FRA/TTC-82/08

BALLAST EXPERIMENTS AT FAST
STATUS REPORT

FAST Facility for Accelerated Service Testing

TRANSPORTATION TEST CENTER
PUEBLO, COLORADO 81001

Interim Report

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16. Abstract

This report presents a summary of the Facility for Accelerated Service Testing (FAST) Ballast Experiments. Tests included ballast shoulder width, (Section 15), ballast type and depth, (Sections 18 and 20), ballast type, (Section 03, wood ties; Section 17, concrete ties), comparison of effects of Northeast Corridor wood vs concrete tie design on ballast and subgrade, (Section 22), and geotextiles (Section 17).

The ballast shoulder width test demonstrated that increased ballast shoulder width can provide increased track geometry retention capabilities and reduced maintenance. Slag ballast exhibited the best performance in Section 20, and limestone the worst. Comparing Sections 03 and 17, concrete track showed higher track modulus, less total settlement and ballast degradation than wood tie track. In Section 22, ballast degradation and total settlement were approximately equal between wood and concrete ties. Dynamic loading applied to the subgrade and dynamic subgrade deformation were higher for wood ties. Geotextile penetration resistance and ballast stiffness varied considerably with fabric type.

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PREFACE

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ACRONYMS

AAR	Association of American Railroads
AREA	American Railway Engineering Association
BSW	ballast shoulder width
CEB	cleaned existing ballast
FAST	Facility for Accelerated Service Testing
FRA	Federal Railroad Administration
HTS	horizontal track stiffness
NEC	Northeast Corridor
RPI	Rail Progress Institute

ABBREVIATIONS AND METRIC CONVERSIONS

1 MGT	million gross tons	= 0.907 MGMg
1 ",in	inch	= 2.54 cm
1 ',ft	foot	= 0.304 m
1 lb/yd	pounds per yard	= 0.496 kg/m
1 kips	kilopound	= 453.59 kg
G	granite	
TR	traprock	
S	blast furnace slag	
LS	limestone	
°	degree	= (-32° F)5/9° Celsius
%	percent	
1 lb/in/in		= 0.0703 kg/cm/cm

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EXECUTIVE SUMMARY

This report is a summary of the results obtained from the Facility for Accelerated Service Testing (FAST) ballast experiments. When FAST operations began in September 1976, the ballast tests included: ballast shoulder width (Section 15), ballast depth (Sections 18 and 20), and ballast type (Sections 18 and 20). These tests were concluded at 425 MGT. In the fall of 1979, Section 03 and a portion of Section 17 were rebuilt from the subgrade level using a total of seven ballast types. Although these are basically rail, tie, and fastener test sections, ballast performance is carefully monitored to detect differences which may exist between the ballast types. Section 22 was rebuilt as a direct comparison test of wood vs concrete ties using Northeast Corridor ballast, ties, and fasteners. Various ballast parameters are measured to determine the effect on the ballast of loading differences between wood and concrete ties. While Section 17 was being rebuilt, several types of geotextiles were installed in a portion of the section to determine their effect on track stability.

Results from the Ballast Shoulder Width Test show that an increase in shoulder width from 6" to 18" resulted in reduced maintenance requirements and increased track geometry retention capabilities, particulary surface profile. Widths between 6" and 18" were not tested, so optimum width has not been determined in this experiment. Of the five ballasts in the Ballast Type Test, one limestone (LS-2 Dolostone) exhibited the worst performance based on track geometry and maintenance parameters, while blast furnace slag exhibited the best.

Results from the Ballast Depth Test revealed no significant differences in performance based on the measured parameters and near ideal subgrade conditions existing at FAST. However, no conclusion should be drawn from this test that ballast depth is not an important factor in track structure design.

Comparison of ballast types occurring in both Sections 03 and 17 show the concrete tie track in Section 17 having higher track modulus and experiencing less ballast degradation and total track settlement than the wood tie track in Section 03. Track modulus varied considerably between ballast types. Lateral tie push data from Section 03 show a drastic decrease in lateral resistance occurring as a result of tamping.

In Section 22 ballast degradation and total settlement were approximately equal for wood and concrete ties. Dynamic loading applied to the subgrade and dynamic subgrade deformation were higher for wood ties.

Ballast penetration into the geotextiles varied considerably with fabric type. There appeared to be a ballast stiffness increase due to the presence of the fabric which varied inversely with the degree of ballast penetration.

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INTRODUCTION

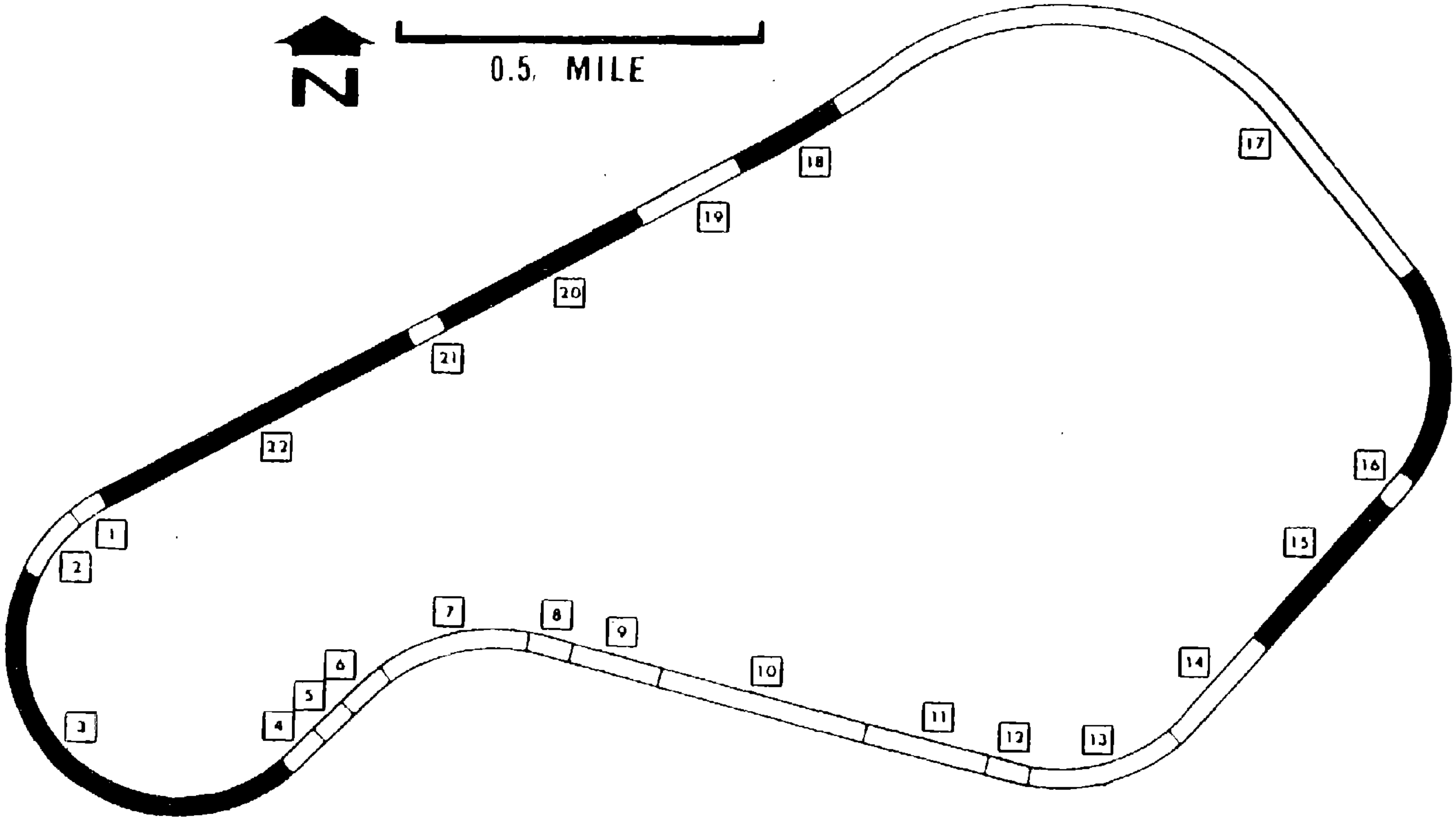
Located at the U.S. Department of Transportation Test Center (TTC) near Pueblo, Colorado, the Facility for Accelerated Service Testing (FAST) provides a full systems approach to track structure and rail vehicle research. Operated by the Federal Railroad Administration (FRA) in cooperation with the Association of American Railroads (AAR) and the railroad companies and supply industry, FAST simultaneously tests various track structures, safety equipment, vehicle components, and maintenance methods under heavy demand conditions.

The FAST Program is designed to shorten the time necessary to complete full-scale testing. By operating a heavy freight train around the 4.8-mi FAST track 75 hours a week, the track and mechanical components are exposed to nearly ten times the wear experienced in one year of revenue service. Each test run, approximately 120 laps of the FAST track, results in the accumulation of about 1 million gross tons (MGT) on the track and 600 mi on the cars.

The FAST Program is directed by a Policy Committee composed of representatives from the FRA, AAR, RPI, and the railroad industry. Its policies are implemented through Experiment Managers, each responsible for one or more experiments in a particular technical area. They report to the FAST Technical Manager, who requests the FAST Operations Office to conduct the tests.

This report presents a brief summary of the results obtained from the FAST Ballast Experiments. Figure 1 depicts the track layout and ballast experiment test sections. When FAST operations began in September 1976, the ballast tests included ballast shoulder width (Section 15), ballast depth (Sections 18 and 20), and ballast type (Sections 18 and 20). These tests were concluded at 425 MGT. In the fall of 1979 (425 MGT), Section 03 and a portion of Section 17 of FAST were rebuilt from the subgrade level using a total of seven ballast types. Although these are basically rail, tie, and fastener test sections, ballast performance is carefully monitored to detect differences which may exist between the ballast types. Section 22 was rebuilt as a direct comparison test of wood vs concrete ties using Northeast Corridor (NEC) ballast, ties, and fasteners. Various ballast parameters are measured to determine the effect on the ballast of loading differences between wood and concrete ties. While Section 17 was being rebuilt, several types of geotextiles (filter fabrics) were installed in a portion of the section to determine their effect on track stability.

It should be noted the Pueblo area receives very little rainfall (approximately 11" per year). This condition is not typical of a large portion of American railroad track. This should be considered when relating FAST results to areas with different rainfall and resulting drainage conditions; however, this is less a considration when comparing one component to another within the FAST Program.



Note: Sections containing ballast tests are shaded. Only the 5° curve, 2% grade portion of Section 17 is shaded.

FIGURE 1. FAST TEST SECTIONS.

BALLAST SHOULDER WIDTH TEST

Section 15 contains two 550-ft subsections, labeled A and B, with 6" and 18" ballast shoulder widths (BSW), respectively, as the principal section variables. There are no other known differences between the subsections which could affect their performance. Standard 136 lb/yd jointed rail, on 7"x9"x8.5' wood ties on 19.5" centers, are the common track components throughout Section 15. The ballast is an American Railway Engineering Association (AREA) No. 4 gradation blast furnace slag from a local source. Turnouts bound either end of the test section.

The data from the whole of each subsection were not used because of influence from the turnouts. It was evident from the maintenance data that the turnouts had a very great effect extending well into each test section. For that reason, data from the 125 ft of test section adjoining each turnout were ignored. Similarly, data were ignored in a 50-ft transition zone between the subsections.

The ballast shoulder is, for purposes of this experiment, defined as the distance along the horizontal surface of ballast, measured from the tie end to the point where the surface breaks into an obvious slope. Measuring the BSW is, therefore, not a precise procedure and requires a great deal of subjective judgment, especially when rounding of the shoulder occurs quite often, as was the case at FAST.

Mean and standard deviations of shoulder width for the duration of the experiment were calculated and are shown below:

Track Subsection		15A	15B
BSW:	Mean	9.4"	16.9"
	Standard deviation	3.3"	5.0"

The student's T test for statistical significance shows that the shoulder width difference is significant at the 99.9% level. However, the large variation in measured shoulder width as indicated by the standard deviations means that the two subsections can be recognized as having different shoulder widths; the magnitude of the difference cannot be precisely defined.

The track parameter originally believed to be most affected by ballast shoulder width is the horizontal, or lateral, track stiffness. Accordingly, horizontal track stiffness (HTS) measurements were used to characterize the lateral resistance of Section 15 for comparison with available data. However, several procedural inconsistencies and sources of uncertainty were found in the FAST HTS measurement,[1]* so the following HTS data are provided only as

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* Numerical references are listed at end of text.

general information, not as a source for future comparisons. Improved methods have been developed but were not available in time for this experiment.

