TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle	5. Report Date
THE EFFECT OF STUDDED TIRES ON DIFFERENT PAVEMENT MATERIALS AND SURFACE TEXTURES	May 22, 1972
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Milan Krukar, P.E. and John C. Cook, P.E.	H-36
9. Performing Organization Name and Address	10. Work Unit No.
Transportation Systems Section College of Engineering Research Division Washington State University Pullman, Washington 99163	11. Contract or Grant No. Y-1439
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Washington State Highway Commission Department of Highways Highway Administration Building Olympia, Washington 99163	Interim #1 9-3-71 to 6-30-72
	14. Sponsoring Agency Code

15. Supplementary Notes

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration, Washington Dept. of Hwys., and the Idaho Dept. of Highways. Study Title: Studded Tire Pavement Wear Reduction and Repair

16. Abstract

This preliminary report presents data obtained from testing at the G.A. Riedesel Pavement Testing Facility, during the period from February 11 to May 4, 1972. The purpose of this project was fourfold: (1) to determine pavement wear caused by studded tires; (2) to evaluate the resistance of different pavement materials and textures used in the states of Washington and Idaho to wear caused by tire studs; (3) to test pavement materials and overlays to reduce tire stud damage; and, (4) to study the effect of studded truck tires on pavements.

17. Key Words	18. Distribution Statement
Pavement durability, life & performance, asphalt pavement, portland cement concretes overlay course, studded tires, tires, skid resistance	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	32	

Form DOT F 1700.7 (8-69)

PAVEMENT RESEARCH
at the
WASHINGTON STATE UNIVERSITY
TEST TRACK

EXPERIMENTAL RING NO. 5: THE EFFECT OF STUDDED TIRES ON DIFFERENT PAVEMENT MATERIALS AND SURFACE TEXTURES

INTERIM REPORT #1

Report to the Washington State Department of Highways
on Research Project Y-1439

by

Milan Krukar and John C. Cook

Transportation Systems Section
College of Engineering Research Division
Washington State University
Pullman, Washington
July, 1972

In Cooperation with
U.S. Department of Transportation
Federal Highway Administration

Washington Department of Highways
and
Idaho Department of Highways

Transportation Systems Section Publication H-36

ACKNOWLEDGMENTS

The Transportation Systems staff wishes to thank the Washington Highway Department for their financial and technical support. There were many Highway Department personnel from Olympia who helped; particularly the following: Hollis Goff, Assistant Director for Planning, Research and State Aid; Roger V. LeClerc, Materials Engineer; Ray Dinsmore, Research Coordinator; Mrs. Willa Mylroie, Special Assignments and Research Engineer; and Tom R. Marshall, Special Assignments Engineer. The Transportation Systems staff also wishes to thank the Idaho State Highway Department for their financial and technical support, and especially Leif Ericson, Materials Engineer for his interest and help.

Thanks go to Robert Bureau, Leadman with Electrical Engineering Section, who designed and built the WSU Profilometer; Dave Heinen and Jim Logan, with the Electrical Engineering Section, for developing the computer programs; and to Norm Shoup and Kal Pell, the mechanical engineers who designed and built the modifications to the G.A. Riedesel Pavement Testing Facility. Max Huffaker and Dr. Raff, of the Materials Chemistry Section, worked on the polymer concrete design and its construction.

Thanks go to the secretaries, Sue Vickerman and Sharla Pace, who helped in typing and editing the rough drafts. The list of WSU students who worked on this project is too lengthy for inclusion.

A word of appreciation goes to the different organizations who contributed free material for testing in this project, and technical help.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

This report presents some data from tests done on Ring #5 at the G.A. Riedesel Pavement Testing Facility at Washington State University, Pullman, Washington. Ring #5 consisted of three concentric tracks on which 16 tires travelled in eight wheel paths. Three studded types and unstudded passenger tires, studded and unstudded truck tires, and 46 sections of various types of pavement materials, surface overlays and surface textures were tested from February to May 1972. The results presented here are based on wear as measured on the basis of maximum rut depth using the WSU Profilometer, and are valid only under WSU testing conditions.

The findings indicate that some pavement materials are more resistant to the effect of studded tires than others. Different types of studs reduced wear of various pavement materials. All types of studded tires tested caused some pavement wear and this affected the skid resistance values. A more complete report on all data will be forthcoming.

The Effect of Studded Tires on Different Pavement Materials and Surface Textures

Introduction

This preliminary report presents results from some of the data obtained from testing on Ring #5 at the G.A. Riedesel Pavement Testing Facility at Washington State University, Pullman, Washington, during the period from February 11, 1972 to May 4, 1972. The purpose of this project was fourfold: (1) to determine pavement surface wear caused by studded tires; (2) to evaluate the resistance of different pavement materials and textures used in the states of Washington and Idaho to wear caused by studded tires; (3) to test new pavement surface materials, finishes, and overlays to reduce tire stud damage; and, (4) study the effect of studded truck tires on pavements.

This project, Y-1439, was initiated by the Transportation Systems Section (formerly Highway Research Section) of the College of Engineering Research Division, Washington State University and is financed by the Washington State Highway Commission, Department of Highways; the Federal Highway Administration of the U.S. Department of Transportation as an HPR federal aid research project; and the Idaho Department of Highways.

The data has not been analyzed and this report summarizes the result with respect to pavement surface wear. The final report results may modify analytically the findings presented here. These results were obtained and measured under WSU Test Track conditions. Conclusions may not be valid elsewhere.

Description

This test track ring consists of three concentric tracks; the inside and outside track are 3.5 feet wide and the center track is 3.0 feet wide. The rings were divided into six sections of 43 feet in length and then further subdivided.

The pavement structure consists of 6.0 inches of asphalt treated base and 6.0 inches of surfacing of different types. The center ring was constructed of reinforced portland cement concrete with 12 different surface textures. The inside and outside tracks were constructed of asphalt concrete consisting of the types used by the Department of Highways and portland cement concrete with different types of overlays. A total of 46 sections were tested; 20, 12 and 14 sections in the outside, center, and inside rings, respectively. Figure 1 shows the arrangement of sections of the test track and Table 1 shows the types of materials, their surface textures, lengths and widths.

The three tracks were constructed during the months of October and November, 1971 under less than ideal construction weather. Some of the polymer concrete overlays were laid down in December, January and February. The result was that some of the sections suffered premature failure and wear due to construction difficulties rather than to the materials themselves. The data for these sections are not presented here, as these materials will be retested in the next ring.

Apparatus

The G.A. Riedesel Pavement Testing apparatus consists of three arms supporting a water tank. These arms revolve in a circle on three sets of truck dual tires. A 60 hp D.C. electric motor on each arm provides the motive power. An eccentric mechanism enables the apparatus to move so that a considerable width of the pavement can be covered by the test wheels.

The apparatus was extensively modified so that more tires could be used in the tests. This modification allowed the placing of two sets of passenger tires inside the truck duals so that these tires could run on the inside track. The truck dual tires run on the center track. On the outside track, two passenger tires were hung on each of two arms so as to travel on the outside ring in four separate wheel paths. A total of 16 tires were mounted on the apparatus. The passenger car tires carried 1,000 lb loads, applied via air load cells, and the truck dual tires each carried 6,600 lbs. This modification took some four months.

A hydraulic braking system was installed on two of the arms on the inside tires. Brakes were applied at intervals of 1 min.-2 sec. on a 4 min. off on each of the inside "b" sections.

