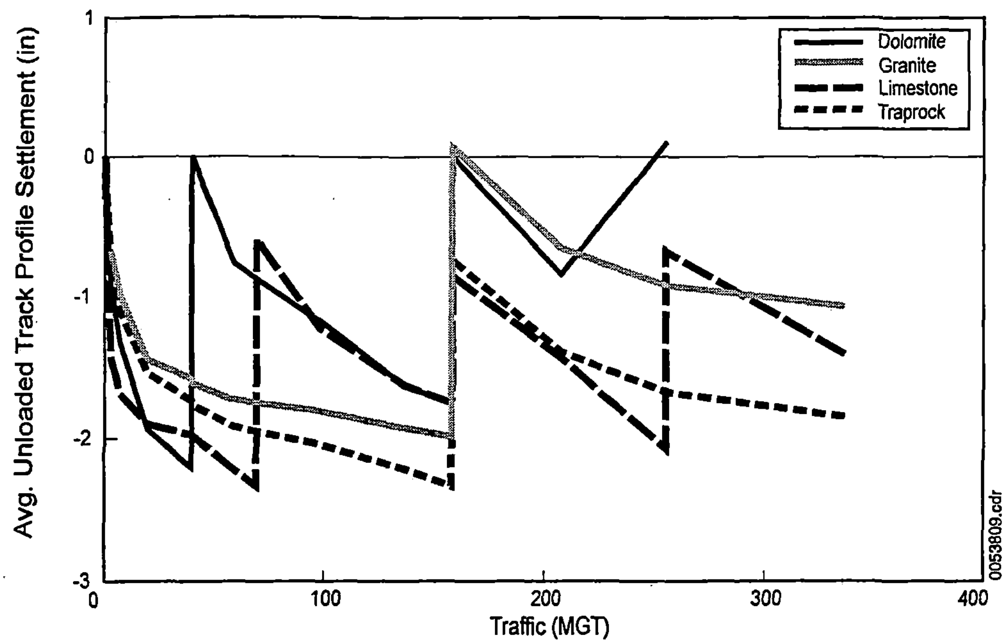

Exhibit 9. Track Settlement from Unloaded Survey — High Rail

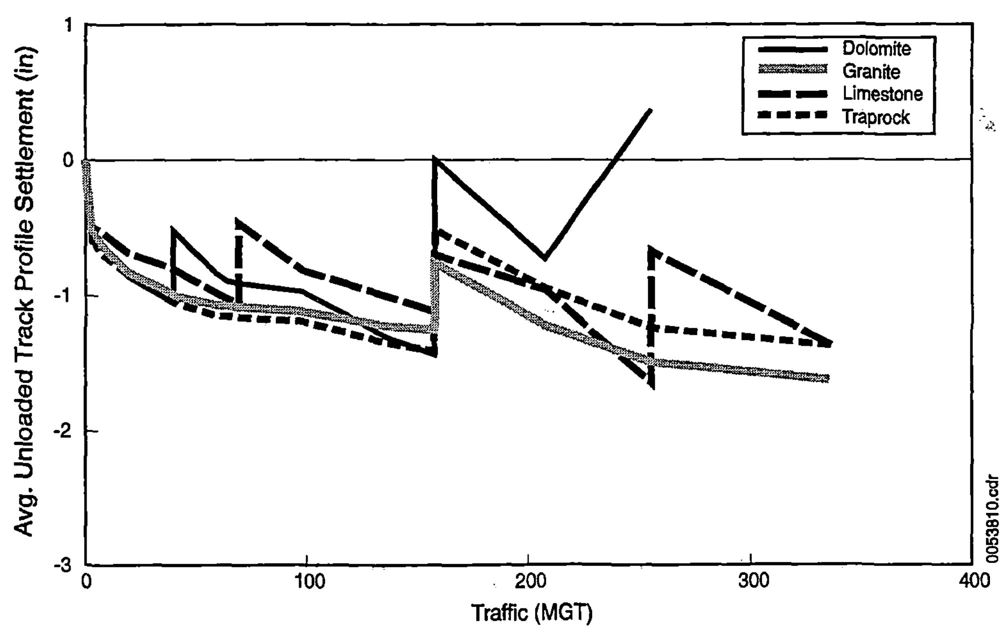

Exhibit 10. Track Settlement from Unloaded Survey — Low Rail

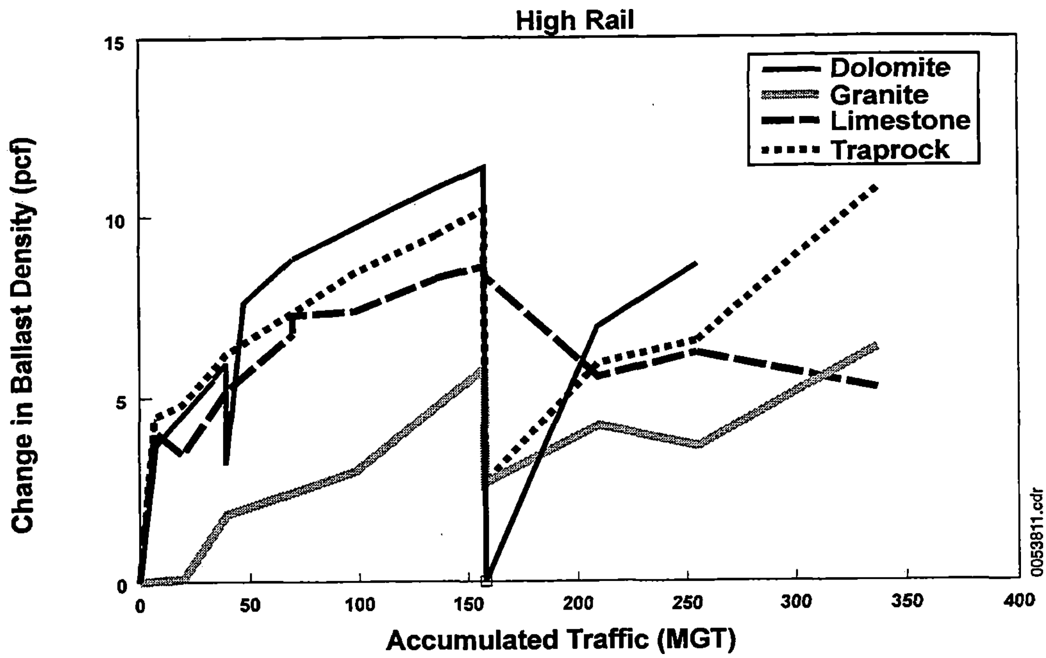

Exhibit 11. High Rail — Ballast Density

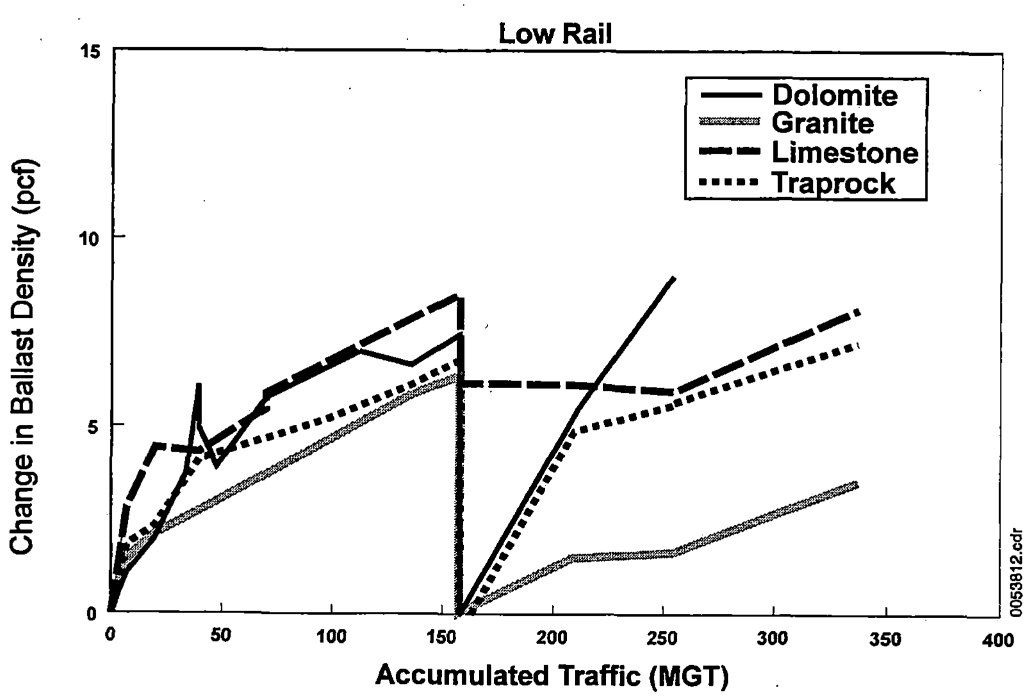

Exhibit 12. Low Rail — Ballast Density

5.5 VERTICAL TRACK MODULUS

Data from Exhibits 13 and 14 show there to be no major difference in track modulus between the four ballast materials. There appears to be a variation in track modulus with tonnage, although surfacing operations and frozen ballast conditions also may have had an effect on some of the measurements. Track modulus values for both the high and low rail typically ranged between 2,500 and 6,000 pound per inch per inch.

5.6 GEOMETRY CAR MEASUREMENTS

Exhibits 15 through 19 show the cross-level measurements taken with TTC's EM 80 geometry car. The geometry data in the dolomite section was taken at 0 MGT, and at 40 (pre- and post-maintenance). Because the cross-level deviation in the dolomite section exceeded the FRA Class 4 limits of 1.25 inches at 40 MGT, tamping was performed at this tonnage. Tamping was required again at 160 MGT due to other experiment maintenance requirements. Exhibit 16 shows the cross level for the limestone ballast which was surfaced after 70 MGT of HAL traffic due to loss of cross level. The limestone ballast was also surfaced at 160 and 360 MGT due to maintenance requirements related to the rail not to the ballast, and at 255 MGT due to a track buckle in the area. Exhibit 17 shows the track geometry for the limestone ballast from 160 MGT to 610 MGT.

The granite and traprock ballast were surfaced at 160 and 360 MGT of HAL traffic due to rail-related experiment maintenance requirements, not due to the ballast. Exhibits 18 and 19 show the cross-level measurements for these ballast materials taken at the start of the test through to 610 MGT. As shown in Exhibits 18 and 19, the granite and traprock have no deviations that exceed the FRA Class 4 limits.