The HTS measurement consisted of a horizontal load applied through a yoke to two points on the rail. The rail displacement was measured at the centerline and on five ties on either side of the load application points. The data are quite variable and show little or no effect of BSW, quite contrary to previous experiments that have indicated a pronounced increase in HTS as the BSW increases from 6" to about 12".[2,3]

Mean load values at two rail displacements from the FAST tests are:

Track Subsection	15A	15B
0.05" rail displacement	6.3 kips	6.0 kips
0.20" rail displacement	13.2 kips	14.3 kips

It has been theorized that the real effect of ballast shoulder width would show up at higher displacements (up to 1"). However, this cannot be verified since at FAST the test was performed to a maximum of only slightly greater than 0.2".

Section maintenance is one of the most significant measures of section performance used in this experiment. Maintenance hour expenditures in Subsections A and B were recorded and plotted vs MGT. Figure 2 shows the cumulative maintenance labor calculated per track mile. The figure shows that nearly 40% more hours were expended in Subsection A, with the 6" BSW, than in Subsection B, with the 18" BSW. The paired T test shows the maintenance hour differences not to be statistically significant. This is due to the fact that maintenance occured at irregular intervals creating a large standard deviation.

Track geometry car data between 50 and 438 MGT were analyzed to determine the effect of shoulder width on the rate of track geometry deterioration; no data were available prior to 50 MGT. Geometry parameters measured were profile (left and right), alignment (left and right), twist, gage, and superelevation. FAST Class A* limits were used to maximize the amount of data available for comparison of the two subsections, since the FAST limits are more stringent than FRA Class 6 and yield a higher number of exceptions. At 25 MGT intervals, the percent of each subsection exceeding the Class A track geometry limit was calculated for each parameter. The profile parameter shows the largest amount of deviation from the limits, and figure 3 records the average percentage of track containing profile exceptions. Up to approximately 175 MGT, both subsections exhibited roughly equivalent surface deterioration. However, after tamping performed at 175 MGT, the 18" BSW section retained a generally constant profile exception level, while the 6" section level increased significantly. Out-of-face surfacing was performed at approximately

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* FAST Class A profile exceedance level is ± 1/4" as opposed to FRA Class 6 which is ± 1/2". Class A alignment exceedance levels, compared to FRA Class 6 (in parentheses) are: Tangent ± 1/4" (± 1/2"), Curve ± 1/4" (± 3/8"), Twist ± 1.4" (± 5/8").

430 MGT, and brought the exception level in each section to nearly zero. Alignment exceptions were also generally higher for the 6" section, as shown in figure 3. The paired T test shows both the profile and alignment exception differences to be statistically significant at the 99% level.

As evidenced by the test, an increase in ballast shoulder width can result in a reduction in maintenance effort and reduce the rate of track geometry deterioration.

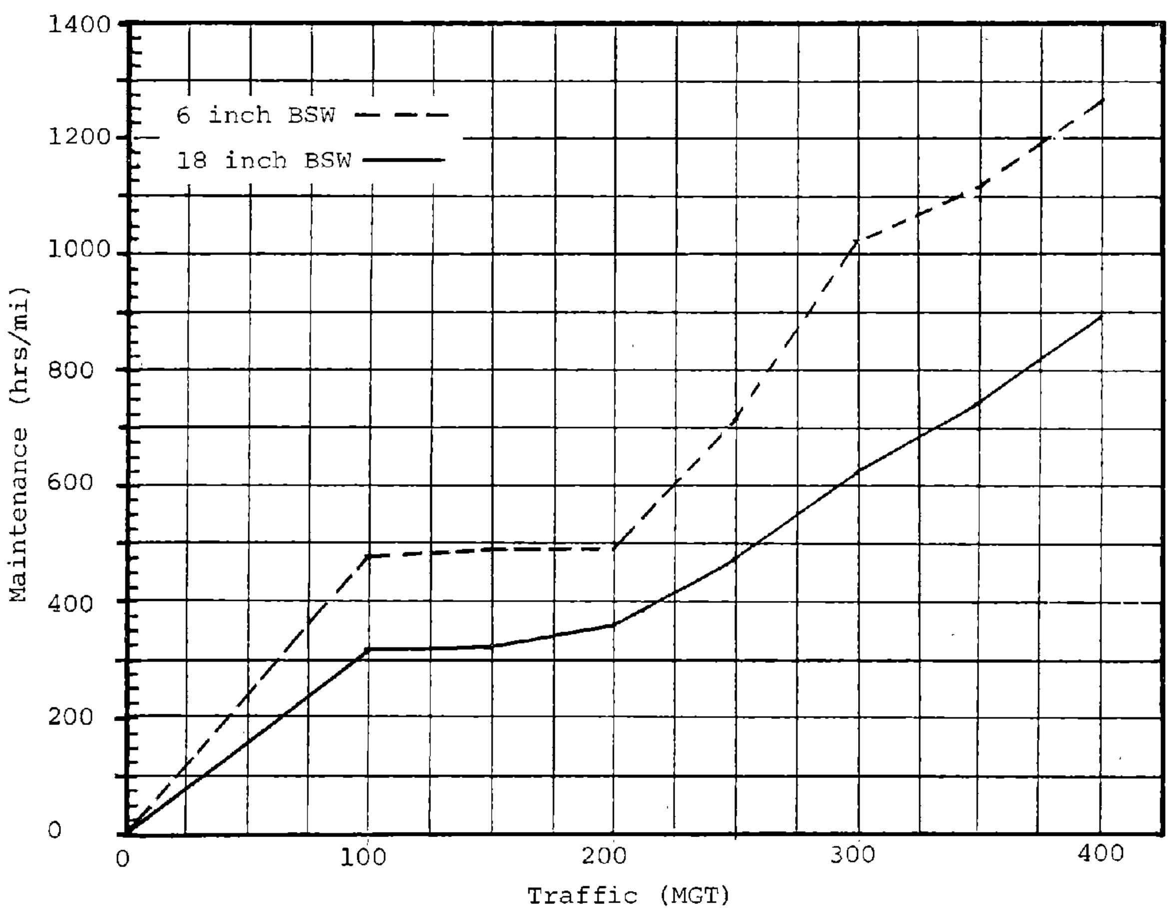
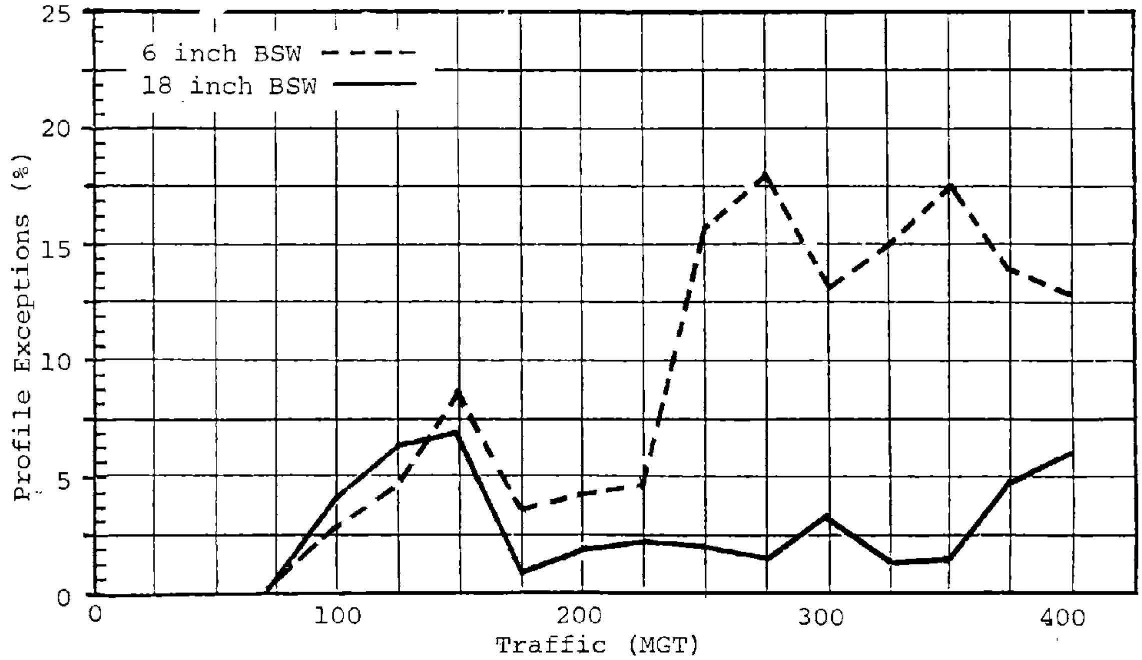
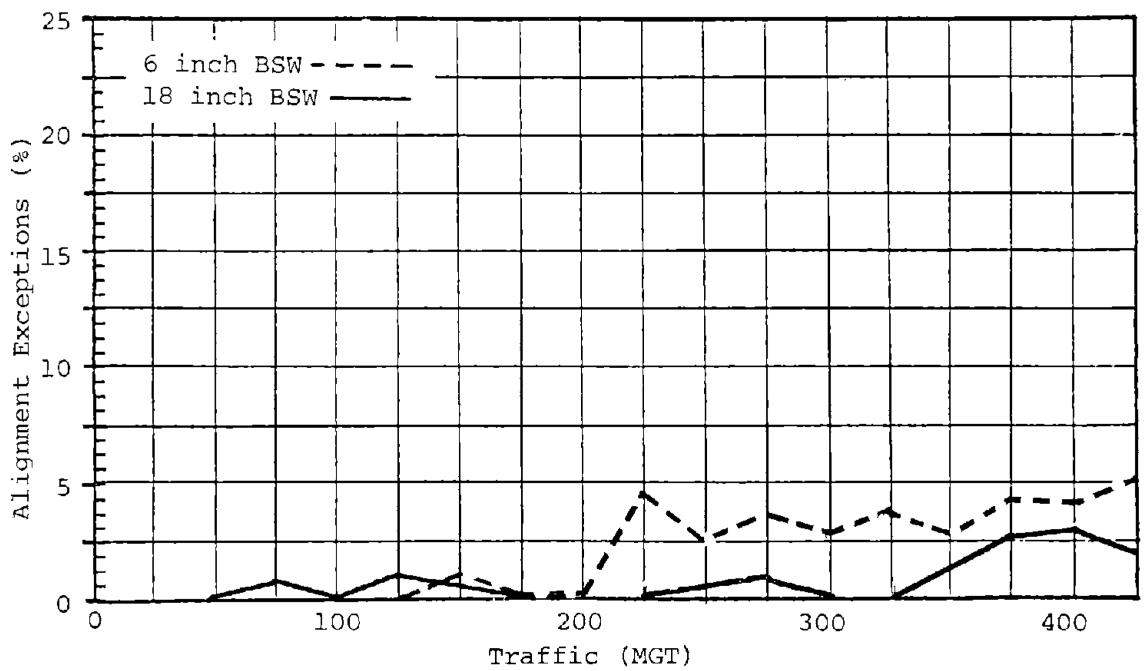


FIGURE 2. BALLAST SHOULDER WIDTH TEST, CUMULATIVE MAINTENANCE VS TRAFFIC.



TRACK GEOMETRY PROFILE EXCEPTIONS



TRACK GEOMETRY ALIGNMENT EXCEPTIONS

FIGURE 3. BALLAST SHOULDER WIDTH TEST, EXCEPTIONS VS TRAFFIC.