Tires

A total of 16 tires were used at one time; 6 truck tires, 3 of which were studded and 3 unstudded; and 10 passenger winter snow tires. The truck tires used in the center track were size 14 x 22.5, inflated to 80 psi air pressure; the inside tire, the driving tire, had 240 type 3 studs; the outside tire was free-wheeling and unstudded. The center track had three passes per revolution.

The passenger tires were all 6.78 x 14 with winter snow tread and consisted of four unstudded, four with 108 type 1 studs, and one with 108 type 3 and one with 114 type 2 studs. Each tire was inflated to 28 psi and carried a 1,000 lb load. The inside track had three unstudded and three type 1 studded tires. The studded tires travelled in wheel path #7 and the unstudded tires travelled in wheel path #8. The inside track had three passes per revolution.

On the outside track, four passenger car tires were used on four different wheel paths. The unstudded, the type 1, the type 2 and the type 3 studded tires were in wheel paths #1, #2, #3 and #4, respectively. The outside track had one pass per revolution. Figure 1 shows the eight different wheel tracks.

Measurements

Reference pins were installed in all the sections so that transverse profile measurements could be taken. Profiles were made by the camera box/wire technique. A shadow of the wire is superimposed on the pavement and the difference in wear between successive readings can be detected. The results from this technique are still being analyzed and are not presented in this report.

Another apparatus used to measure transverse profiles is the WSU Profilometer. This apparatus consists of ten fingers which travel across each wheel track. Each finger is connected to a capacitor. A D.C. linear electric motor drives the apparatus and the results are recorded on a Brush recorder. The results are plotted on a chart as a transverse profile of the section; any point on the chart is the average of ten different readings over a 3-inch wide span. The limit of the apparatus is $\pm$ 0.5 inch with an error of $\pm$ 0.02 inch. Typical curves are shown in Figures 2, 3 and 4. Most of the data presented in this report were obtained from the WSU Profilometer and are presented as maximum rut depth. Analyses on average wear rate, average wear and average depth are still continuing and will be presented in the final report.

Depth measurements with a straight edge were also taken.

Temperature measurements using iron-constantan thermocouples were used for measuring surface and air temperatures on a 48 point Honeywell recorder. A thermograph was also used to monitor ambient temperatures. Complete analyses of the thermocouple readings have not been completed. Table 2 shows the maximum and minimum monthly ambient temperatures for the test months of February, March and April.

Tire tread depth measurements and stud protrusions were also taken at regular intervals. Table 3 shows the stud protrusion lengths for the different type studs and the corresponding tire tread depth.

The California Skid Tester, courtesy of the Washington Highway Department, was used to measure the skid resistance of the various sections and wheel paths. Results of some of these measurements are shown in Tables 4, 5 and 6. The final skid resistance measurements will be included in the final report.

Conditions of Test

Time Period: Testing started on February 11, 1972 and terminated on May 4, 1972. At that time, some 542,357 revolutions had been recorded. This means that 542,357; 1,627,071 and 1,627,071 wheel passes had been applied on the outside, center and inside tracks.

A total of 12,601 brake applications were applied on the "b" sections of the inside track. Problems with the braking system did not allow more applications.

Speed: The speed of the apparatus was kept between 20 - 25 mph. The differences in wear occurring on the various pavement surfaces prevented higher speeds.

Eccentricity: Initially, the eccentricity was kept at zero inches. This was changed to 0.50 inch total at 13,535 revolutions and then to 3.50 inches total at 62,357 revolutions. This was done to eliminate tire grooves in the wheel paths. The wheel paths for the individual tires are shown in Figures 5 and 6.

Temperature and Environment: The high and low ambient temperatures for the months of February, March and April are shown in Table 2. More temperature data will be forthcoming in the final report.

The WSU Test Track was operated in all weather conditions that occurred during the testing period. The only abnormal condition was that the track was kept clear of snow at all times. The snow was not allowed to accumulate on the pavements.

Stud Protrusion and Tread Depth

The stud protrusion varied with the different types and over the length of test. Tread depth measurements also showed variation. Table 3 shows the average stud protrusion and corresponding tread depths during the test period.

Skid Resistance Values

These measurements were taken in each of the wheel paths. The length of time needed to take these readings precluded their frequency. However, the few taken and shown in Tables 4, 5 and 6 reveal that the skid resistance values were reduced considerably in the studded tire wheel paths.

Summary of Results

1. It should be noted that comparisons of materials between the three tracks should be made with care and judgment. There were enough differences in the tests,that in some cases, direct comparisons cannot be made. The center track had truck tires while the inside and outside tracks had passenger tires. Each of the tracks had different amounts of wheel passes. Wheel paths #1-4 of the outside track had 542,357 passenger tire wheel passes; wheel paths #5 and #6 had 1,627,071 truck tire wheel passes on the center track. (Wheel path #6 had 1,396,935 studded truck tire passes and 230,136 unstudded truck tire passes); while wheel paths #7 and #8 had 1,627,071 passenger tire passes. Then also the effect of speed with the inside wheels traveling at slightly lower speeds than the outside wheels; this could have affected the rate of wear.
2. All studded tires tested caused abnormal wear on all surfaces of the test track. Table 7 shows the percentage of wear caused by unstudded, type 1 and type 2 studded tires as compared with the type 3 studded tires, which are shown as 100%, and also at times less than type 3 studded tire wear. Tables 8 and 9 indicate the maximum rut depth measured by a straight edge. Figures 7 through 11 indicate wear depths caused by studded tires on various pavement surface types. Pavement surface wear caused by unstudded tires was essentially unmeasureable.
3. The portland cement concrete pavements showed more resistance to studded tire wear than the asphalt concrete pavements (see Table 9 and Figure 7).

The skid resistance values of the portland cement concrete pavements were slightly lower than the asphalt concrete pavements after wear occurred (see Table 6).

4. Considering the asphalt concrete pavement sections, the Class "B" asphalt concrete pavement showed the most resistance to wear by the studded tires followed by the Class "G" and then the Class "E" asphalt concretes on an overall basis. This is shown in Figure 7. The Class "E" asphalt concrete with respect to maximum rut depth at the end of the test was slightly superior to the Class "G" asphalt concrete (see Tables 8 and 9).

5. Tests made on the steel fibrous concrete overlays (Wirand® Concrete) were to study different types of mix designs with respect to their wear resistance to studded tires. The Wirand® Concrete in Section 0-2aC proved to be the most resistant to wear from studs and to be the equal of the 1/4" polymer concrete overlay in Section 0-2bB and regular portland cement concrete. This was the Wirand® Concrete with the 3/8" aggregate (see Table 8 and Figures 8 through 10). All the steel fibrous concrete sections showed superior skid resistance values as wear progressed. This is shown in Table 4. Under WSU test conditions, the steel fibers had a tendency to work themselves loose and spread over the track, and protrude somewhat out of the pavement.

6. The gilsonite product (tradename Gilsabind) rejuvenating treatment on two of the asphalt pavement types showed that it reduced the wear of tire studs slightly, but this was so small that it could be within the measure-

---

® Registered trademark of Battelle Development Corporation error (see Table 8 and Figure 10). The Gilsabind treatment initially reduced the skid resistance, but this equalized after a few wheel passes (see Table 4).