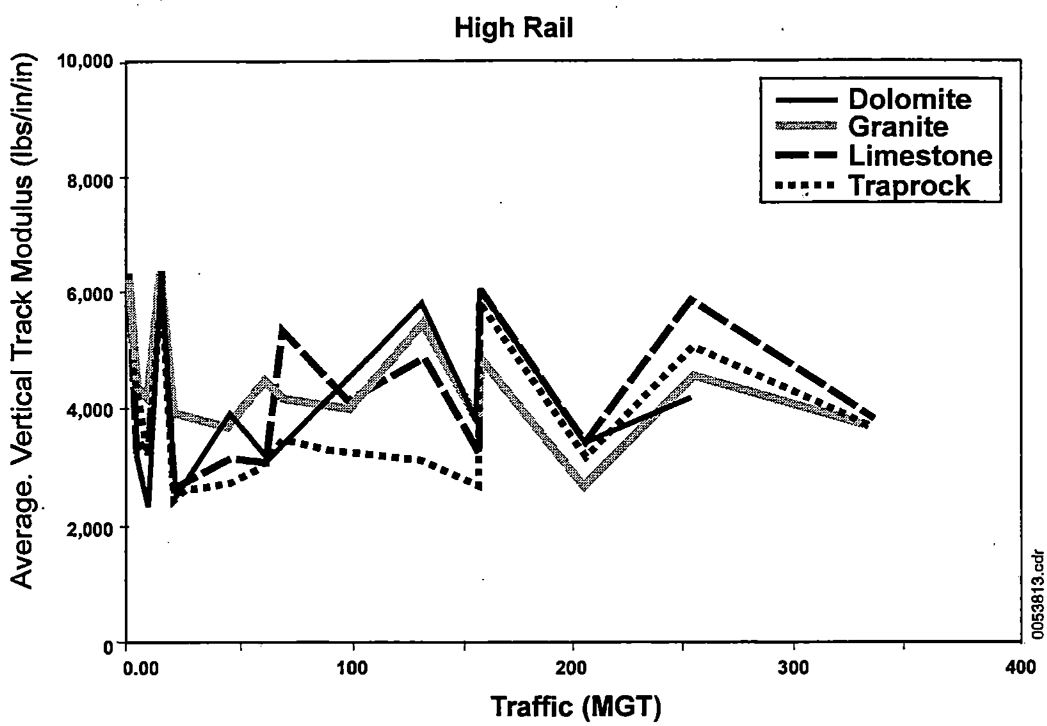

Exhibit 13. High-Rail Vertical Track Modulus

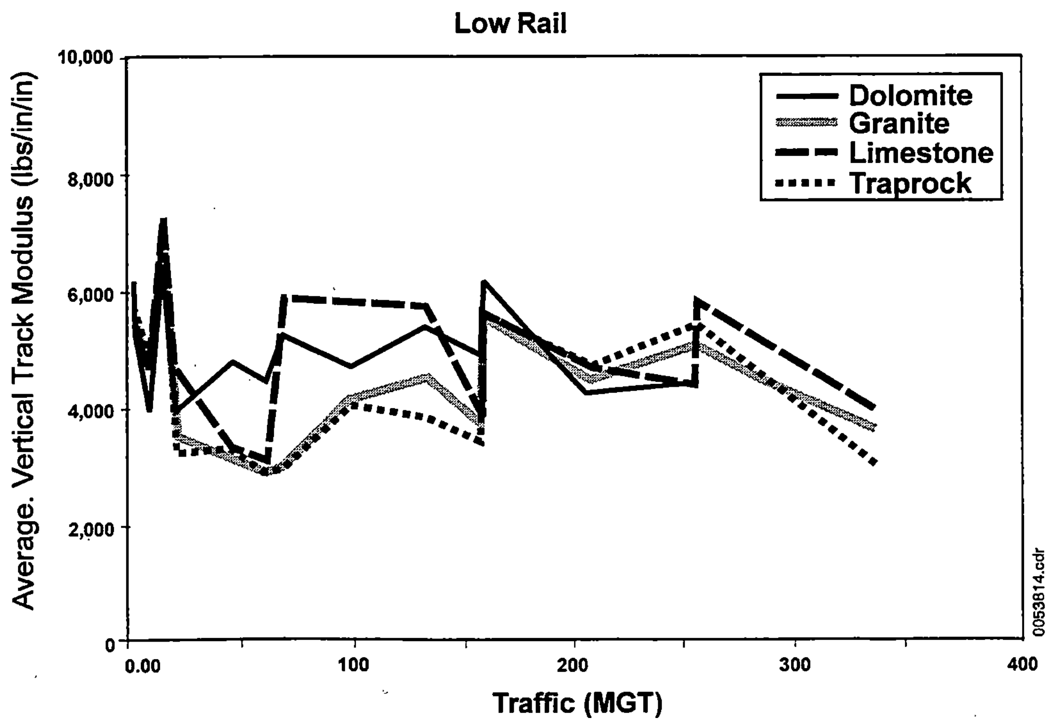

Exhibit 14. Low-Rail Vertical Track Modulus

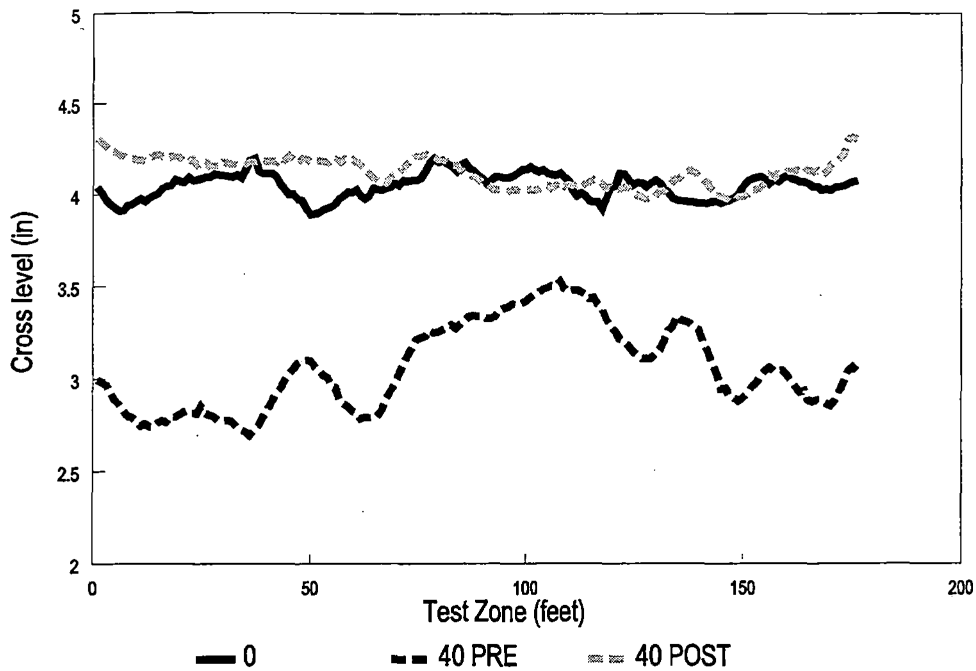

Exhibit 15. Cross-level Measurements — Dolomite Ballast

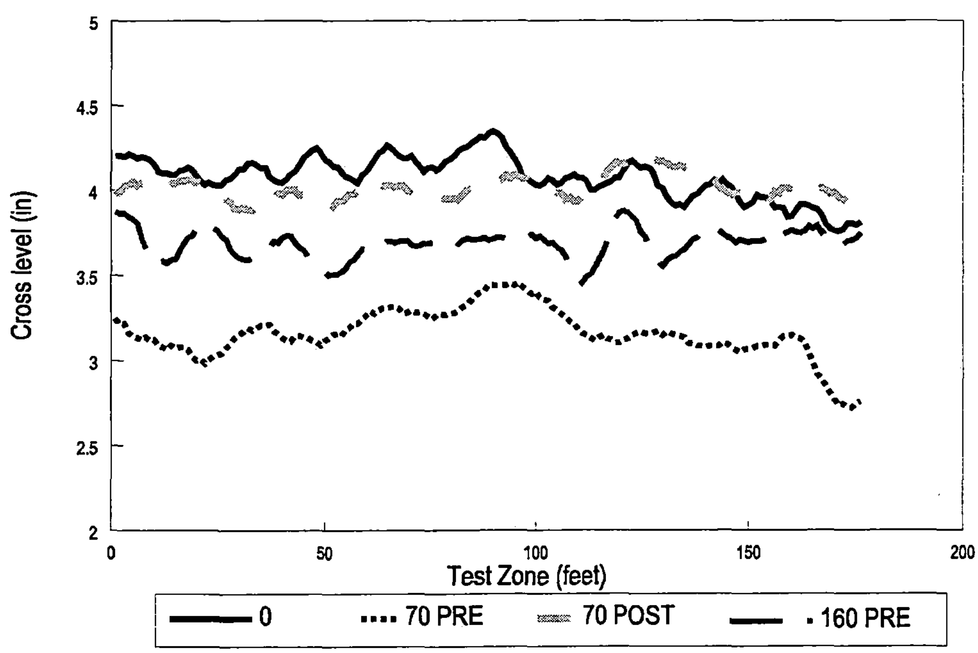

Exhibit 16. Cross-level Measurements — Limestone Ballast

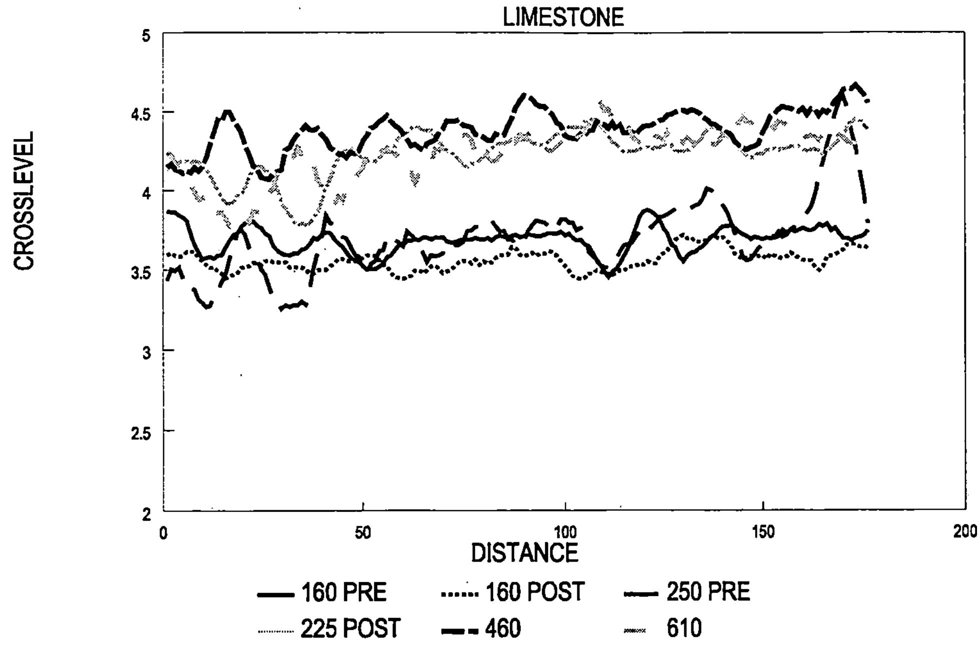

Exhibit 17. Cross-Level Geometry — Limestone Ballast

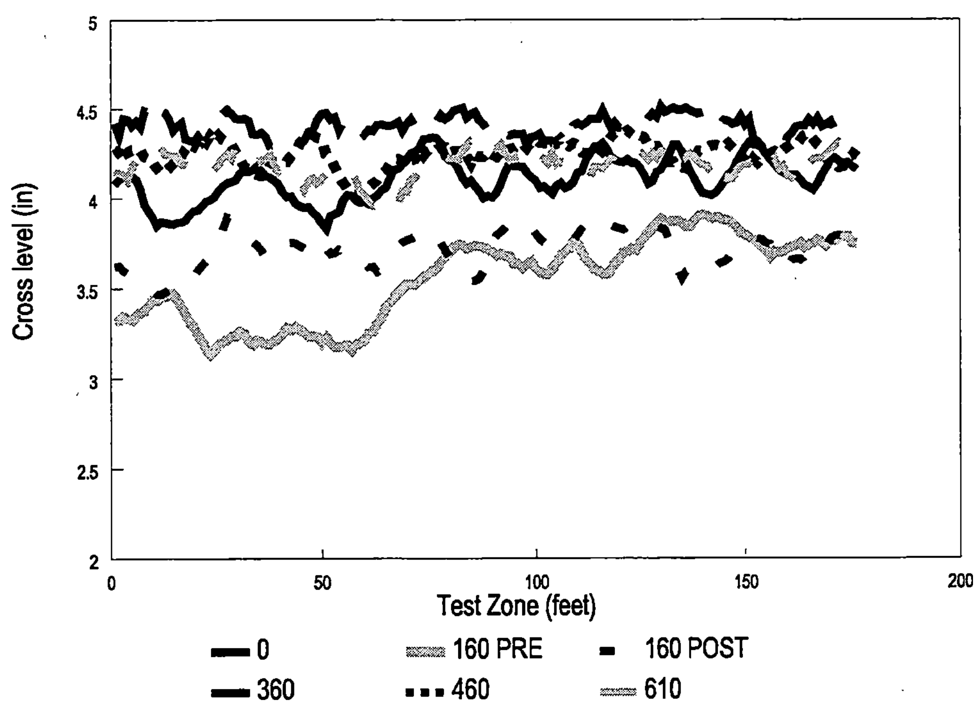

Exhibit 18. Cross-Level Measurements — Granite Ballast

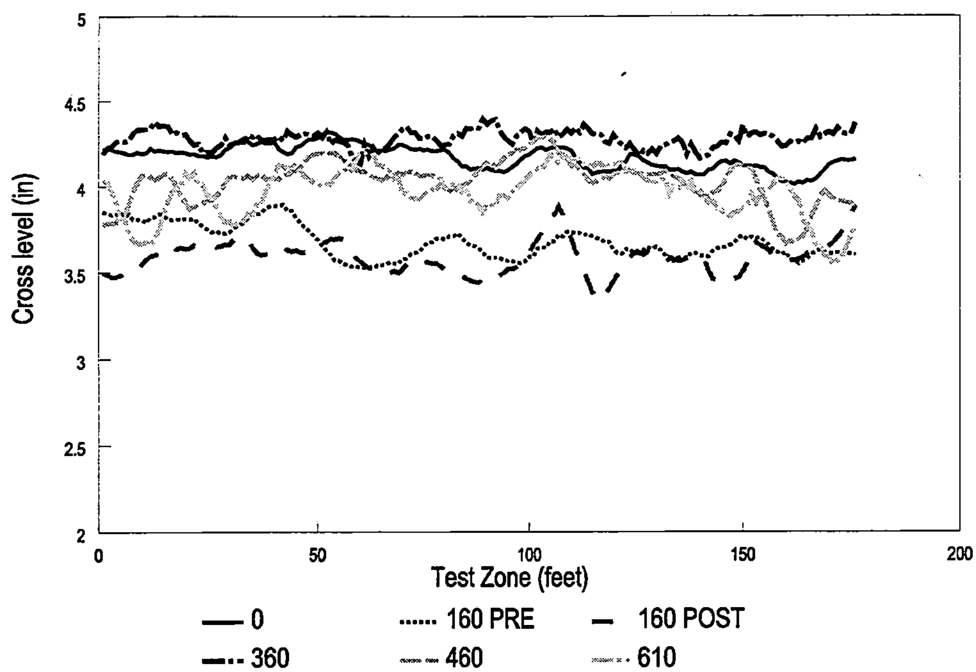

Exhibit 19. Cross-Level Measurements — Traprock Ballast

The three remaining ballast materials in test after 255 MGT, (granite, limestone, and traprock) have not required any maintenance since the surfacing performed on all three ballast materials after a rail change in the test zone at 360 MGT of HAL traffic. No surfacing was required due to geometry deviations exceeding the FRA Class 4 limits.

5.7 BALLAST GRADATION ANALYSIS

As shown in the gradation curves in Exhibits 20 through 27, a small amount of ballast degradation occurred in all four ballast materials during the test. This breakdown was observed in both the ballast samples removed from track and the ballast removed from the bins.