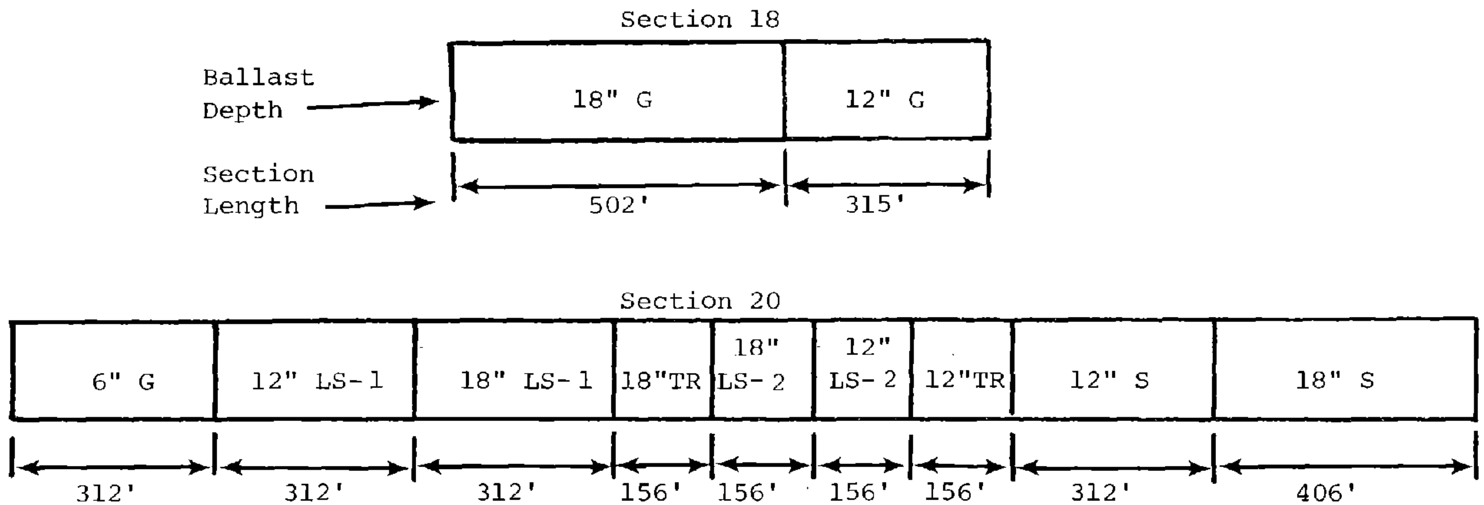
BALLAST TYPE AND DEPTH TESTS

Sections 18 and 20 are both tangent track, jointed rail on wood ties. The section layouts are shown in figure 4. Section 18 consists of two subsections of granite (G) ballast with nominal 12" and 18" ballast depths beneath the ties. Section 20 is made up of nine subsections, one of 6" deep granite and the others of 12" and 18" depths of each of the following: traprock (TR), blast furnace slag (S), and limestone from two different sources, labeled limestone I (LS-1) and limestone II (LS-2)). Petrographic analysis has shown the limestone I to be primarily dolomite while limestone II is dolomitic limestone. Following are the initial AREA classifications for each ballast type:

Granite	- AREA 5
Limestone I (Dolomite)	- AREA 4
Traprock	- AREA 3-4 (falls between limits)
Limestone II (Dolomitic Limestone)	- AREA 4
Slag	- AREA 4

As for the shoulder width experiment, track geometry data were analyzed to provide a comparison of the track geometry degradation rates for Sections 18 and 20. Figure 5 shows a plot of average profile exceptions vs MGT for the five ballast materials. Exceedances are based on FAST Class A. The drop at 175 MGT occurred as a result of surfacing and lining. It is not known why the sudden jump at 225 MGT occurs. Track maintenance-hour expenditures were recorded and calculated on a manhours per mile basis. Figure 6 shows the results for all subsections of each ballast type. The most obvious conclusion drawn from the two plots is the limestone II shows more track geometry exceptions and higher maintenance-hour expenditures. The ballast showing the best performance based on track geometry and maintenance was the slag.

Numerous other tests were conducted on the various ballast subsections. These included physical state tests (ballast density, lateral tie push, and plate load);[4] static measurement of long-term ballast, subballast, and subgrade deformation; and dynamic measurement of deformations and stress applied to the subgrade.[5] Considerable data were collected concerning the effects of track maintenance on ballast physical state, and the dynamic response of the track substructure due to train loading. There were no significant differences in these test parameters comparing the various ballast types and depths.



Legend:
G - Granite
LS-1 - Limestone I (Dolomite)
TR - Traprock
LS-2 - Limestone II
S - Slag

FIGURE 4. BALLAST TYPE AND DEPTH TEST SECTIONS.

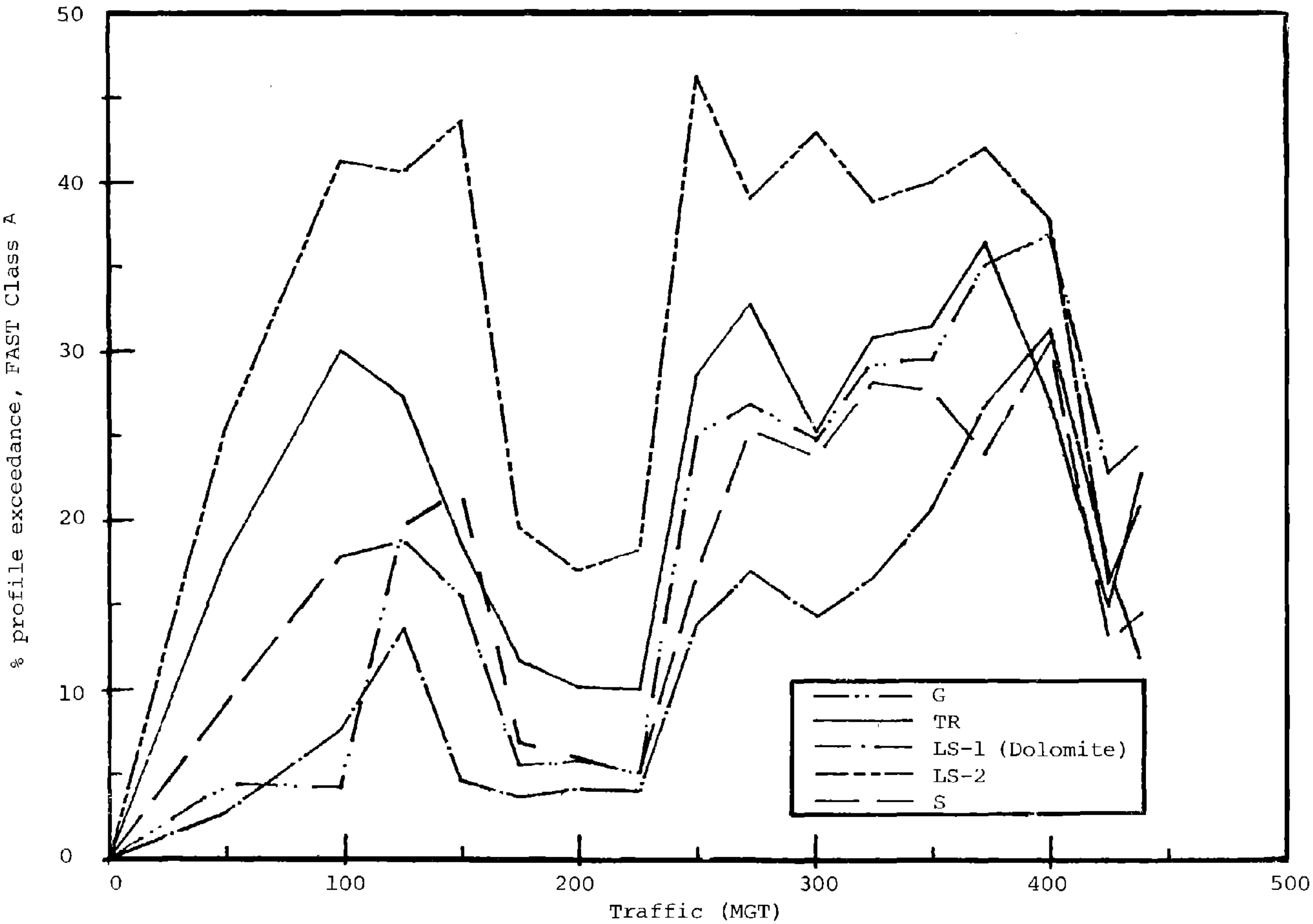


FIGURE 5. BALLAST MATERIAL TYPE TEST, PROFILE EXCEPTIONS VS TRAFFIC.

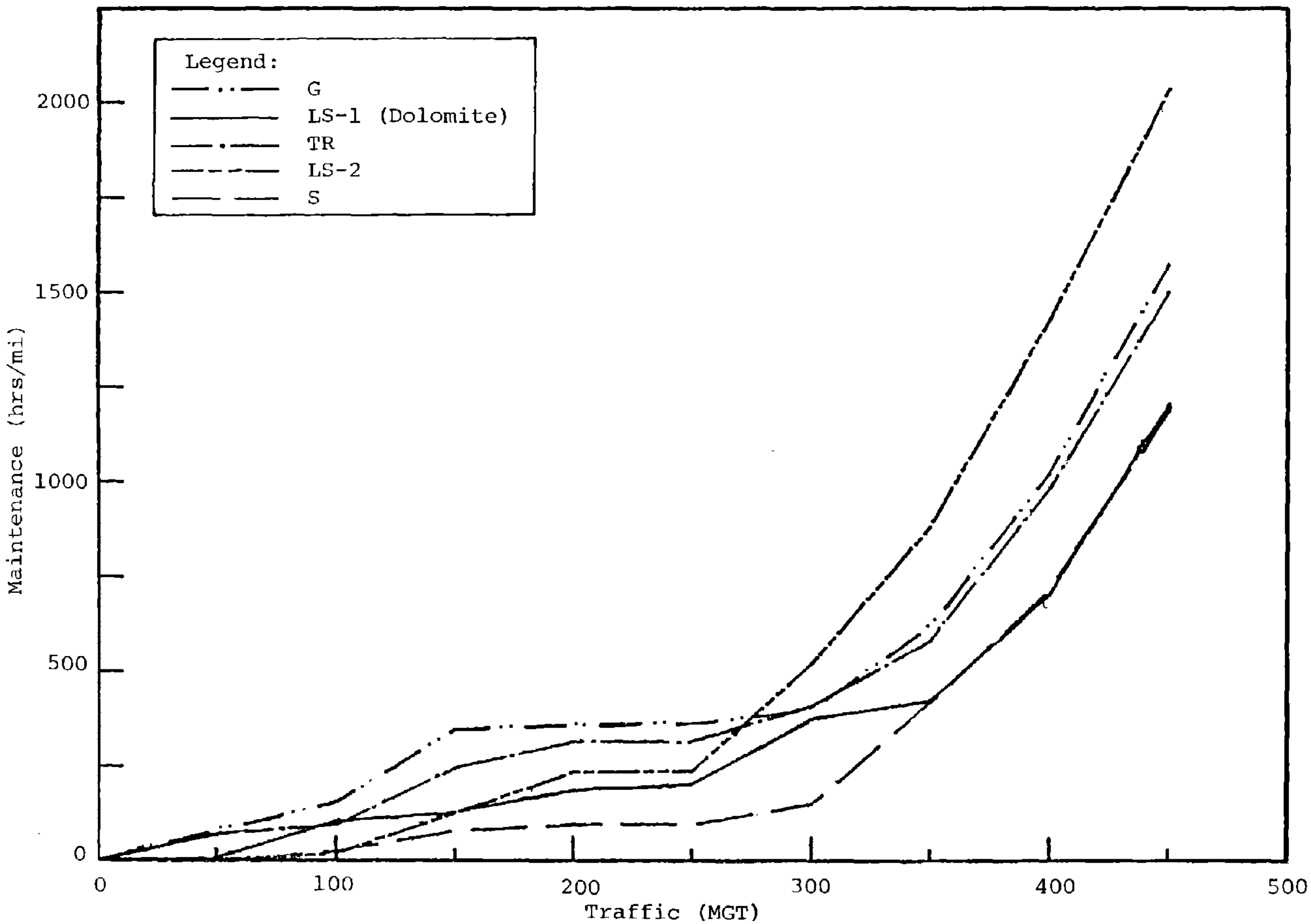


FIGURE 6. BALLAST MATERIAL TYPE TEST, MAINTENANCE VS TRAFFIC.

REBUILD OF FAST SECTIONS 03 AND 17

Section 17 has been a test section for concrete ties since FAST began. Throughout the first 425 MGT, the 5° curve, 2% grade, portion of Section 17 experienced numerous instances of fastener fallout and breakage, tie skewing, and some difficulty in maintaining surface and line. Poor ballast support was believed to be a major contributor to those occurrences. The ballast exhibited substantial degradation and intrusion of subballast and subgrade fines. Petrographic analysis revealed that the material is mineralogically and texturally classed as hornfels, a typically hard and brittle rock that is incapable of withstanding any great shock effects.[6] Yet, no significant ballast problems were experienced in Section 17, outside of the 5° curve, 2% grade portion, or in Sections 18 and 20, all of which contained this same ballast material.