7. The surface materials showing the greatest resistance to studded tire wear tested were the different types of polymer overlay--the polymer cement and polymer flyash concretes (see Tables 8 and 9 and Figures 7 and 11). These materials showed good resistance to all tire studs. However, the skid resistance values of the polymer concretes decreased drastically with wear (see Tables 4 and 6).
8. Different surface textures, formed while the portland cement concrete was plastic, showed no great advantage for wear resistance. The reason is that the textures probably consisted of sand-cement mortar deficient in coarser aggregate. These surface textures thus had relatively little strength to resist the tire studs (see Tables 1 and 9).
9. Skid resistance values dropped with wear caused by the studded tires. The portland cement concrete value reduction was particularly noticeable, and showed a polishing effect in the worn wheel paths (see Tables 5 and 6).
10. Poor construction weather plagued the 2.0 inch thick polymer concrete, where the epoxy replaced the cement in a regular portland concrete mix. Low temperatures resulted in poor bonding of the aggregate which quickly came loose with wheel passes. Therefore, the data on this material is excluded from this report.
11. The Idaho Chip Seal center sections also were placed under extremely poor weather conditions with the result that the chips did not adhere to the rubberized asphalt. In areas where the chips were retained, the pavement

showed good resistance to tire studs. Therefore, the data on these sections are excluded from this report.

12. Additional analysis of data including computer print-out of cross-section of wear areas should provide more definitive results.

13. The next phase of this project involves application of overlays and additional wear testing. Replication and expansion of present data will be possible.

14. Tire stud types are identified by number in the following data. Type 1 is a controlled protrusion type; type 2 is a composite core type with small tungsten carbide chips in a soft binding matrix; type 3 is the conventional solid tungsten carbide pin encased in a steel jacket. Use of any material in this project or reporting of results does not imply or constitute an endorsement by the sponsors or the research agency.

TABLE 1

RING #5 - TYPES OF SECTIONS AS BUILT

Types of Pavement Materials & Textures - Outside Track

Section	Type	Texture	Dimensions - Ft.	
			Length	Width
0-1aA	Polymer Concrete-2"-Mix A	Hand Trowelled Finish	3.0	3.5
B	Polymer Concrete 2"-Mix B	Hand Trowelled Finish	10.0	3.5
C	Polymer Concrete 2"-Mix C	Hand Trowelled Finish	9.0	3.5
0-1bA	1/2" Wirand Concrete - Mix 1	Light Transverse Brooming	7.5	3.5
B	1/2" Wirand Concrete - Mix 2a	Light Transverse Brooming	5.0	3.5
C	1/2" Wirand Concrete - Mix 2b	Light Transverse Brooming	3.5	3.5
D	1/2" Wirand Concrete - Mix 3	Light Transverse Brooming	6.5	3.5
0-2aA	1" Wirand Concrete - Mix 3	Light Transverse Brooming	7.5	3.5
B	1" Wirand Concrete - Mix 4	Light Transverse Brooming	7.5	3.5
C	3" Wirand Concrete - Mix 5	Plastic Grooving	7.5	3.5
0-2bA	1" Polymer Concrete	Hand Trowelled Finish	11.0	3.5
B	1/4" Polymer Concrete	Hand Trowelled Finish	11.0	3.5
0-3a	Class "E" A.C.	Rolled Finish	22.0	3.5
b	Class "E" A.C. Gilsabind	Rolled Finish	22.0	3.5
0-4a	Class "B" A.C.	Rolled Finish	22.0	3.5
b	Class "B" A.C. Gilsabind	Rolled Finish	22.0	3.5
0-5a	Class "G" A.C.	Rolled Finish	22.0	3.5
b	Class "G" A.C.	Rolled Finish	22.0	3.5
0-6a	Idaho Chip Seal - Cl "B" A.C.	Rolled Finish	22.0	3.5
b	Idaho Chip Seal - Cl "B" A.C.	Rolled Finish	22.0	3.5

20 DIFFERENT SECTIONS

TABLE 1

RING #5 - TYPES OF SECTIONS AS BUILT

Types of Pavement Materials & Textures - Center Track

Section	Type	Texture	Dimensions - Ft.	
			Length	Width
C-1a	Portland Cement Concrete--Reinforced	Heavy Longitudinal Brooming	21	3.0
b	" " "	Light Transverse Brooming	21	3.0
C-2a	Portland Cement Concrete--Reinforced	Heavy Transverse Brooming	21	3.0
b	" " "	Burlap	21	3.0
C-3a	Portland Cement Concrete--Reinforced	Longitudinal Grooving	21	3.0
b	" " "	Light Longitudinal Brooming	21	3.0
C-4a	Portland Cement Concrete--Reinforced	Transverse Grooving	21	3.0
b	" " "	Light Transverse Brooming	21	3.0
C-5a	Portland Cement Concrete--Reinforced	Light Plastic Grooving	21	3.0
b	" " "	Light Plastic Grooving	21	3.0
C-6a	Portland Cement Concrete--Reinforced	Medium Longitudinal Brooming	21	3.0
b	" " "	Light Longitudinal Brooming	21	3.0

12 DIFFERENT SECTIONS

TABLE 1

RING #5 - TYPES OF SECTIONS AS BUILT

Types of Pavement Materials & Textures - Inside Track

Section	Type	Texture	Dimensions-Ft.	
			Length	Width
I-1a	Portland Cement Concrete	Heavy Longitudinal Grooving	20	3.5
b	Portland Cement Concrete	Heavy Longitudinal Grooving	20	3.5
I-2aA	1/8" Poly. Cement Conc.-Mix 1	Hand Trowelled	10	3.5
aB	1/8" Poly. Flyash Conc.-Mix 2	Hand Trowelled	10	3.5
bA	1/8" Poly. Flyash Conc.-Mix 2	Hand Trowelled	10	3.5
bB	1/8" Poly. Cement Conc.-Mix 1	Hand Trowelled	10	3.5
I-3a	Class "E" A.C.	Rolled Finish	20	3.5
b	Class "E" A.C.	Rolled Finish	20	3.5
I-4a	Class "B" A.C.	Rolled Finish	20	3.5
b	Class "B" A.C.	Rolled Finish	20	3.5
I-5a	Class "G" A.C.	Rolled Finish	20	3.5
b	Class "G" A.C.	Rolled Finish	20	3.5
I-6a	Idaho Chip Seal-Cl "B" A.C.	Rolled Finish	20	3.5
b	Idaho Chip Seal-Cl "B" A.C.	Rolled Finish	20	3.5

14 DIFFERENT SECTIONS

46 DIFFERENT SECTIONS

TABLE 2

HIGH, LOW AND AVERAGE AMBIENT TEMPERATURES*

Month '72	Ambient Temperature °F		Average Ambient Temperature °F	
	Maximum	Minimum	Maximum	Minimum
February	56	-4	38.8	27.6
March	66	28	49.6	35.0
April	70	27	51.2	34.0