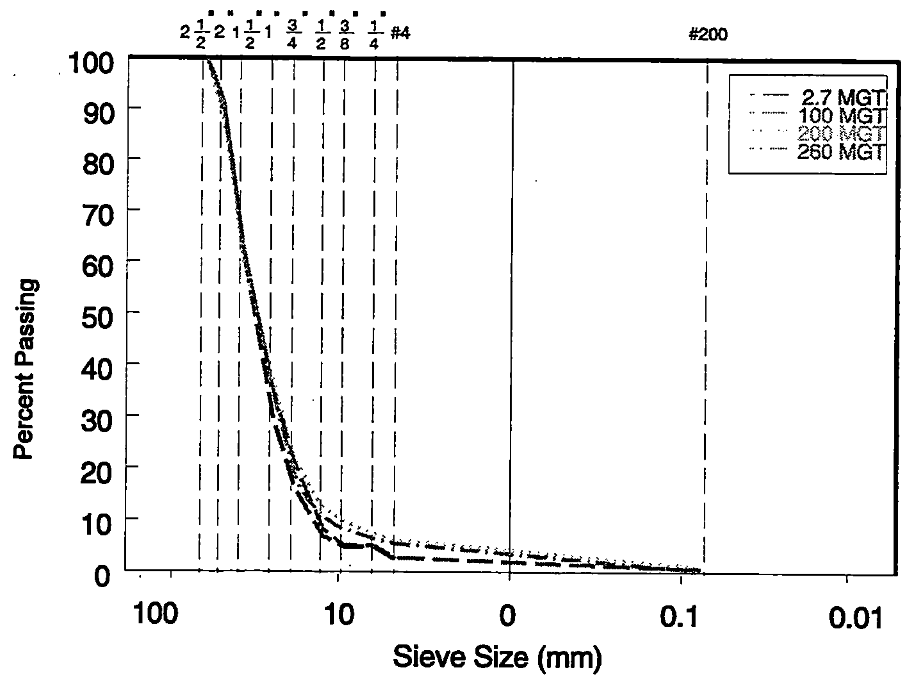

Exhibit 20. Dolomite Ballast — High Rail

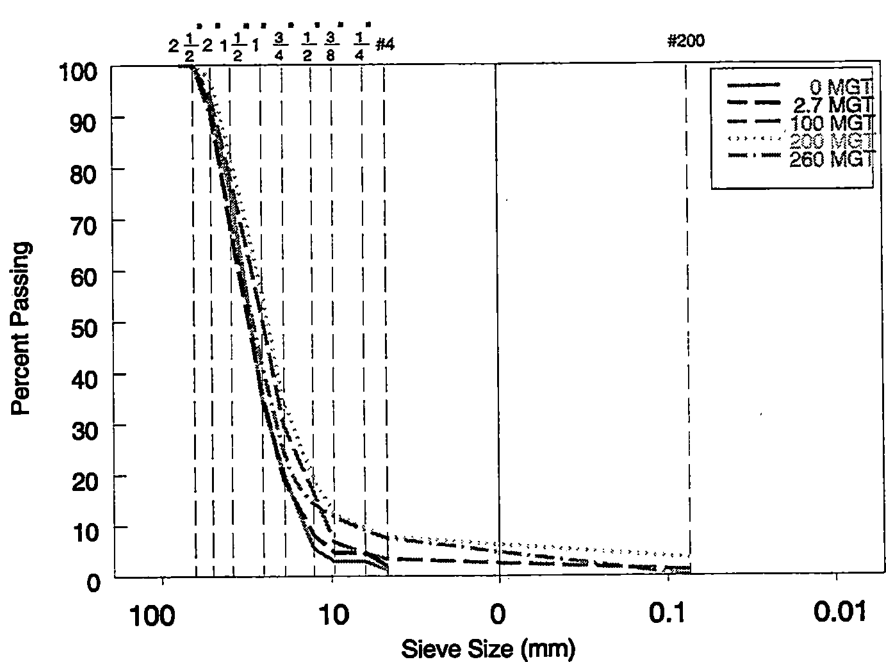

Exhibit 21. Dolomite Ballast — Low Rail

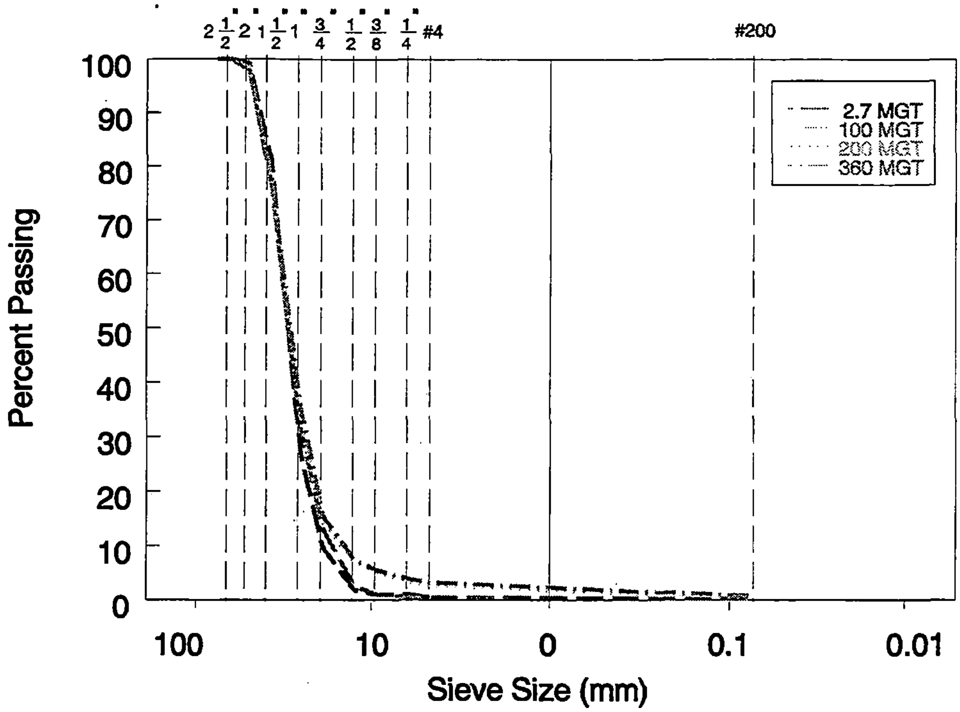

Exhibit 22. Granite Ballast — High Rail

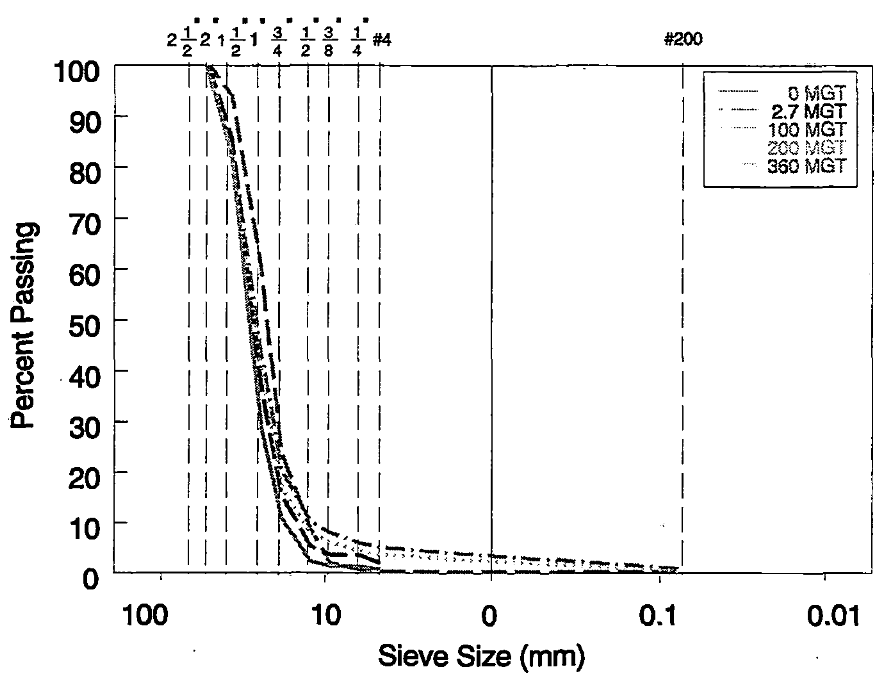

Exhibit 23. Granite Ballast — Low Rail

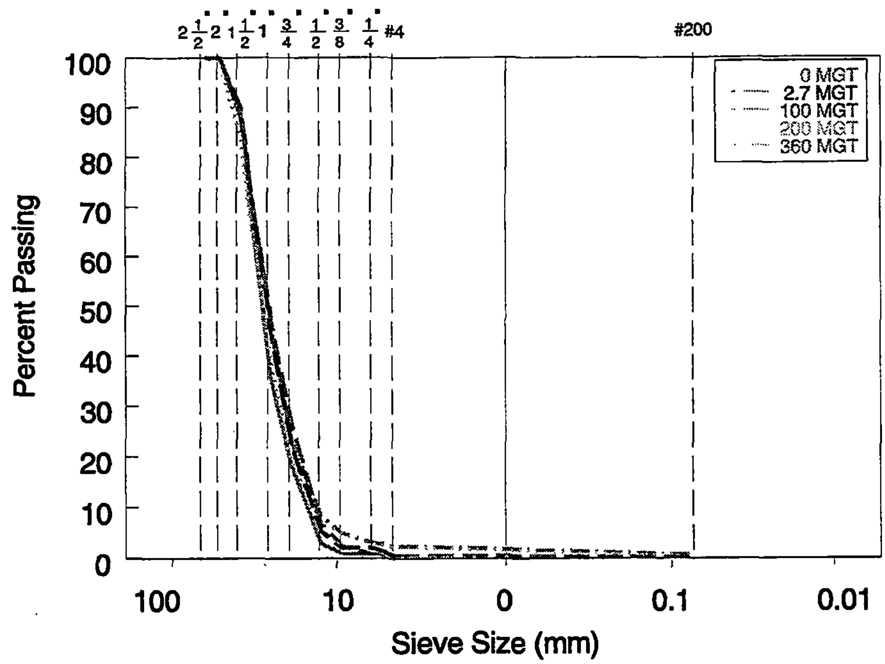

Exhibit 24. Traprock Ballast — Low Rail

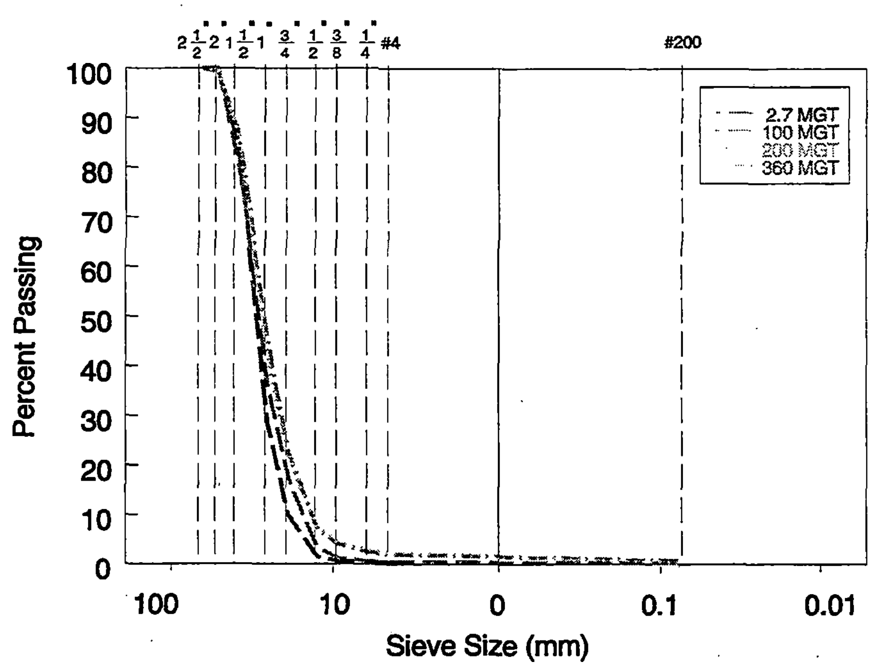

Exhibit 25. Traprock Ballast — High Rail

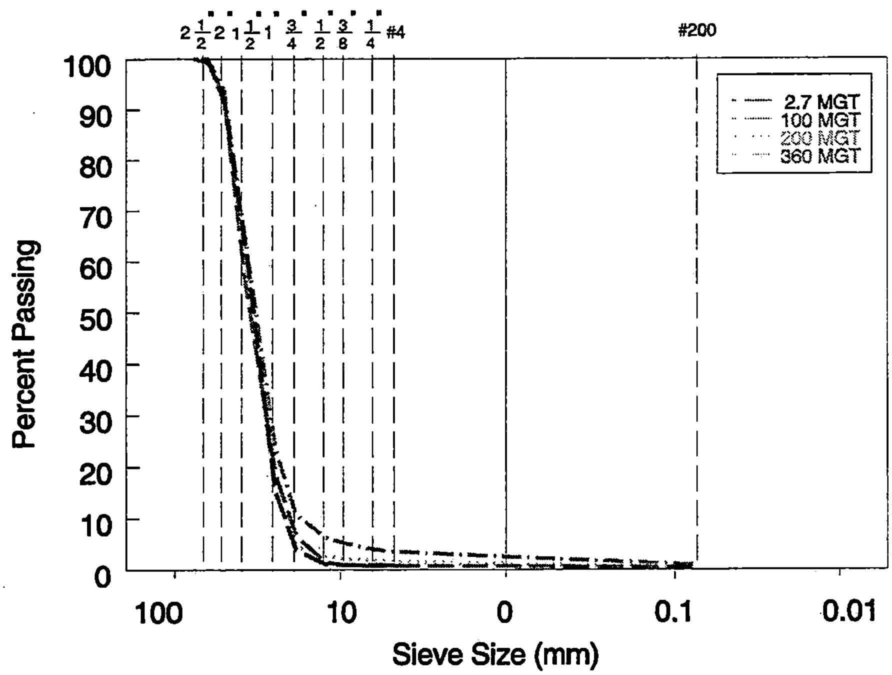

Exhibit 26. Limestone Ballast — High Rail

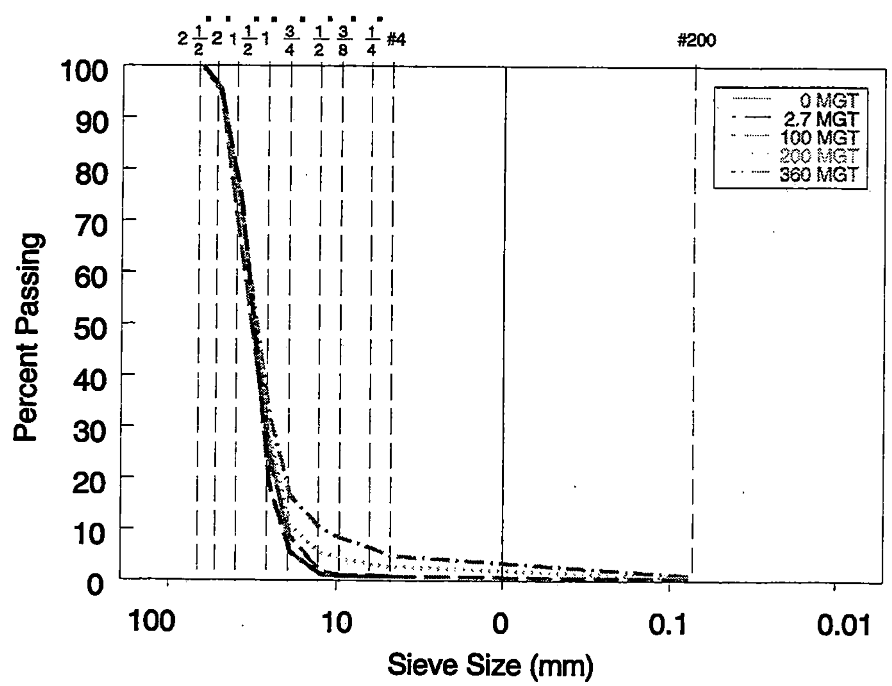

Exhibit 27. Limestone Ballast — Low Rail

5.7.1 Gradation Analysis of Ballast Samples

The gradation analysis of the ballast samples removed from track after 200 MGT of HAL traffic shows a distinct difference in the breakdown rates of the four ballast materials. The dolomite and limestone experienced the greatest amount of breakdown while the traprock had the least and the granite was intermediate.

Although traffic tonnage probably plays the dominant role in determining the amount of breakdown, a portion of the dolomite ballast breakdown may be attributed to the additional out-of-face surfacing that was performed on the test zone to correct cross level error at 40 MGT of HAL traffic. Gradation analysis indicates that tamper damage may increase ballast breakdown, as shown in the next section.

The gradation analysis for the traprock ballast, shown in Exhibits 28 and 29, shows a lower amount of ballast breakdown. The granite and traprock were exposed to only one out-of-face surfacing cycle, which may partly explain the lesser amount of degradation compared to the dolomite and limestone which had two tamping applications within 200 MGT. However it is likely that the harder traprock and granite ballast materials are less susceptible to tamper damage than softer ballast. Despite the relatively small amount of measurable breakdown of the traprock, visual observation of the traprock indicated that this ballast was becoming rounded and losing its angularity, thus degrading somewhat.