In 1979 (at 425 MGT), the 5° curve of Section 17 was completely rebuilt from the subgrade level to provide better ballast support for the concrete tie test. Section 03 (wood ties, 5° curve, 0% grade) was also rebuilt to provide two sections with uniform support conditions so that concrete ties could be installed at a later date to compare the effects of 0% versus 2% grade. Since the quantity of ballast required for the rebuild required donations from more than one source, a total of seven ballast types were used. Table 1 contains a geologic description and initial AREA grain size classifications of each ballast type. Figures 7 and 8 show the section layouts. Five of the ballasts are nominally called "granite" and labeled Type I through Type V. The word "granite" is used here as a generic term and not as an accurate indication of mineralogical content. A portion of the original hornfels was screened and replaced as a control subsection in Section 17; this is referred to as "CEB"--cleaned existing ballast. The traprock (NEC) in Section 17 is identical to that used in Section 22.

Due to the number of ballasts used, a large number of measurements were taken to determine whether uniform support conditions exist within Sections 03 and 17. Brief descriptions of the measurements and summaries of the findings to date follow.

Approximately 10 to 15 ballast samples were collected in each ballast subsection during reconstruction and after 100 MGT of additional traffic (525 MGT). The initial samples were collected at random, while the later samples were taken from under the tie beneath the rail seat. The samples, which weighed 75 to 100 lbs each, were sieved to determine grain size distributions. Type III ballast showed the least amount of degradation; figures 9 and 10 show its change in grain size distribution for Sections 17 and 03, respectively. Type II exhibited more degradation, as seen in figures 11 and 12. Curiously, the L.A. abrasion loss was higher for the type III ballast (25%) than for type II (17%).

This indicates that the L.A. abrasion test is not always a good predictor of ballast degradation. It is also interesting to note that in both cases, the degradation in Section 17 (concrete ties) was appreciably less than in Section 03 (wood ties). This was also the case for the Type I ballast, which

TABLE 1. BALLAST CLASSIFICATIONS, SECTION 03, 17, AND 22.

Ballast	Geologic Description	AREA Classification
Type I	Micaceous-Quartzo Feldspathic Gniess	3-4[1]
Type II	Granite to Quartz Monzonite[3]	3-4[1]
Type III	Alkali-Feldspar Granite to Alkali-Feldspar Syenite[3]	24
Type IV	Hornblende-Biotite Syenite	3-4[1]
Type V	Quartzite	3-4[1]
NEC	Olivine Basalt Porphyry to Quartz Latite Porphyry[3]	3
CEB[2]	Hornblende-Biotite Hornfels	4-5[1]

1 Falls between class limits
2 CEB = cleaned existing ballast
3 Bimodal

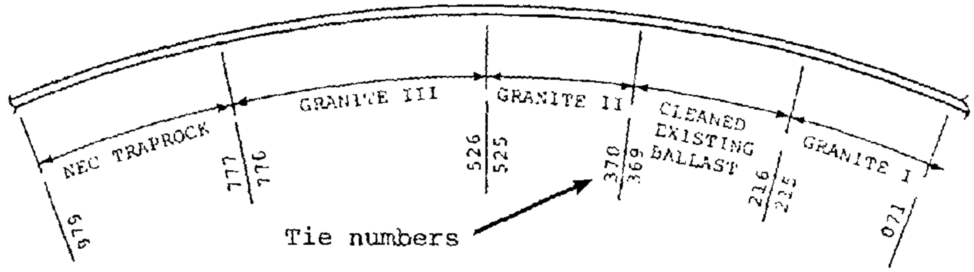


FIGURE 7. REBUILT PORTION OF SECTION 17 (CONCRETE TIES).

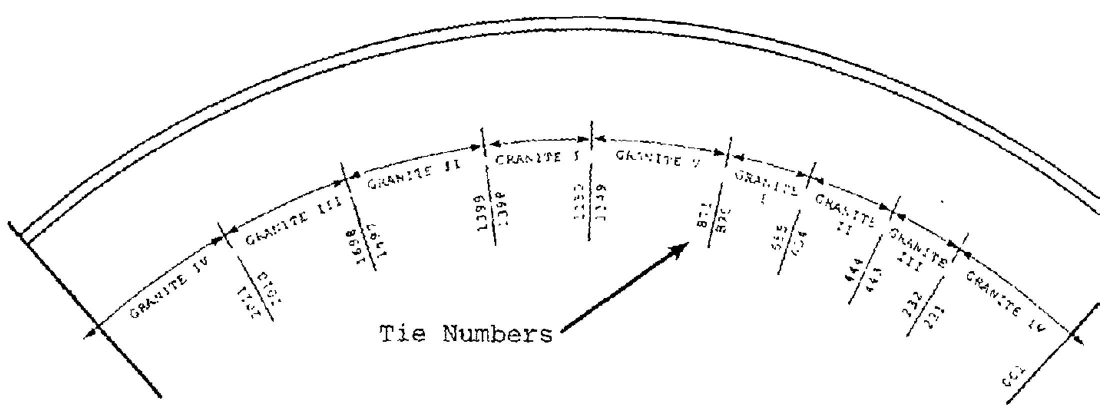


FIGURE 8. SECTION 03 (WOOD TIES).

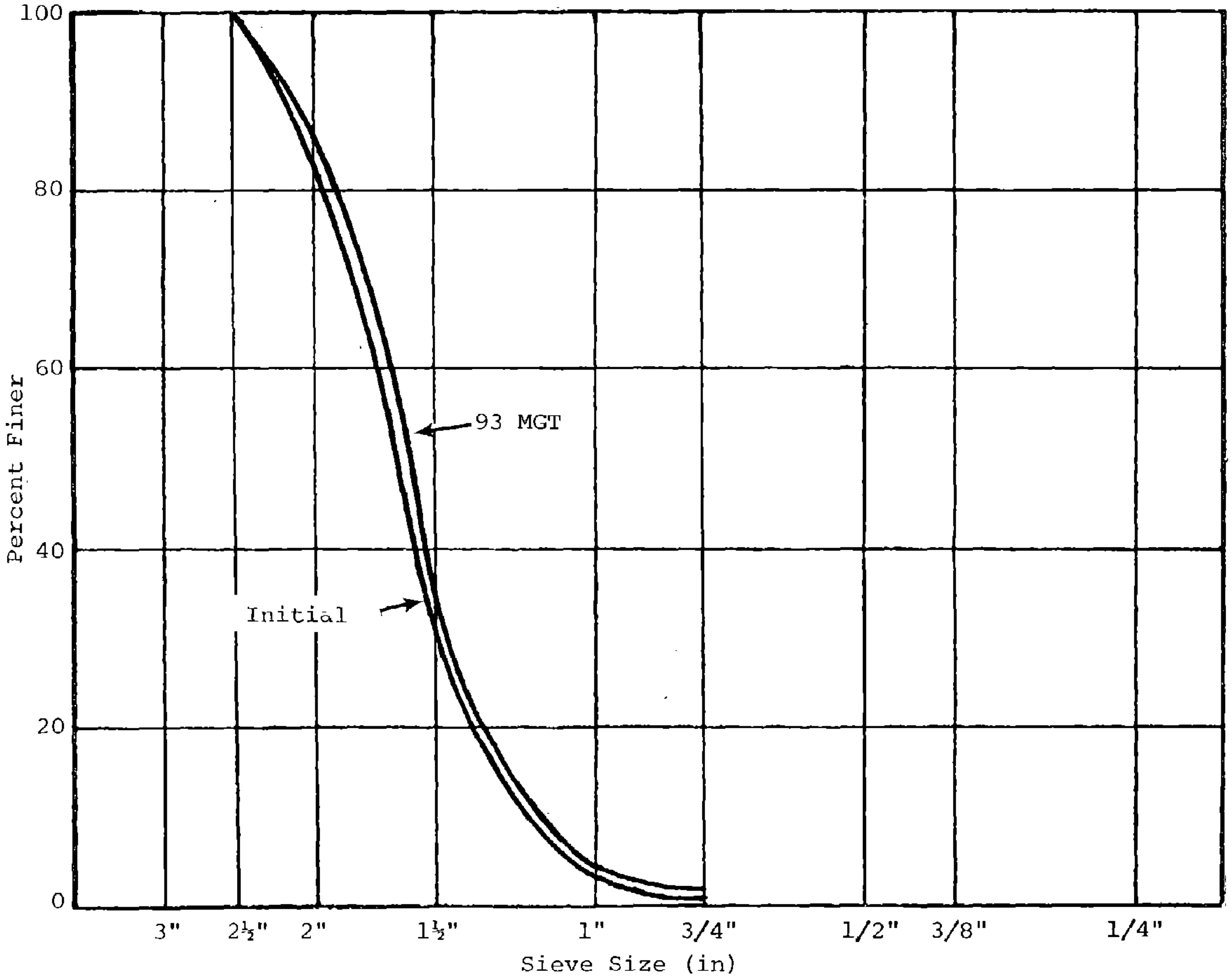


FIGURE 9. CHANGE IN GRAIN SIZE DISTRIBUTION FOR TYPE III BALLAST, SECTION 17.

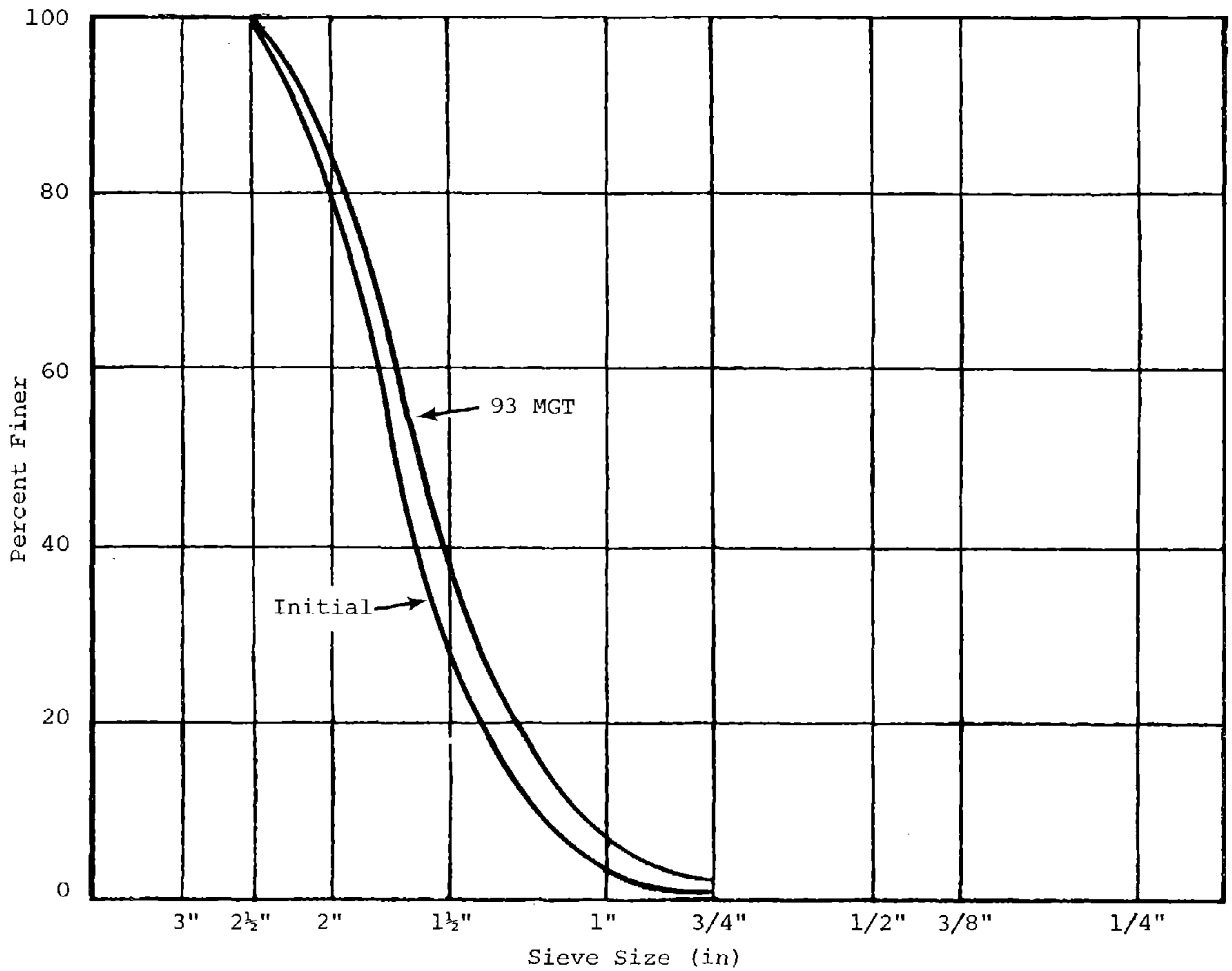


FIGURE 10. CHANGE IN GRAIN SIZE DISTRIBUTION FOR TYPE III BALLAST, SECTION 03.