*Palouse Conservation Field Station

TABLE 3

STUD PROTRUSIONS FOR DIFFERENT STUDS AND

CORRESPONDING TREAD DEPTH

Arm	Wheel Path	Type		Stud Protrusion - inch			Tread Depth - 1/32 inch		
		Tire	Stud	Initial	Final	Average	Initial	Final	Average
1	3	Passenger	#2	0.040	0.040	0.040	16.9	13.2	15.1
	4	Passenger	#3	0.071	0.073	0.072	16.3	11.8	14.1
	5	Truck	No Studs	-	-	-	16.7	10.0	13.4
	6	Truck	#3	0.040	0.037	0.038	17.8	15.6	16.7
	7	Passenger	#1	0.038	0.116	0.077	16.7	14.7	15.7
	8	Passenger	No Studs	-	-	-	16.8	15.3	16.1
2	1	Passenger	No Studs	-	-	-	16.7	13.6	15.2
	2	Passenger	#1	0.048	0.108	0.078	16.3	9.7	13.0
	5	Truck	No Studs	-	-	-	16.7	9.0	12.9
	6	Truck	#3	0.041	0.038	0.039	17.7	14.7	16.2
	7	Passenger	#1	0.040	0.082	0.061	16.9	13.5	15.2
	8	Passenger	No Studs	-	-	-	16.8	15.1	16.0
3	5	Truck	No Studs	-	-	-	16.3	10.6	13.5
	6	Truck	#3	0.032	0.025	0.028	18.1	16.0	17.1
	7	Passenger	#1	0.038	0.097	0.052	16.6	13.8	15.2
	8	Passenger	No Studs	-	-	-	17.1	15.2	16.2

TABLE 4

SKID RESISTANCE VALUES ON OUTSIDE TRACK

Section	Type	0[1]	180,000			
		All[8]	WP #1[2]	WP #2[3]	WP #3[4]	WP #4[5]
0-1aA	2.0" Poly. Conc.	45	--	48[6]	--	--
B	2.0" Poly. Conc.	45	--	43[6]	--	--
C	2.0" Poly. Conc.	44	--	40[6]	--	--
0-1bA	1/2" Wirand Conc.	45	35[7]	32[7]	34[7]	34[7]
B	1/2" Wirand Conc.	43	31[7]	29[7]	25[7]	31[7]
C	1/2" Wirand Conc.	43	30[7]	30[7]	27[7]	29[7]
D	1/2" Wirand Conc.	45	36[7]	31[7]	32[7]	36[7]
0-2aA	1" Wirand Conc.	44	38[7]	39[7]	35[7]	31[7]
B	1" Wirand Conc.	46	39[7]	36[7]	33[7]	34[7]
C	3" Wirand Conc.	46	43[7]	30[7]	29[7]	32[7]
0-2bA	1" Poly. Conc.	40	31	19	18	22
B	1/4" Poly. Conc.	38	29	13	13	13
0-3a	Cl "E" A.C.	42	28	31	17	25
b	Cl "E" Gilsabind	35	31	24	32	35
0-4a	Cl "B" A.C.	40	20	28	25	25
b	Cl "B" Gilsabind	26	19	21	24	30
0-5a	Cl "G" A.C.	40	31	27	21	29
b	Cl "G" A.C.	38	29	36	34	26
0-6a	Idaho Chip Seal	39	--	21	23	--
b	Idaho Chip Seal	34	--	21	23	--

[1]Wheel passes--passenger tires

[2]Unstudded

[3]Type 1

[4]Type 2

[5]Type 3

[6]Taken at 27,000 wheel passes.

[7]Taken at 73,000 wheel passes

[8]Values obtained prior to testing

TABLE 5

SKID RESISTANCE VALUES ON CENTER TRACK

Section	Type	Surface Texture	0[1]	540,000[1]	
			All[4]	WP #5[2]	WP #6[3]
C-1a	PCC	Heavy Long. Brooming	52	36	21
b	PCC	Light Transverse Brooming	45	39	23
C-2a	PCC	Heavy Transverse Brooming	58	33	17
b	PCC	Burlap	50	26	15
C-3a	PCC	Longitudinal Grooving	38	28	14
b	PCC	Light Long. Brooming	53	37	15
C-4a	PCC	Transverse Grooving	48	32	16
b	PCC	Light Transverse Grooving	46	33	15
C-5a	PCC	Light Plastic Grooving	38	26	14
b	PCC	Light Plastic Grooving	33	25	13
C-6a	PCC	Med. Long. Brooming	43	15	35
b	PCC	Light Long. Brooming	45	31	17

[1]Wheel passes
[2]Unstudded truck tires
[3]Type 3 studded truck tires
[4]Values obtained prior to testing

TABLE 6

SKID RESISTANCE VALUES ON INSIDE TRACK

Section	Type	0[1]	540,000[1]	
		All[4]	WP #7[2]	WP #8[3]
I-1a	PCC Heavy Long. Grooving	47	24	33
b	PCC Heavy Long. Grooving	37	25	30
I-2aA	1/8" Poly. Cement	41	15	30
aB	1/8" Poly. Flyash	25	14	21
bA	1/8" Poly. Flyash	23	12	29
bB	1/8" Poly. Cement	25	14	26
I-3a	Class "E" A.C.	36	25	31
b	Class "E" A.C.	43	27	37
I-4a	Class "B" A.C.	39	25	32
b	Class "B" A.C.	45	15	31
I-5a	Class "G" A.C.	34	32	30
b	Class "G" A.C.	44	16	37
I-6a	Idaho Chip Seal	37	27	34
b	Idaho Chip Seal	37	27	38

[1] Wheel Passes--passenger tires

[2] Type 1 Studs

[3] Unstudded

[4] Values obtained prior to testing

TABLE 7

COMPARATIVE PAVEMENT WEAR*

Section	Pavement Type	Percentage Wear[1] and Wear Ratio[2] With Respect to Type 3 Studs							
		WP #1 No Studs		WP #2 Type #1		WP #3 Type #2		WP #3 Type #3	
		P.W.[1]	W.R.[2]	P.W.[1]	W.R.[2]	P.W.[1]	W.R.[2]	P.W.[1]	W.R.[2]
0-1bA	1/2" Wirand Concrete	5.3	19.0	79.0	1.2	36.9	2.7	100	1
B	1/2" Wirand Concrete	6.2	16.0	68.7	1.4	37.5	2.7	100	1
C	1/2" Wirand Concrete	6.9	14.5	96.6	1.0	48.3	2.1	100	1
D	1/2" Wirand Concrete	12.5	8.0	84.4	1.2	40.7	2.5	100	1
0-2aA	1" Wirand Concrete	11.1	9.0	91.8	1.1	38.9	2.6	100	1
B	1" Wirand Concrete	12.5	8.0	72.5	1.4	37.5	2.7	100	1
C	3" Wirand Concrete	12.5	8.0	93.8	1.1	118.8	0.8	100	1
0-2bA	1" Polymer Concrete	12.5	8.0	112.5	0.9	62.5	1.6	100	1
B	1/4" Polymer Conc.	25.0	4.0	70.0	1.4	90.0	1.1	100	1
0-3a	Cl "E" A.C.	4.8	21.0	83.4	1.2	47.7	2.1	100	1
b	Cl "E" A.C. Gilsabind	4.9	20.5	68.2	1.5	41.5	2.4	100	1
0-4a	Cl "B" A.C.	4.1	24.5	89.7	1.1	38.8	2.6	100	1
b	Cl "B" A.C. Gilsabind	5.1	19.5	74.4	1.3	38.5	2.6	100	1
0-5a	Cl "G" A.C.	5.3	19.0	81.7	1.2	47.4	2.1	100	1
b	Cl "G" A.C.	3.3	30.5	49.2	2.0	31.2	3.2	100	1
0-6a	Idaho Chip Seal	-	-	-	-	-	-	-	-
b	Idaho Chip Seal	-	-	-	-	-	-	-	-