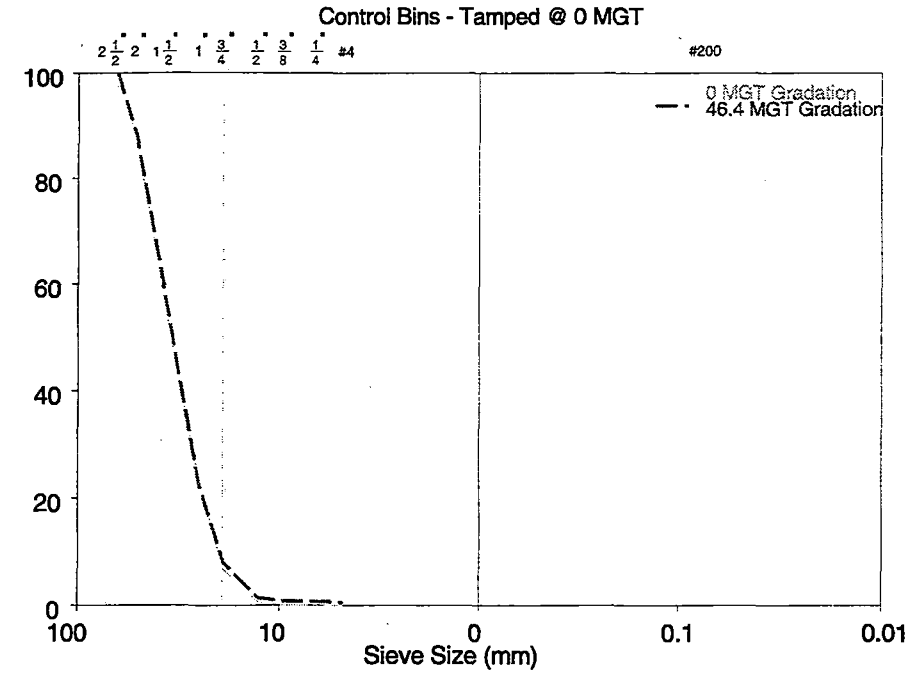

Exhibit 28. Dolomite Ballast — Control Bins

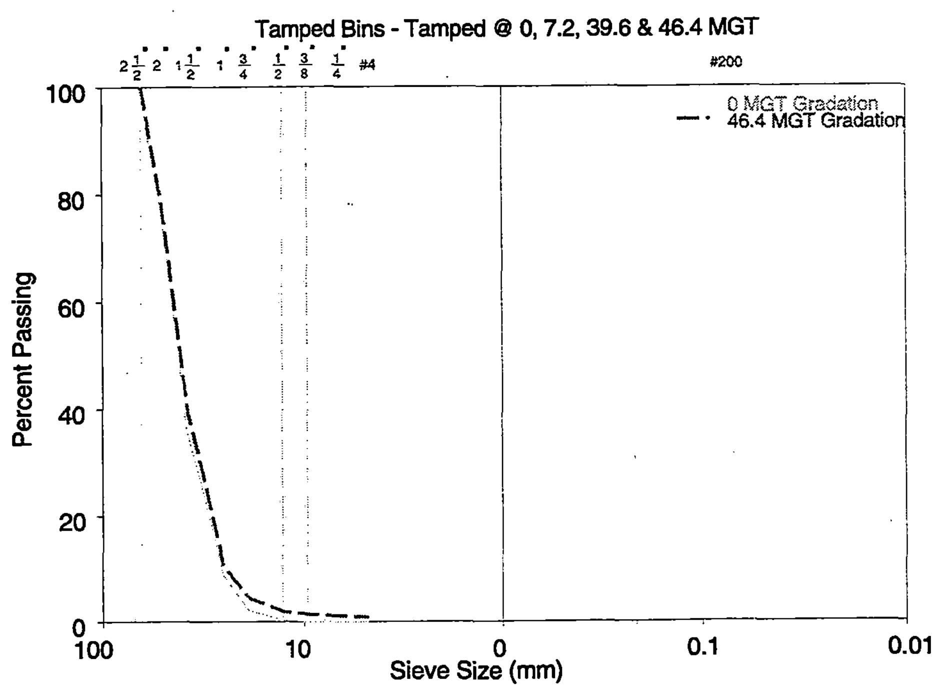

Exhibit 29. Dolomite Ballast — Tamped Bins

The limestone ballast was subjected to three out-of-face surfacing cycles, 70, 160 and 225 MGT, which may have produced a greater amount of tamping damage and provided more breakdown of this softer ballast.

5.7.2 Gradation Analysis on Ballast Bin Samples

As mentioned, the ballast bins were intended to prevent wind-blown or subgrade sources of fines from contaminating the ballast so that only the ballast degradation from loading and tamping effects are measured. Ballast bins were placed only in the dolomite and granite test sections. The dolomite bins were removed from track after 46 MGT of HAL traffic because the ballast in this area required daily tamping due to constant loss of track geometry. The ballast in the granite bin locations did not experience a significant loss of geometry during the first 386 MGT of HAL traffic.

Exhibits 28 and 29 show, respectively, the gradation of the dolomite after 46 MGT and one tamping application (during installation), and that of the dolomite after 46 MGT and four tamping applications. The small but significant increase in ballast degradation due to the three extra tamping applications can be seen. Exhibits 30 and 31, and 32 and 33 show the same tamping damage breakdown for the granite ballast.