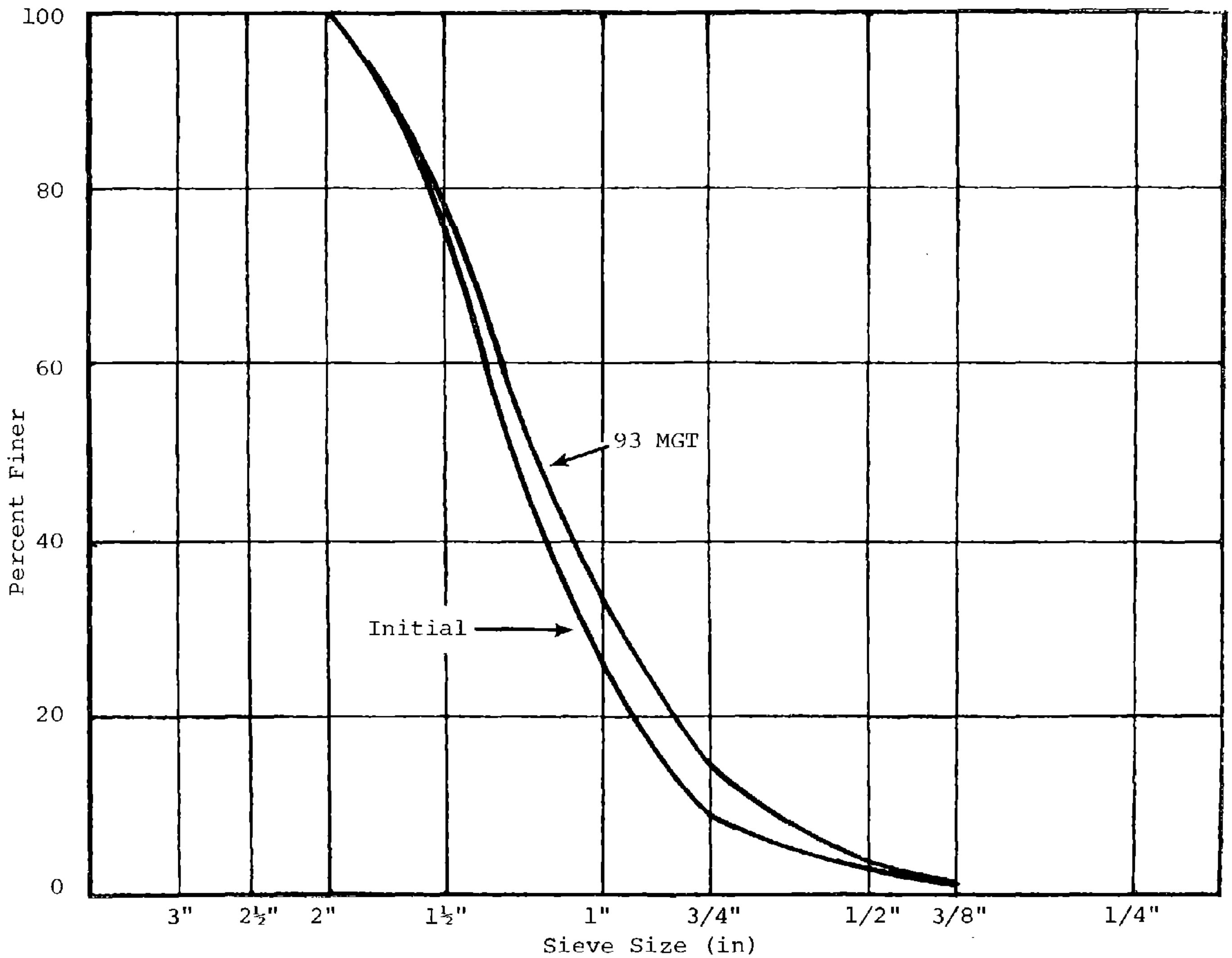


FIGURE 11. CHANGE IN GRAIN SIZE DISTRIBUTION FOR TYPE II BALLAST, SECTION 17.

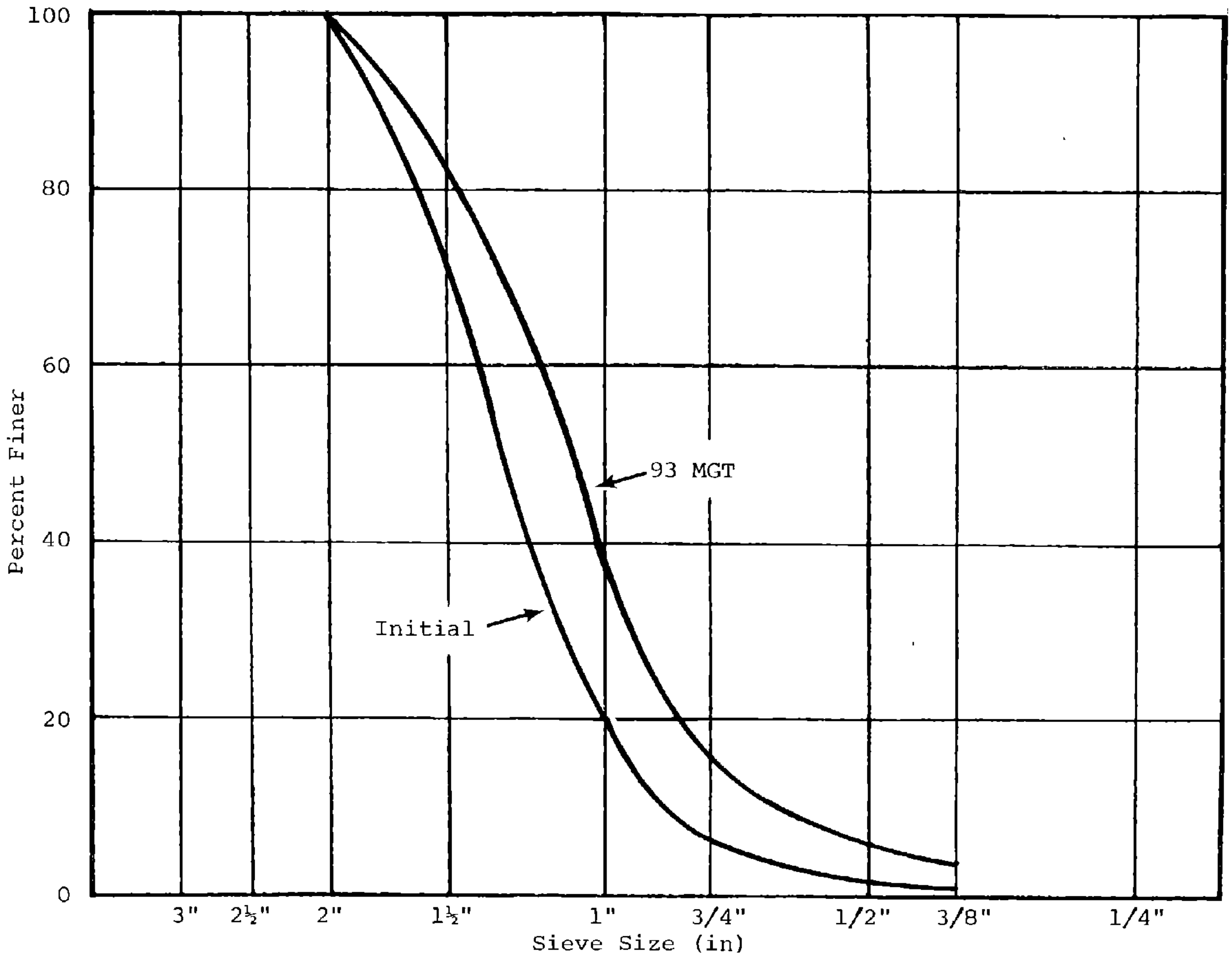


FIGURE 12. CHANGE IN GRAIN SIZE DISTRIBUTION FOR TYPE II BALLAST, SECTION 03.

is the only other material occurring in both Sections 03 and 17. Another interesting finding from the degradation measurements is that through 93 MGT, the much maligned hornfels (CEB) is performing better with respect to degradation than all but the Type III ballast in Section 17.

Track settlement is calculated by measuring top of rail elevation to an accuracy of approximately 0.01 ft at 20-ft intervals throughout each test section. Plotting average settlement vs traffic (MGT) yields curves such as those shown in figure 13. A large percentage of the total settlement is in the first 5 MGT of traffic. Settlement continues with additional traffic but at a much slower rate. Analysis of settlement data has shown no correlation between track settlement and ballast type. This is only a preliminary observation, however, and a more detailed analysis will be conducted.

Comparison of settlement rates between Sections 03 and 17 has shown the amount of settlement in Section 03 to be generally 25 to 50% higher than in Section 17. This is illustrated in figure 13 for ballast Type III. For the Section 17 curve, the settlement at 20 MGT is less than at 10 MGT. This type of movement would normally be associated with a lifting operation during tamping. Since no such operation occurred, either the 10 or 20 MGT data point is an outlier, and the real settlement curve probably is better represented by one of the dashed lines in figure 13. The difference in total settlement after 93 MGT is shown by the T test to be significant at the 99.9% level.

Track modulus is determined by measuring vertical rail deflection under a known static wheel load and performing the appropriate calculations based on beam-on-an-elastic-foundation theory.[7] Measurements were made at three locations, both on the inside and outside rail, in each ballast subsection. Table 2 presents the overall average modulus values for each ballast type in Sections 03 and 17. Analysis of variance shows the variations in track modulus with ballast type to be significant at the 99.9% level in Sections 03 and 17. As expected, the average difference in track modulus between Section 03 (wood ties) and Section 17 (concrete ties) is also significant, with the average modulus measured over 90 MGT for concrete ties being 2 1/2 times that for wood ties.

Lateral tie push tests were conducted on each ballast type in Section 03. These tests were performed, following the procedure described by Selig,[8] after approximately 90 MGT of traffic and again after an out-of-face surfacing and lining of Section 03. Figure 14 shows the average load-deflection plots for each ballast type before maintenance (after 90 MGT of traffic), and figure 15 gives the same plots after surfacing and lining. Two trends are evident from these figures. The maintenance operation reduced peak lateral resistance by roughly 50%. Also, there is considerable variability in peak resistance of various ballast types for the pre-maintenance condition. For the post-maintenance condition, the difference between ballast types is not nearly as pronounced.

Analysis of variance shows the differences in lateral resistance between ballast types for both the pre- and post-maintenance conditions not to be statistically significant. However, for all ballast types, the differences between the pre- and post-maintenance conditions are significant, from the T test, at the 99.9% level.