*Passenger tires

[1] Percentage Wear (P.W.) = $\frac{\text{Stud Type y Wear}}{\text{Stud Type 3 Wear}}$

[2] Wear Ratio (W.R.) = $\frac{100}{\text{Percentage Wear}}$

TABLE 8

FINAL MAXIMUM RUT DEPTH VIA STRAIGHT EDGE - OUTSIDE TRACK*

Section	Type	Type 1 WP #2	Type 2 WP #3	Type 3 WP #4
0-1bA	1/2" Wirand Concrete	0.30	0.13	0.38
B	1/2" Wirand Concrete	0.27	0.15	0.38
C	1/2" Wirand Concrete	0.23	0.13	0.33
D	1/2" Wirand Concrete	0.25	0.15	0.29
0-2aA	1" Wirand Concrete	0.31	0.29	0.35
B	1" Wirand Concrete	0.29	0.13	0.35
C	3" Wirand Concrete	0.21	0.19	0.21
0-2bA	1" Polymer Concrete	0.30	0.19	0.42
B	1/4" Polymer Concrete	0.23	0.19	0.21
0-3a	Cl "E" A.C.	0.36	0.26	0.46
b	Cl "E" A.C. Gilsabind	0.36	0.26	0.46
0-4a	Cl "B" A.C.	0.45	0.20	0.45
b	Cl "B" A.C. Gilsabind	0.39	0.25	0.44
0-5a	Cl "G" A.C.	0.39	0.24	0.49
b	Cl "G" A.C.	0.43	0.29	0.58
0-6a	Idaho Chip Seal	-	-	-
b	Idaho Chip Seal	-	-	-

*After 542,357 wheel passes -- passenger tires

TABLE 9

FINAL MAXIMUM RUT DEPTH VIA STRAIGHT EDGE - CENTER & INSIDE TRACKS

CENTER TRACK*			INSIDE TRACK**		
Section	Type of Material	Type 3 WP #6	Section	Type of Material	Type 1 WP #7
C-1a	Portland Cement Concrete	0.26	I-1a	Portland Cement Concrete	0.30
b	Portland Cement Concrete	0.25	b	Portland Cement Concrete	0.39
C-2a	Portland Cement Concrete	0.25	I-2aA	1/8" Polymer Concrete	0.27
b	Portland Cement Concrete	0.20	2aB	1/8" Polymer Flyash	0.25
C-3a	Portland Cement Concrete	0.30	2bA	1/8" Polymer Flyash	0.17
b	Portland Cement Concrete	0.20	2bB	1/8" Polymer Cement	0.25
C-4a	Portland Cement Concrete	0.26	I-3a	Cl "E" A.C.	0.80
b	Portland Cement Concrete	0.23	b	Cl "E" A.C.	0.83
C-5a	Portland Cement Concrete	0.24	I-4a	Cl "B" A.C.	0.84
b	Portland Cement Concrete	0.26	b	Cl "B" A.C.	0.81
C-6a	Portland Cement Concrete	0.23	I-5a	Cl "G" A.C.	0.98
b	Portland Cement Concrete	0.23	b	Cl "G" A.C.	0.98
			I-6a	Idaho Chip Seal	-
			b	Idaho Chip Seal	-

*After 1,396,935 wheel passes-- truck tires
**After 1,627,071 wheel passes-- passenger tires

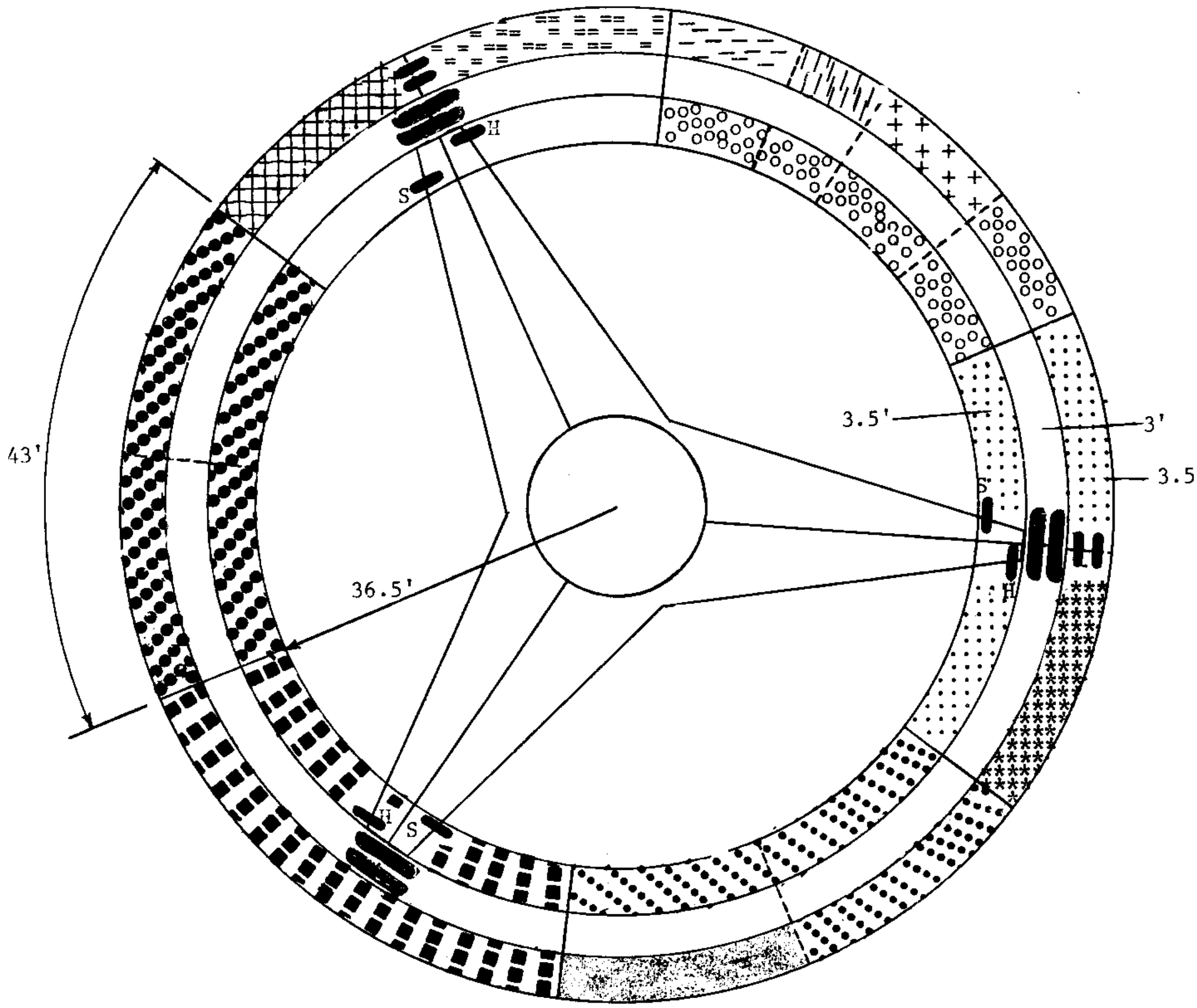
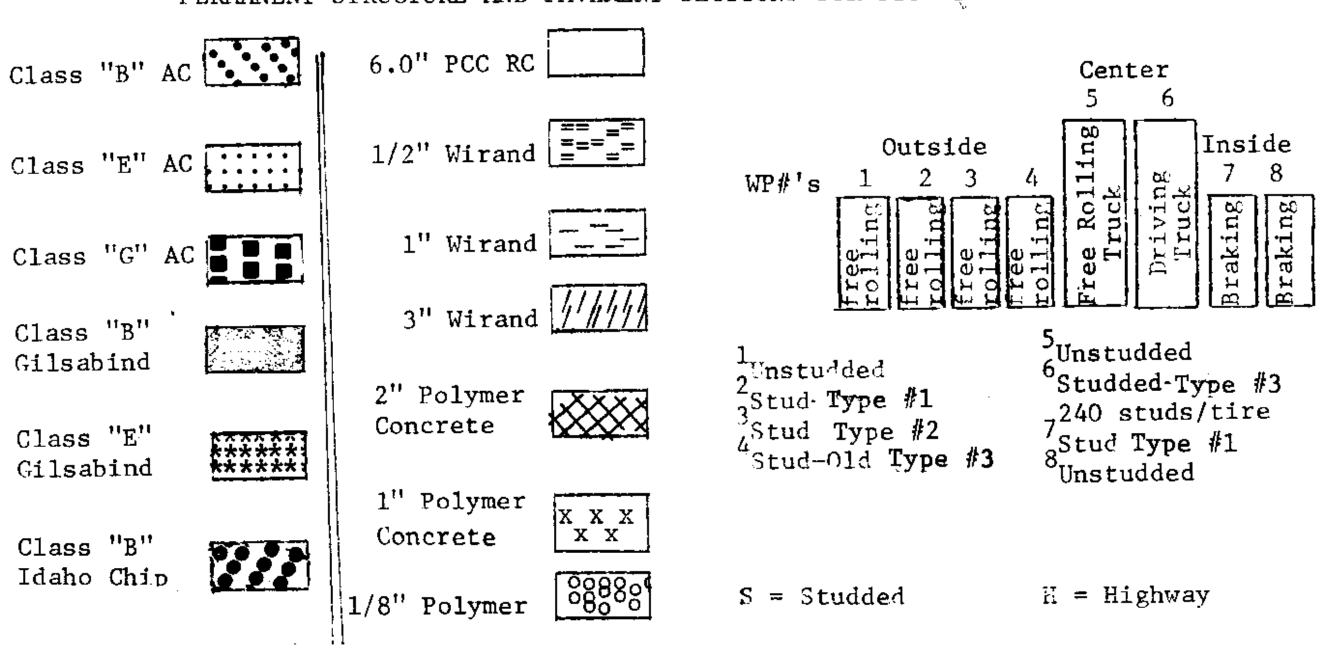