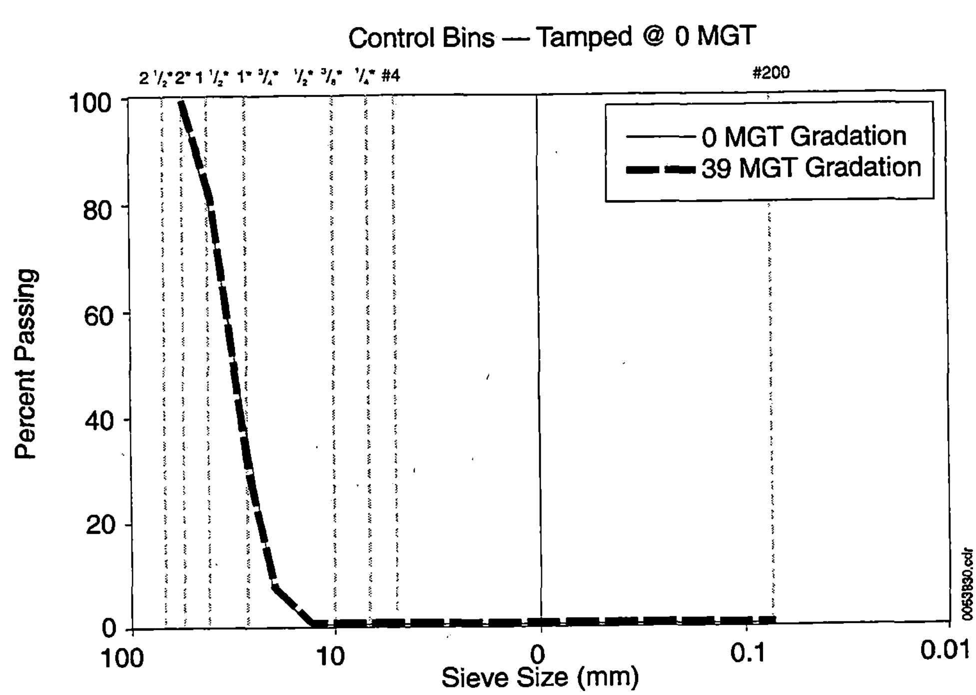

Exhibit 30. Granite Ballast — Control Bin — 39 MGT

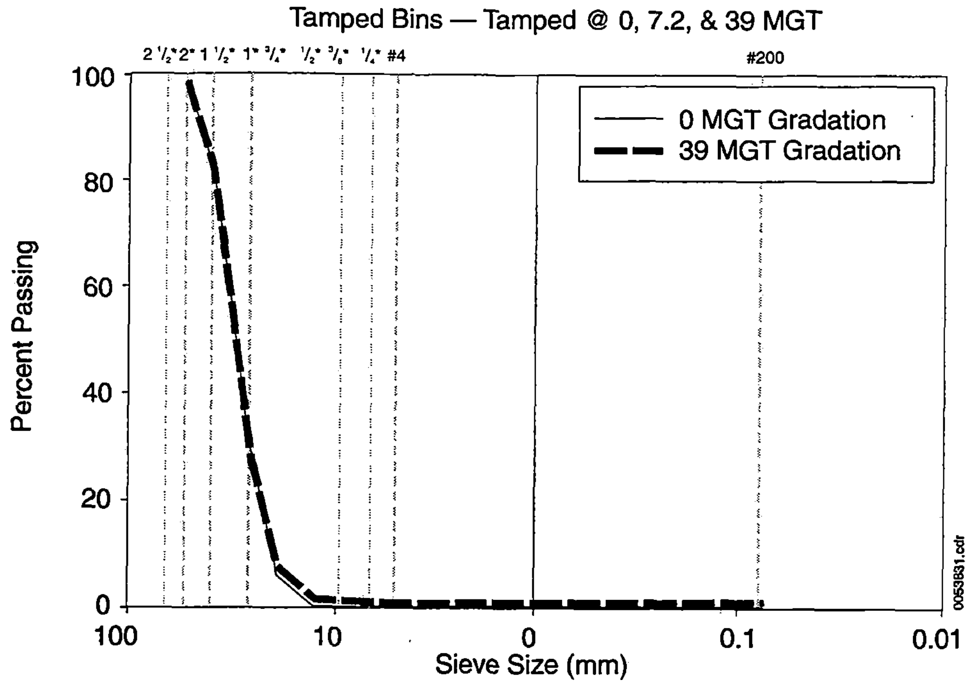

Exhibit 31. Granite Ballast — Tamped Bins — 39 MGT

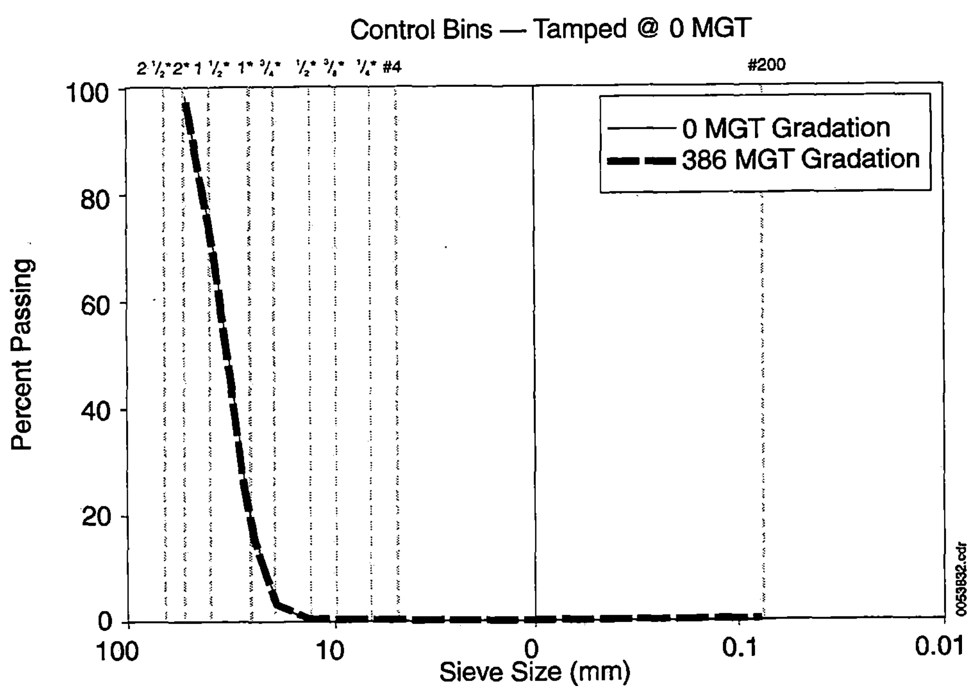

Exhibit 32. Granite Ballast — Control Bin — 386 MGT

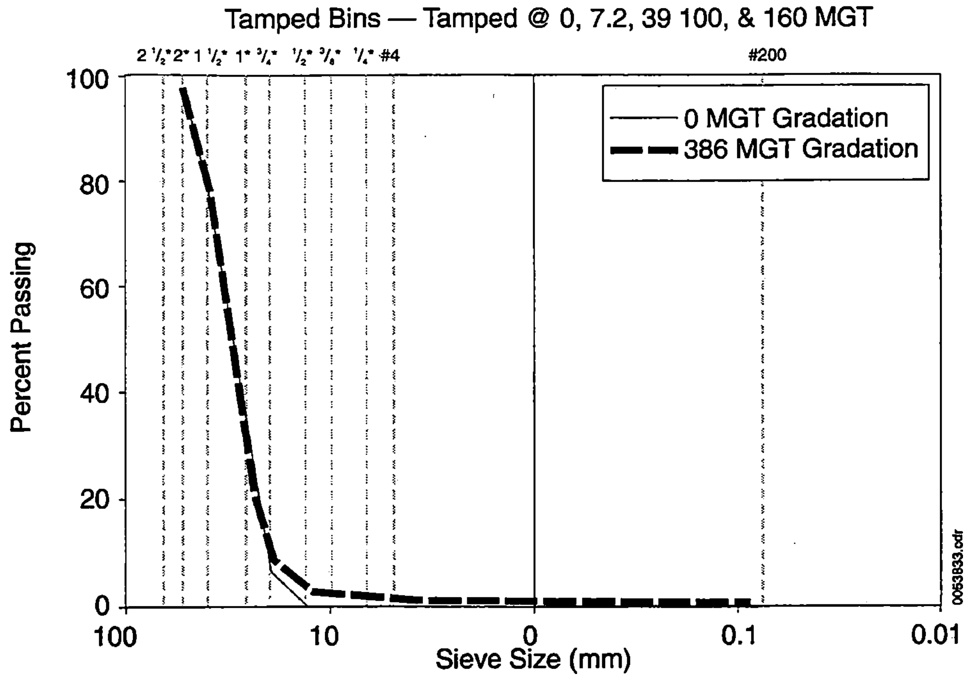

Exhibit 33. Granite Ballast — Tamped Bins — 386 MGT

6.0 CONCLUSIONS

Four ballast materials — grantie, traprock, limestone, and dolomite — were tested under 39-ton axle loads in the HTL at FAST. Even though a direct comparison between 33- and 39-ton axle load traffic cannot be made due to differences in ballast types and accumulated tonnage, it appears that degradation of the material in test is more dependent on accumulated tonnage than on increased axle load.

The granite and traprock ballast maintained adequate geometry throughout the 750 MGT duration of the test, while the dolomite required an out-of-face surfacing after the first 40 MGT and again after the first 260 MGT. The limestone required surfacing after the first 70 MGT of traffic.

Results from the gradation analysis comparing the tamper-caused degradation of dolomite and granite show that degradation increases significantly with tamping. The dolomite ballast appears to be more susceptible to the tamper damage than the granite.

These gradation results also show that, although the four ballast materials experienced different breakdown rates, the amount of breakdown under HAL traffic was relatively small after more than 750 MGT. Semi-arid climatic conditions at the testing site were probably a factor in these results. Wetter climatic conditions would probably produce more particle breakdown under loading.