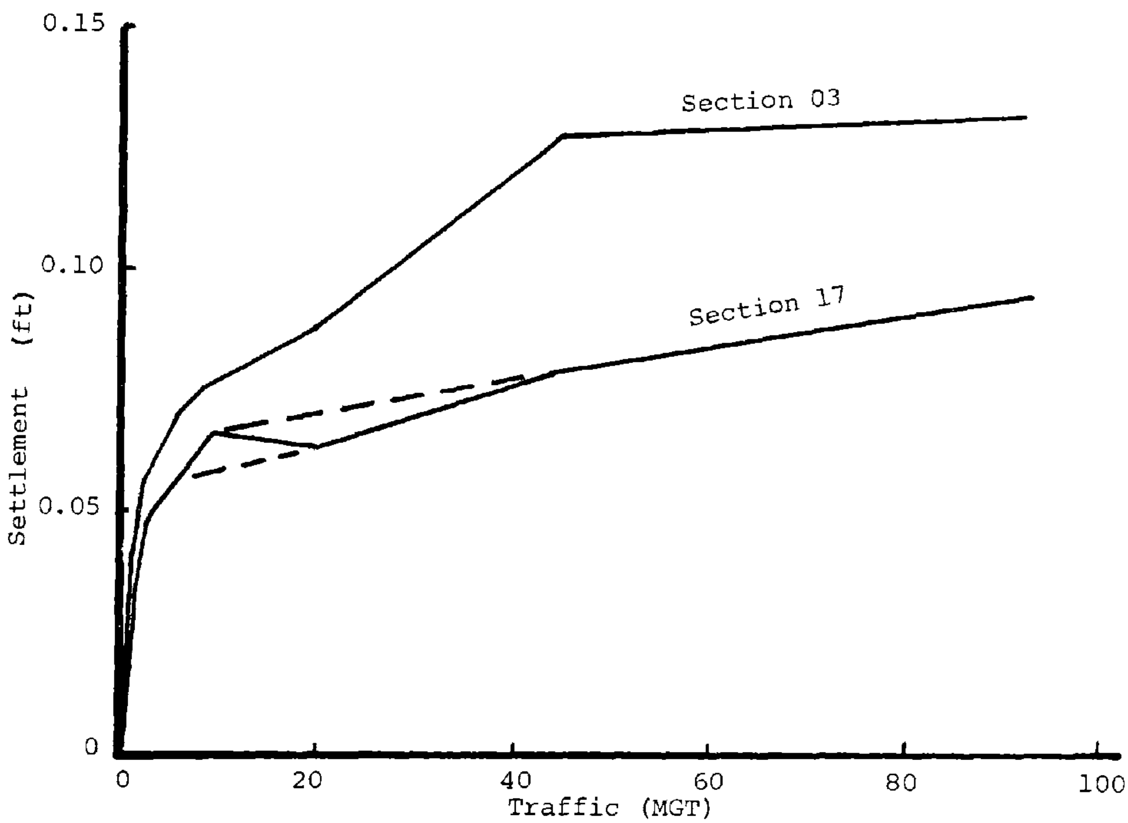


FIGURE 13. TOP OF RAIL SETTLEMENT VS TRAFFIC, BALLAST TYPE III.

TABLE 2. AVERAGE TRACK MODULUS FOR BALLAST TYPES IN SECTIONS 03 AND 17 (0-90 MGT).

Section 03 - Wood Ties

Ballast	Modulus (lb/in/in)
Type I	2,700
Type II	3,000
Type III	3,500
Type IV	2,300
Type V	3,400
Average	3,000

Section 17 - Concrete Ties

Ballast	Modulus (lb/in/in)
Type I	6,700
CEB	6,500
Type II	5,900
Type III	9,000
NEC	9,300
Average	7,500

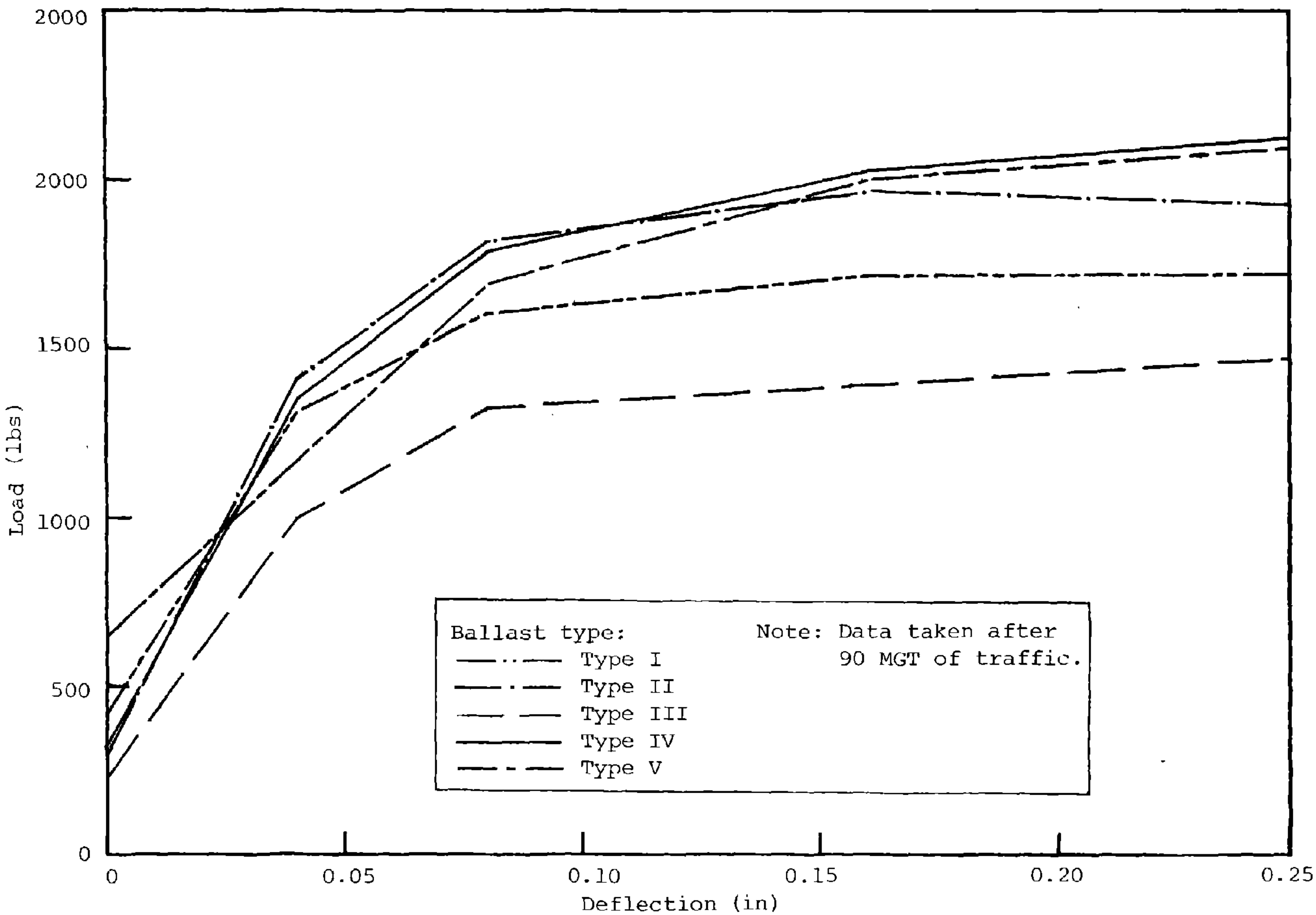


FIGURE 14. LATERAL TIE RESISTANCE, SECTION 03, PRE-MAINTENANCE AFTER 90 MGT OF TRAFFIC.

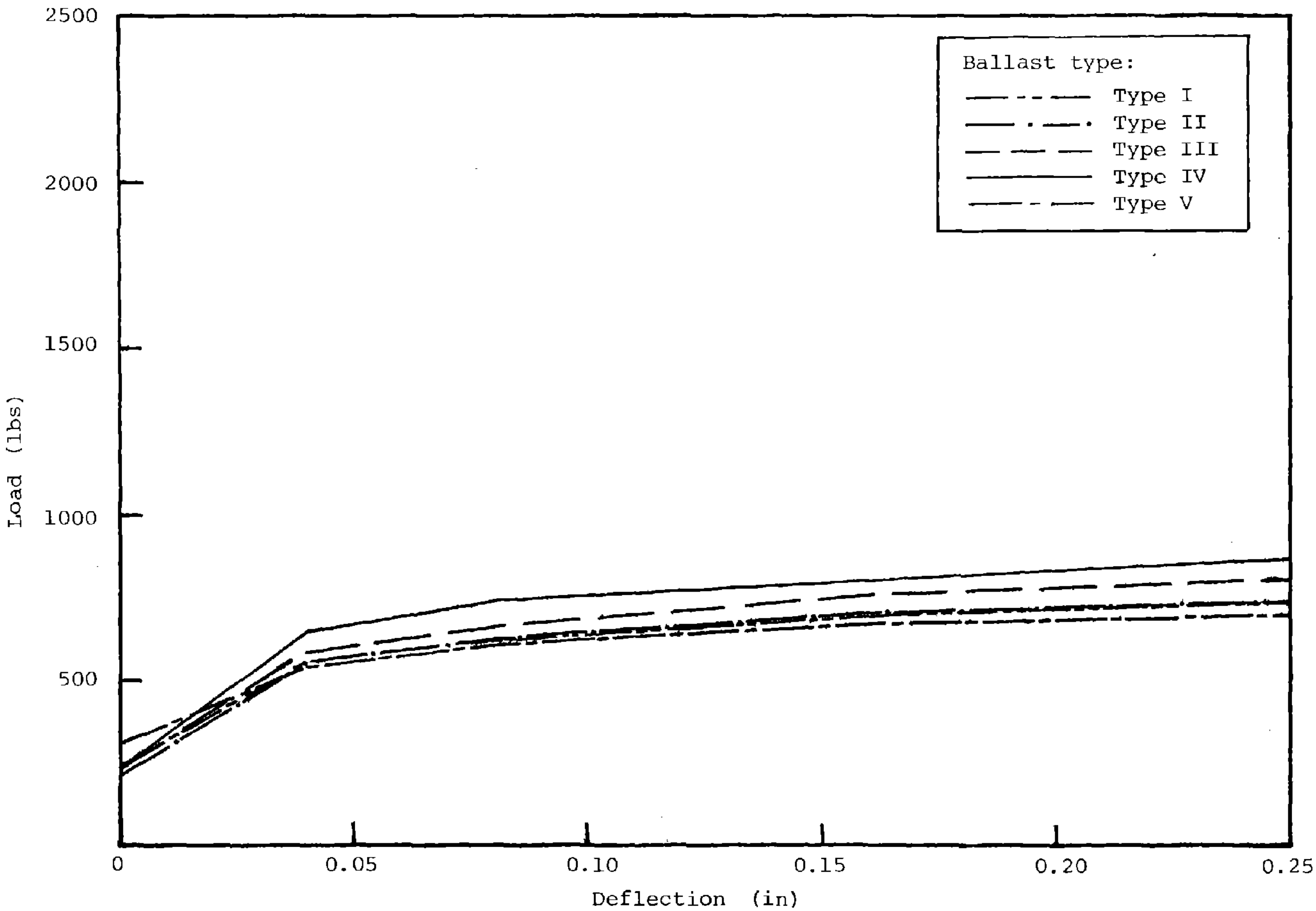


FIGURE 15. LATERAL TIE RESISTANCE, SECTION 03, POST-MAINTENANCE.

NORTHEAST CORRIDOR TEST: WOOD VS CONCRETE TIES

At the request of the Office of Intercity Programs (Northeast Corridor Project), Section 22 was rebuilt (at 425 MGT) to serve as a test for its concrete tie design. The test section consists of two subsections, one containing Northeast Corridor concrete ties and fasteners and the other containing wood ties and cut spikes. Each subsection contains 300 ties with 136 lb/yd standard carbon rail. The ballast is traprock (NEC) with size and physical characteristics similar to those used on the Corridor.

Grain size distribution tests were conducted in Section 22 as in Sections 03 and 17. Table 3 presents the change in gradation for the traprock ballast under both wood and concrete ties between 0 and 93 MGT. There appears to be little difference in the degradation that occurred under wood and concrete ties.

Track settlement was measured for both the wood and concrete tie subsections. Figure 16 shows the total settlement accumulation between 0 and 93 MGT. The settlement after 93 MGT, when out of face surfacing was performed, was equal for each subsection. The curves themselves differ primarily in the high settlement value for concrete ties at 50 MGT. The settlement for concrete ties is less at 93 MGT than at 50 MGT, but no track raise occurred during this interval. The raw data have been rechecked and it must be assumed that a field data entry error occurred at either 50 MGT or 93 MGT. It is impossible to define precisely where, but the main point to be drawn from the plot remains that the settlement was essentially equal for wood and concrete ties and approximately half of the total settlement occurred in the first two MGT's of train operations.

Track modulus values were also calculated for Section 22. As in Sections 03 and 17, the concrete ties on the average exhibited a much higher average modulus (7,800 lb/in/in) than the wood ties (3,700 lb/in/in). The T test shows this difference to be statistically significant at the 99.9% level. Figure 17 shows the variation of track modulus with time. Interesting trends are evident from the figure. Between 2 MGT and 5 MGT, both wood and concrete ties exhibited peaks in track modulus. These peaks correspond to a period of very cold weather preceded by a snowfall that melted into the ballast, thus creating a frozen condition that is believed to have caused the modulus increase.

Other than the early peak, the concrete ties exhibited a gradual increase in modulus with traffic while that for the wood ties remains essentially constant. Section 03 exhibited a similar trend for wood ties. In Section 17, two of the ballast types showed slight increases in modulus, while for the other three, it remained relatively constant.