FIGURE 1 Not Drawn to Scale
PLAN VIEW OF
PERMANENT STRUCTURE AND PAVEMENT SECTIONS FOR STUDDED TIRE STUDY



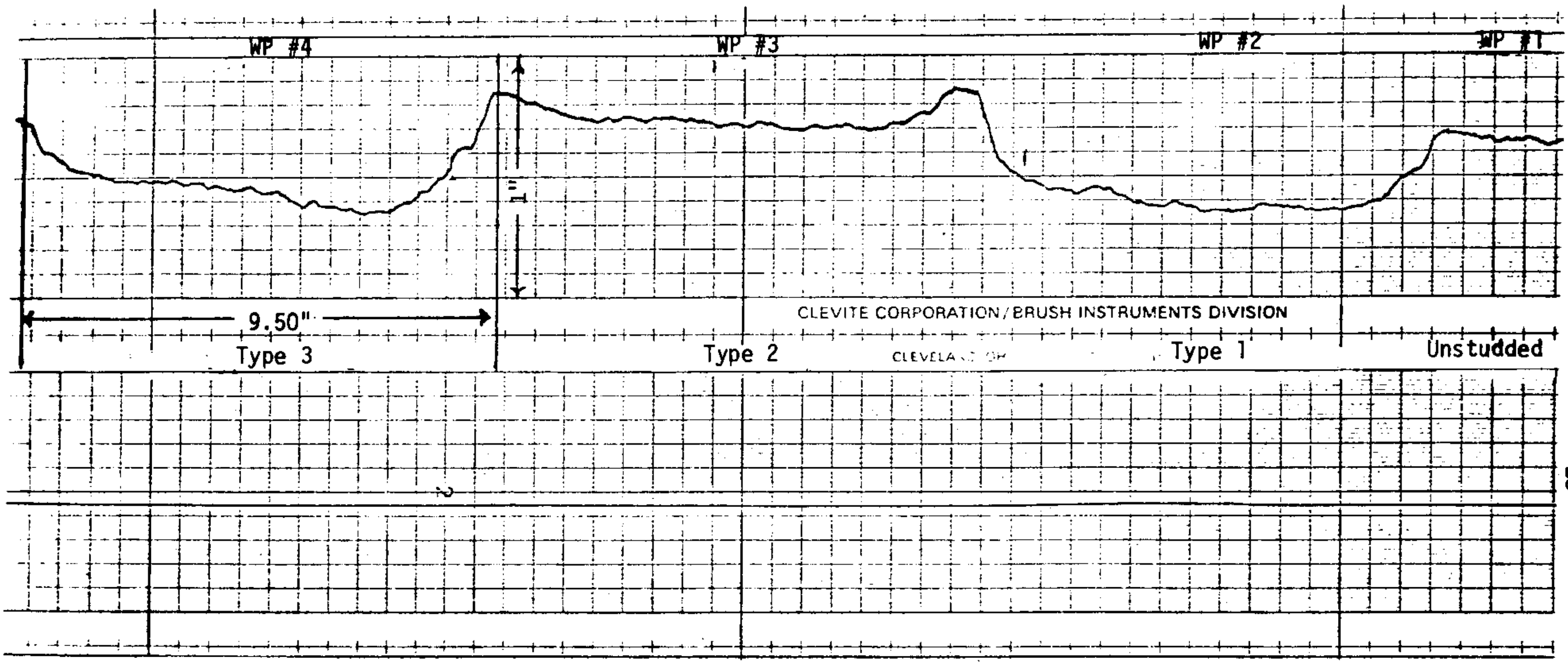


Figure 2. A Typical Chart Obtained from WSU Profilometer
Section 0-4a: Class "B" Asphalt Concrete
528,000 Wheel Passes - Outside Track