Although HAL does not seem to produce a significant increase in ballast degradation, other tests have shown that the subgrade can be very sensitive to this increase in loading. More investigation of HAL effects upon fine-grained, soft subgrades should be performed.

Appendix

LABORATORY TEST RESULTS

Soundness of Aggregate

	Granite (% loss)	Dolomite (% loss)	Traprock (% loss)	Limestone (% loss)
Magnesium Sulfate	0.24	0.23	0.56	0.24
Sodium Sulfate	0.20	0.26	0.13	0.23

Los Angeles Abrasion (LA)

	Granite	Dolomite	Traprock	Limestone
% loss after 1000 revolutions	18.5	34.1	10.2	29.7

Clay Lumps and Friable Particles

	Granite	Dolomite	Traprock	Limestone
% loss	0.80	3.37	0.14	0.29

Scratch Hardness of Coarse Aggregates

	Granite	Dolomite	Traprock	Limestone
% soft particles	20.7 (loss due to mica)	No loss	No loss	No loss

Unit Weight of Aggregate

	Granite	Dolomite	Traprock	Limestone
cu. ft - lbs	101.8	104.8	106.9	93.8

Initial Sieve Gradation Analysis

	Granite	Dolomite	Traprock	Limestone
Sieve Size		Percent	Passing	
2 ½"	100.0	100.0	100.0	100.0
2"	97.6	84.8	99.0	89.5
1 ½"	84.5	67.4	68.9	50.3
1"	37.9	33.9	10.9	6.4
3/4"	16.1	17.3	2.4	1.0
½"	8.0	9.0	0.2	0.9
3/8"	5.4	6.3	0.2	0.9
# 4	3.2	3.9	0.2	0.9
# 200	0.8	1.2	0.1	0.5

Particle Indices

	Granite	Dolomite	Traprock	Limestone
Avg. FAST Elongation Index	44.80	46.09	46.23	26.90
Avg. FAST Flakiness Index	24.62	15.18	28.86	11.12

CIGGT Shape Factor

	Granite	Dolomite	Traprock	Limestone
Average Value	2.34	2.09	2.46	1.98

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