A recently designed fixture, developed at the University of Massachusetts, was used to measure lateral resistance of concrete ties for comparison with wood ties in Section 22. As in Sections 03 and 17, lateral resistance was measured both before and after a surfacing and lining operation. Figure 18 shows the load-deflection curves for wood and concrete ties (after 90 MGT of

TABLE 3. BALLAST GRAIN SIZE DISTRIBUTION, NORTHEAST CORRIDOR TRAPROCK, SECTION 22.

Sieve Size	Percent Passing		
	0 MGT	93 MGT	
		Wood	Concrete
2 1/2"	100	100	100
2"	97	98	97
1 1/2"	49	60	55
1"	5	11	11
3/4"	1.3	3	5
1/2"	0.4	1.2	1.9
3/8"	0.3	0.7	1.1

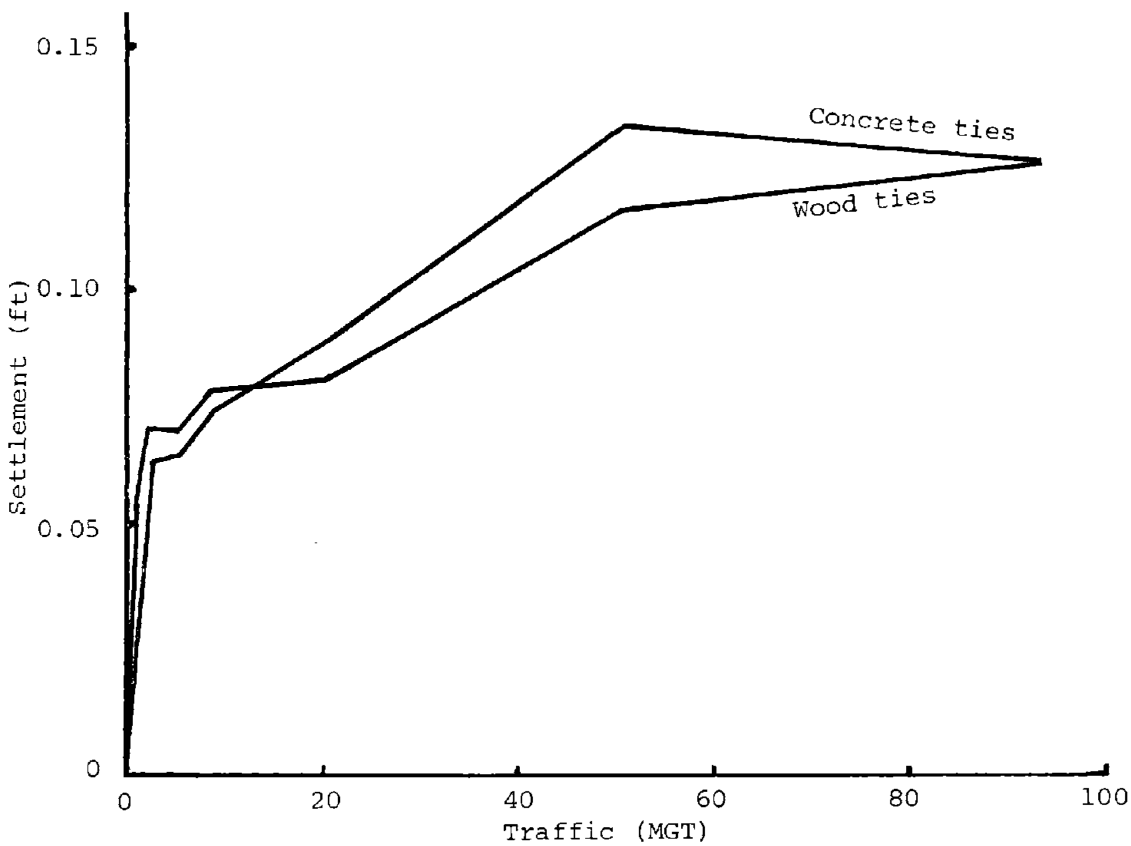
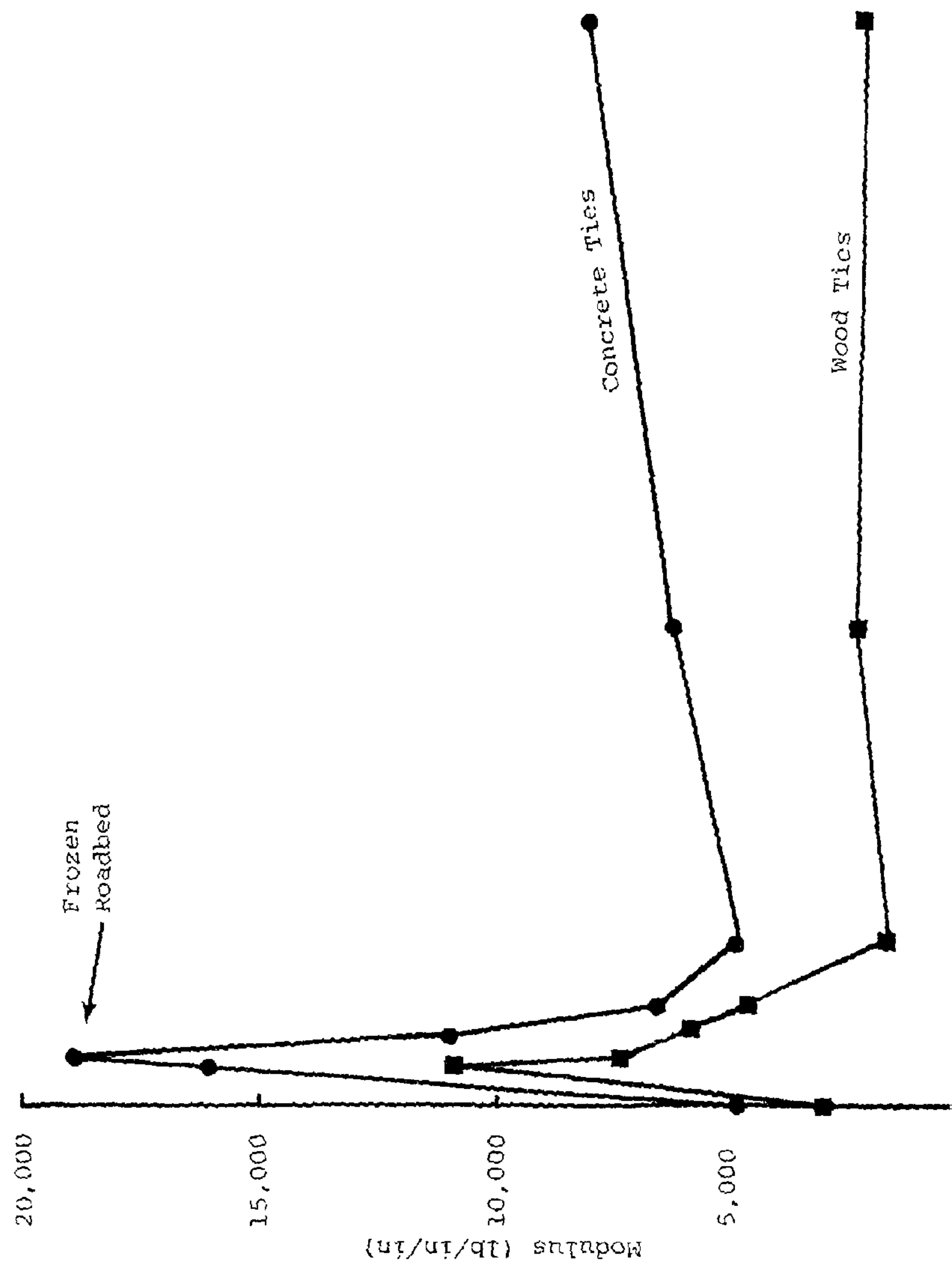


FIGURE 16. TOP OF RAIL SETTLEMENT VS TRAFFIC, SECTION 22.


Concrete Ties
Wood Ties
Frozen Roadbed
20,000
15,000
10,000
5,000
Modulus (lb/in/in)

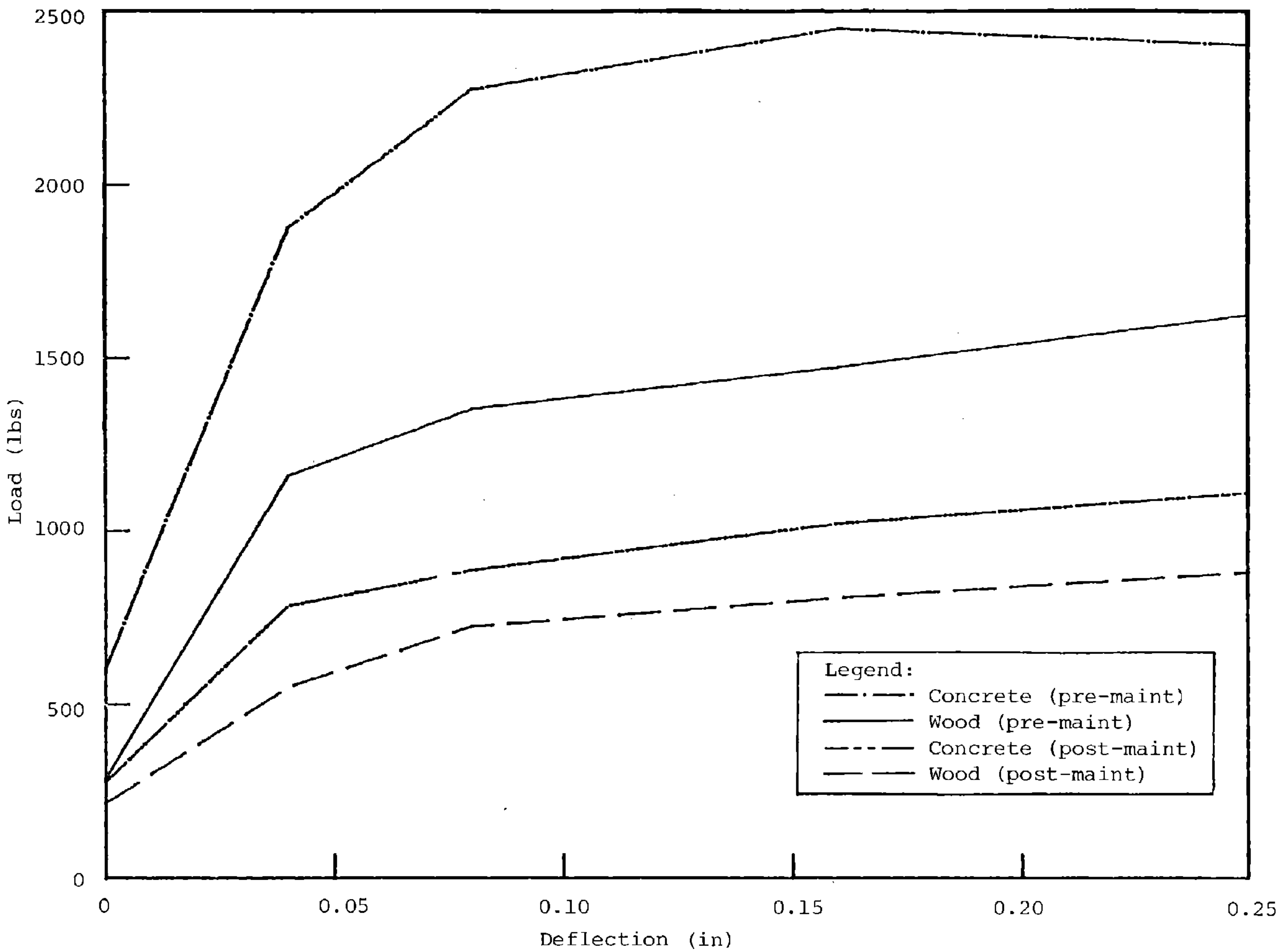


FIGURE 18. LATERAL TIE RESISTANCE, SECTION 22, (AFTER 90 MGT TRAFFIC), PRE- AND POST-MAINTENANCE.

traffic) both pre- and post-maintenance. The reduction in lateral resistance after maintenance is clearly evident for both tie types. Prior to maintenance, the lateral resistance of the concrete ties was 1.6 times that for wood ties. Following maintenance, this factor reduced to 1.3. It must be remembered that the tie spacing for concrete ties is 24" while spacing for wood ties is 19 1/2". When considering lateral resistance per foot of track, the advantage shown by concrete ties is reduced to 1.3 (pre-maintenance) and 1.1 (post-maintenance). T tests performed on the data show the differences between tie types not to be statistically significant at the 95% level. This is due in part to large variability in the data and relatively small sample sizes (5-7 samples).