Horizontal scale compressed
Vertical scale expanded

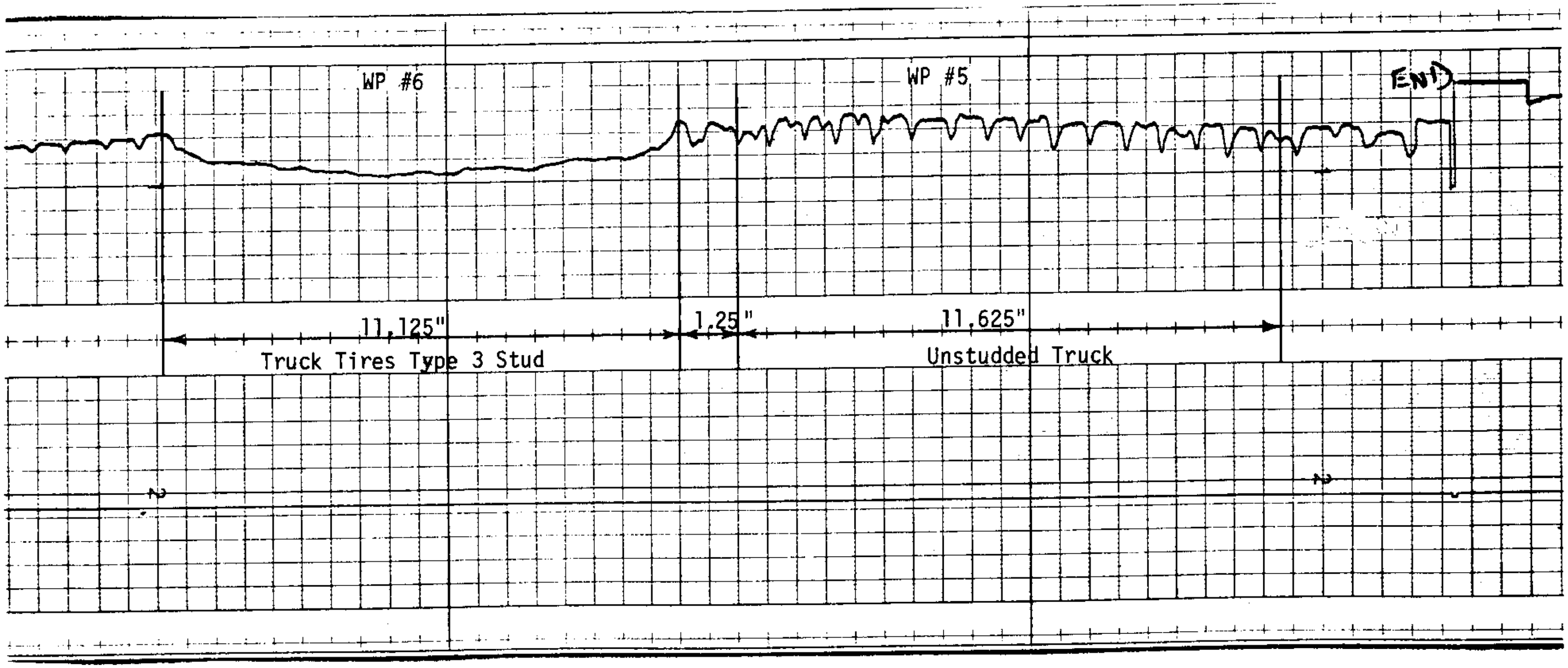


Figure 3. A Typical Chart Obtained from WSU Profilometer
Section: C-3a: Portland Cement Concrete with Plastic Longitudinal Grooving Texture

Horizontal Scale Compressed
Vertical Scale Expanded

1,368,421 Wheel Passes - WP #6
1,568,421 Wheel Passes - WP #5
Center Track

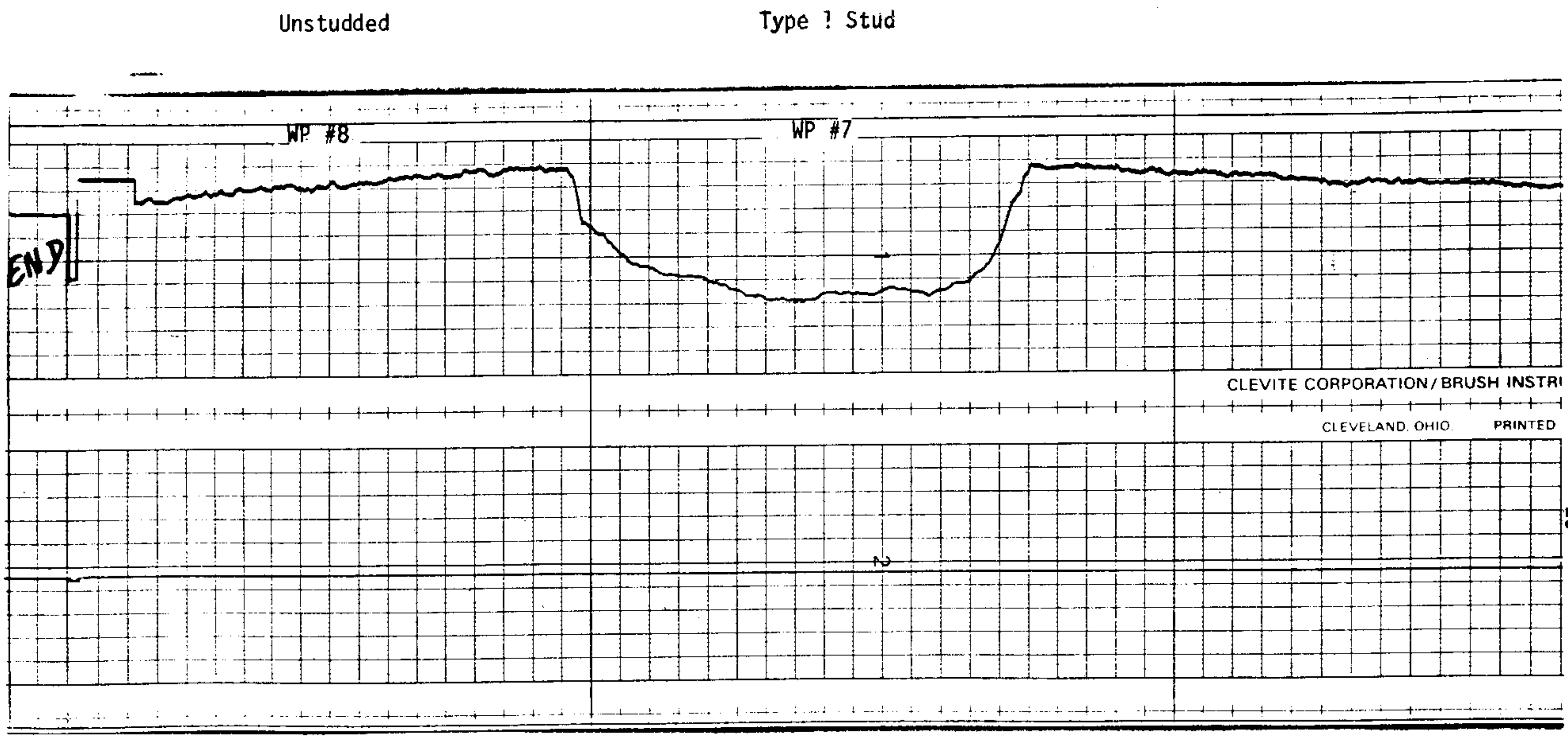
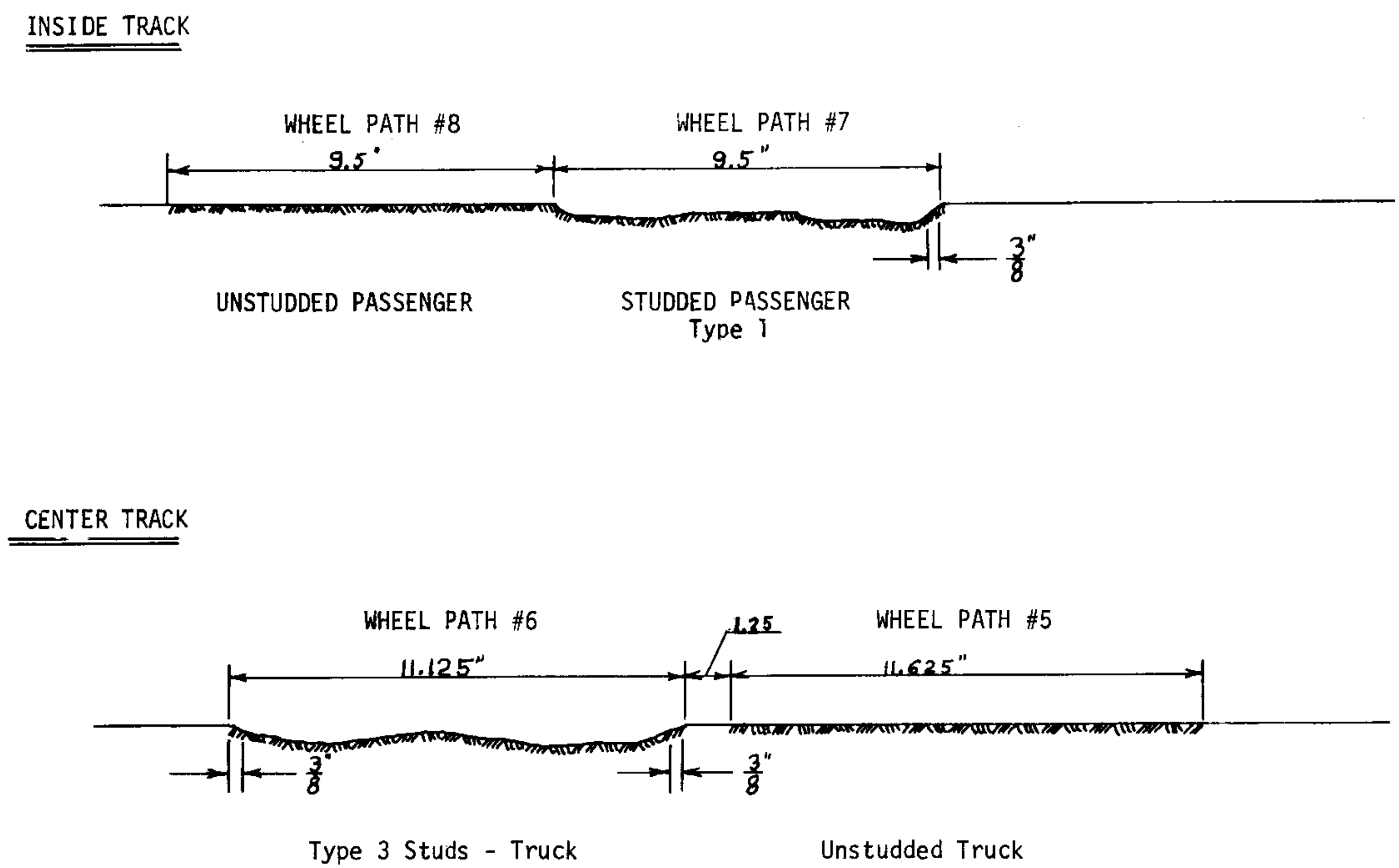