Four locations in Section 22, two in each subsection, were instrumented to measure strain in the ballast, stress applied to the subgrade, and subgrade deformation.[9] Ballast strains and subgrade deformations are measured both on a long-term permanent and dynamic (under train loading) basis. Subgrade stresses are measured only dynamically. Long term strain and deformation data are currently under analysis.

Preliminary results of dynamic data analysis are presented in figures 19 and 20. Figure 19 shows plots of peak subgrade stress plotted vs axle load for various cars in the FAST consist. Subgrade stress was measured approximately 24" below the bottom of the tie. Figure 20 presents similar plots for subgrade deflection. The plots indicate higher stresses and deflections occurring under wood ties, although the relative magnitude of the stress differences under wood and concrete ties is not as great as that of the deflections. T tests show that differences between tie types for subgrade deflection are significant at the 95% level, at least, for all axle loads. However, due in part to higher variability in the data and smaller differences in magnitude, the tie types show no significant differences in subgrade stress at the 95% level. It must be emphasized that these data are preliminary; more data are being reduced, and analysis is continuing.

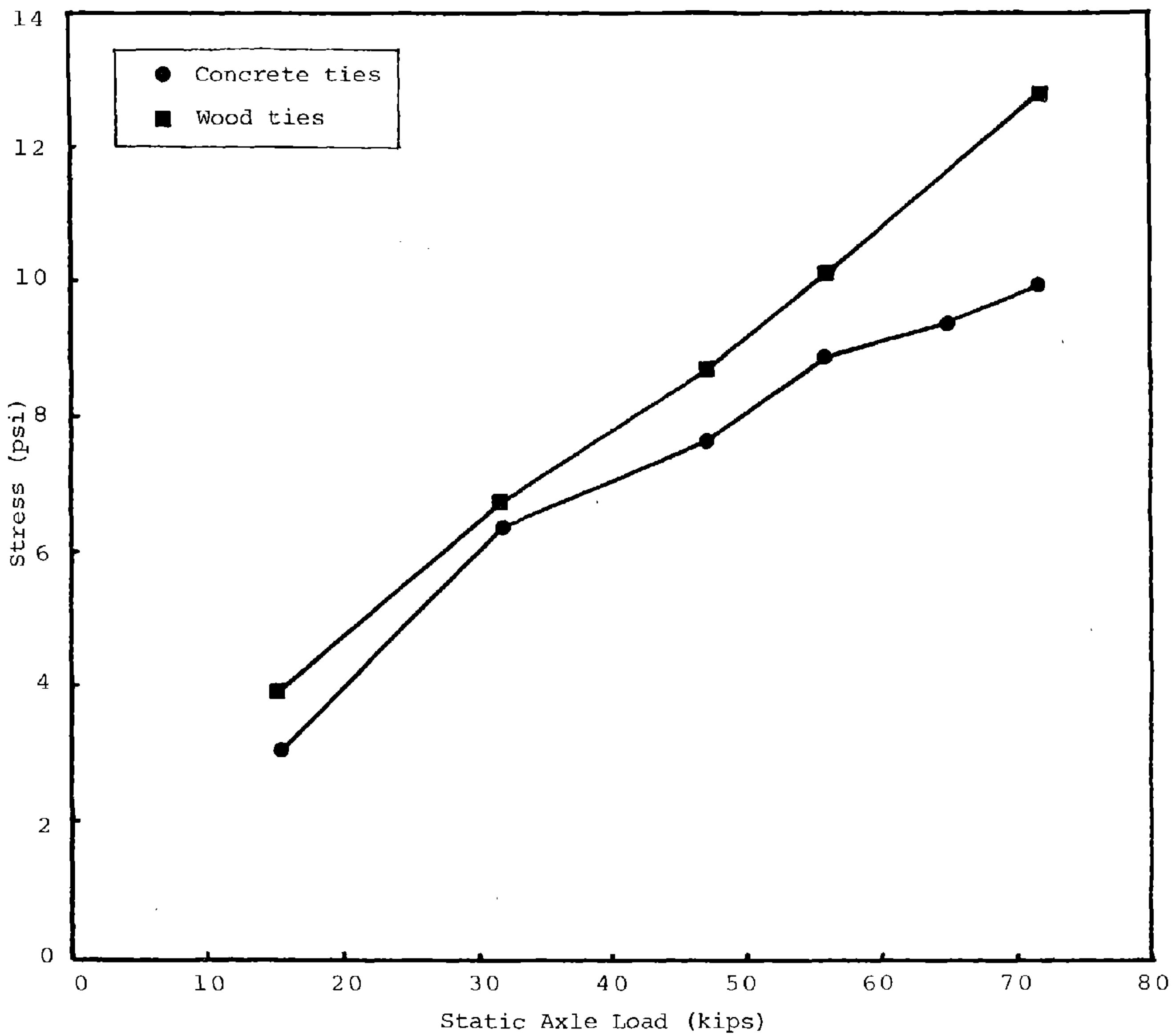


FIGURE 19. PEAK DYNAMIC SUBGRADE STRESS VS AXLE LOAD, SECTION 22, UNDER RAILS.

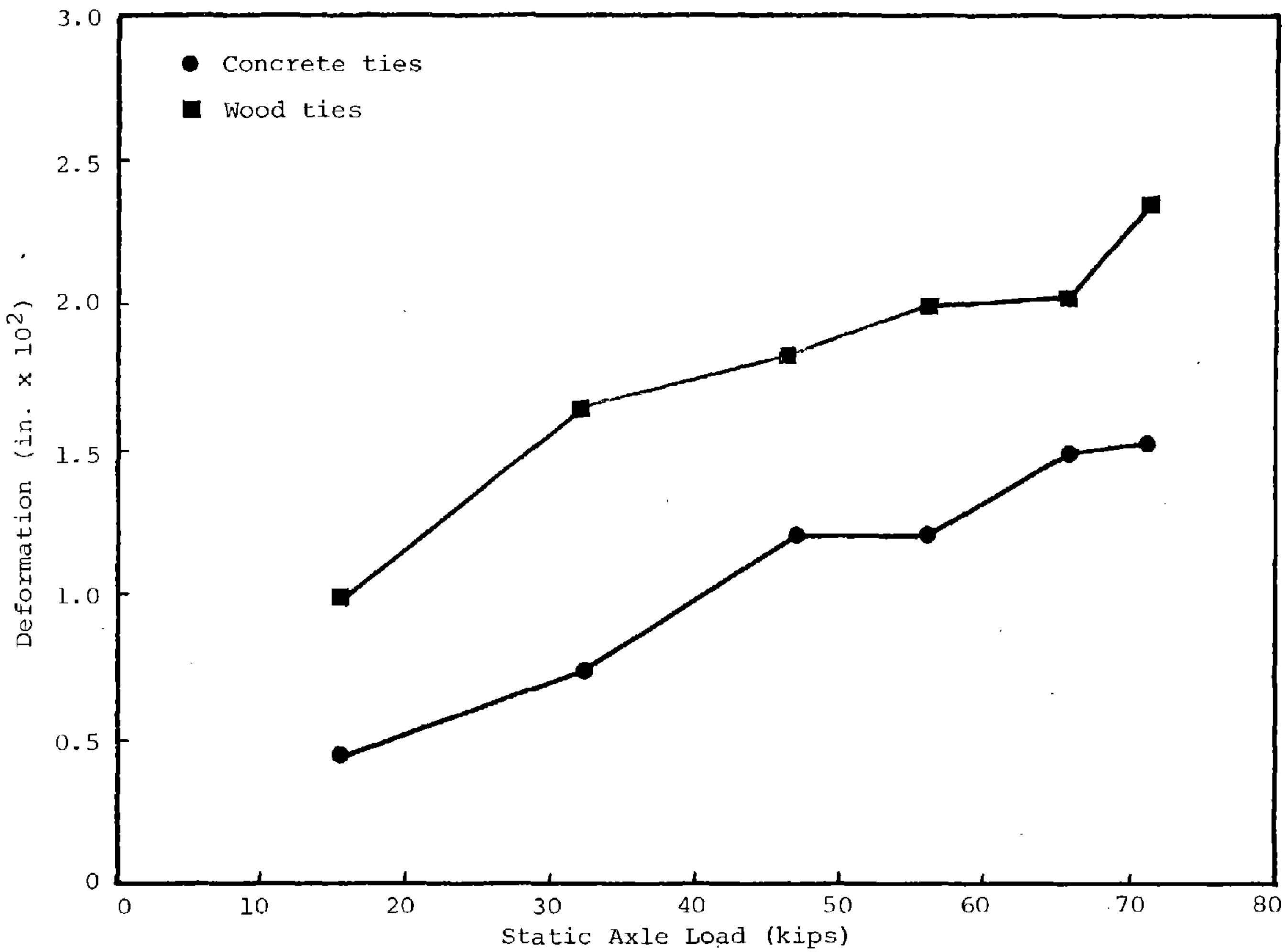


FIGURE 20. PEAK DYNAMIC SUBGRADE DEFLECTION VS AXLE LOAD, SECTION 22, UNDER RAILS.

GEOTEXTILES AT FAST

During the rebuild of the 5° curve 2% grade of Section 17, a 300-ft test zone of geotextiles was installed. Fabrics from three manufacturers, labelled Types I, II and III each with two different weights, were installed in 50-ft segments between ties #70 and #220. Type I was a nonwoven, polyester, continuous filament, needle-punched fabric with weights of 4 and 6 oz/yd^2. Type II was nonwoven, polypropylene, continuous filament, also with 4 and 6 oz/yd^2 weights. Type III was nonwoven, polypropylene, staple filament, needle punched with 5 and 8 oz/yd^2 weights. The objective of the test was to explore the ability of geotextiles to prevent subgrade intrusion into the ballast and to provide added track strength. Lack of precipitation at Pueblo ruled out investigation of drainage improvement capabilities. The original test layout called for 200 ft of two fabric types and 100 ft of track with no fabric to act as a control, all to be located within the 300 ft ballast Type I subsection. Just prior to installation, a third manufacturer was granted permission to place his fabric into the test, which eliminated this 100 ft of control in the subsection.

Plate load tests[10] were conducted at six points on the ballast under tie locations (with the ties removed) in each fabric type and weight. Table 4 presents the plate load bearing pressures at deformations of 0.1" and 0.2". Also given are the same parameters from Section 03, ballast Type I, which has no fabric; these are included only for comparison. Subgrade conditions vary somewhat between Sections 03 and 17,[11] and due to the tie-type difference, ballast stiffnesses were subject to variation.

Small sample sizes prohibited demonstration of statistical significance. However, the following trends were evident: Except for the case at 0.1" deformation for fabric Type III, the bearing pressures were higher for the heavier fabric weight for each type. All of the fabric sections, other than Type I, 4 oz/yd^2 at 0.1" deformations, exhibited higher pressures than in Section 03. Comparing fabric types, II appeared to be the stiffest followed by I and then III. It was surprising that these stiffness differences showed up, when one considers the plate load tests were conducted on top of an 18" ballast layer covering the fabrics and the fact that FAST has a very strong subgrade. Further study is necessary to determine whether the fabrics truly cause an increase in stiffness, and if so, the magnitude of that increase.

Track modulus tests were also conducted at each fabric installation. Table 4 presents the average modulus from five tests at each installation. No relationship was evident between modulus and fabric type and weight.

In August 1980 (approximately 90 MGT after installation), the ballast was excavated at one tie location in each fabric type and weight to expose the surface of the fabric for inspection. The inspections revealed that both weights of the Type II fabric contained numerous holes caused by penetration of the ballast particles. The Type I fabric had also been penetrated, but to a lesser degree. No holes were visible in the Type III fabric. There was no visual evidence of any intrusion of the subgrade into the ballast in any of the fabrics.

TABLE 4. GEOTEXTILE TEST.

Plate Bearing Pressure (lb/in^2)

Deformation	Fabric Type-Weight (Section 17)						No Fabric (Section 03)
	I-6 oz/yd	I-4 oz/yd	II-6 oz/yd	II-4 oz/yd	III-6 oz/yd	III-5 oz/yd	
0.1 in	230	140	230	190	160	160	140
0.2 in	260	210	360	250	240	200	190

Track Modulus (lb/in/in)

Fabric Type-Weight (Section 17)					
I-6 oz/yd	I-4 oz/yd	II-6 oz/yd	II-4 oz/yd	III-8 oz/yd	III-5 oz/yd
5,800	6,400	7,300	6,700	6,600	7,000

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