Figure 4. A Typical Chart Obtained from WSU Profilometer
Section I-4a: Class "B" Asphalt Concrete
1,584,300 wheel passes - Inside Track

Horizontal scale compressed
Vertical scale expanded

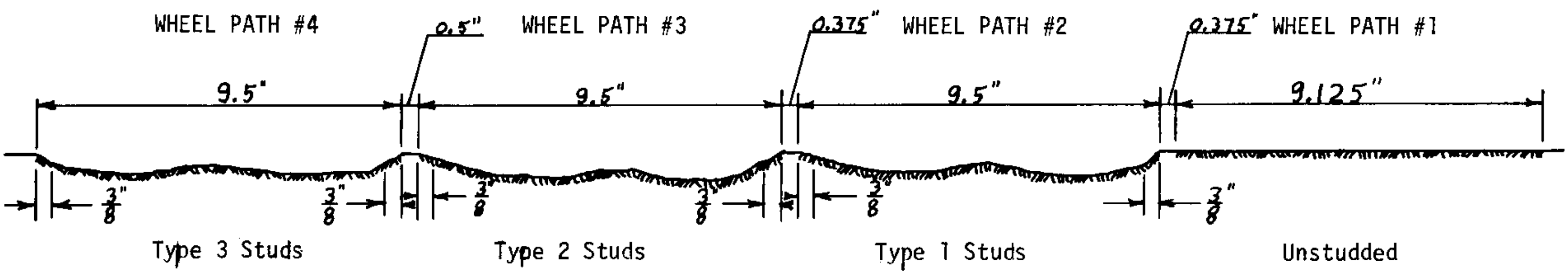


SCALE

Horizontal - 1" = 4.0"
No Vertical (No relation of depth to stud type or number of passes is implied.)

Figure 5. Actual Widths of Wheel Paths at WSU Test Track
Eccentricity = 1.75 inches
Ring #5

OUTSIDE TRACK



SCALE

Horizontal 1" = 4.0"
No Vertical (No relation of depth to stud type or number of passes is implied.)

Figure 6. Actual Widths of Wheel Paths at WSU Test Track
Eccentricity = 1.75"
Ring #5 - 112,000 revolutions

Figure 7

RING #5 - WSU STUDDED TIRE WEAR

Comparison of Max. Rut Depth with Different Pavement Types

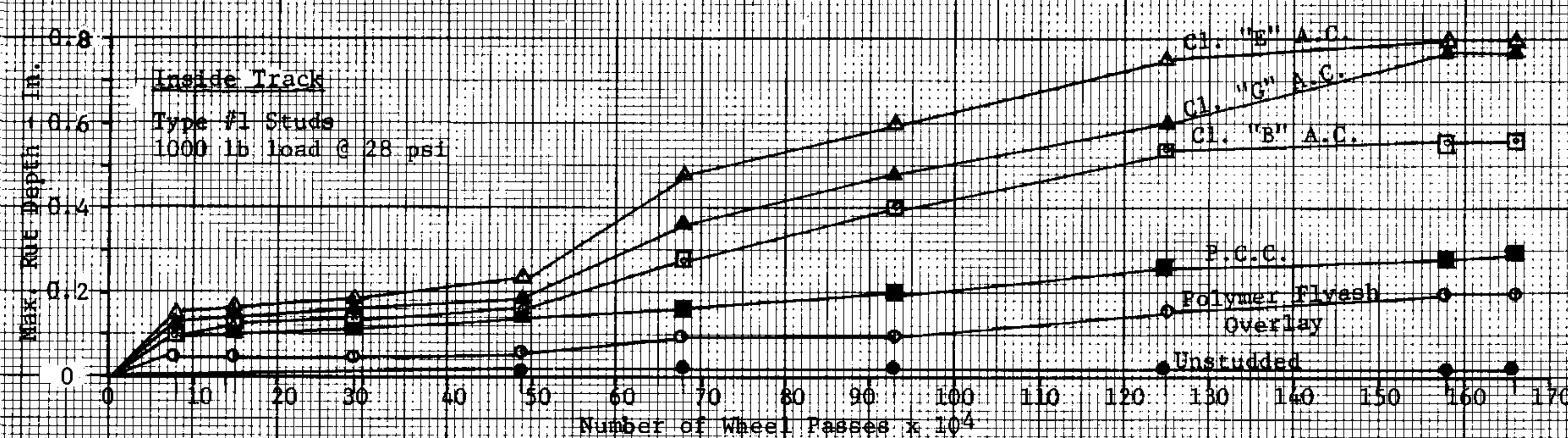


Figure 8

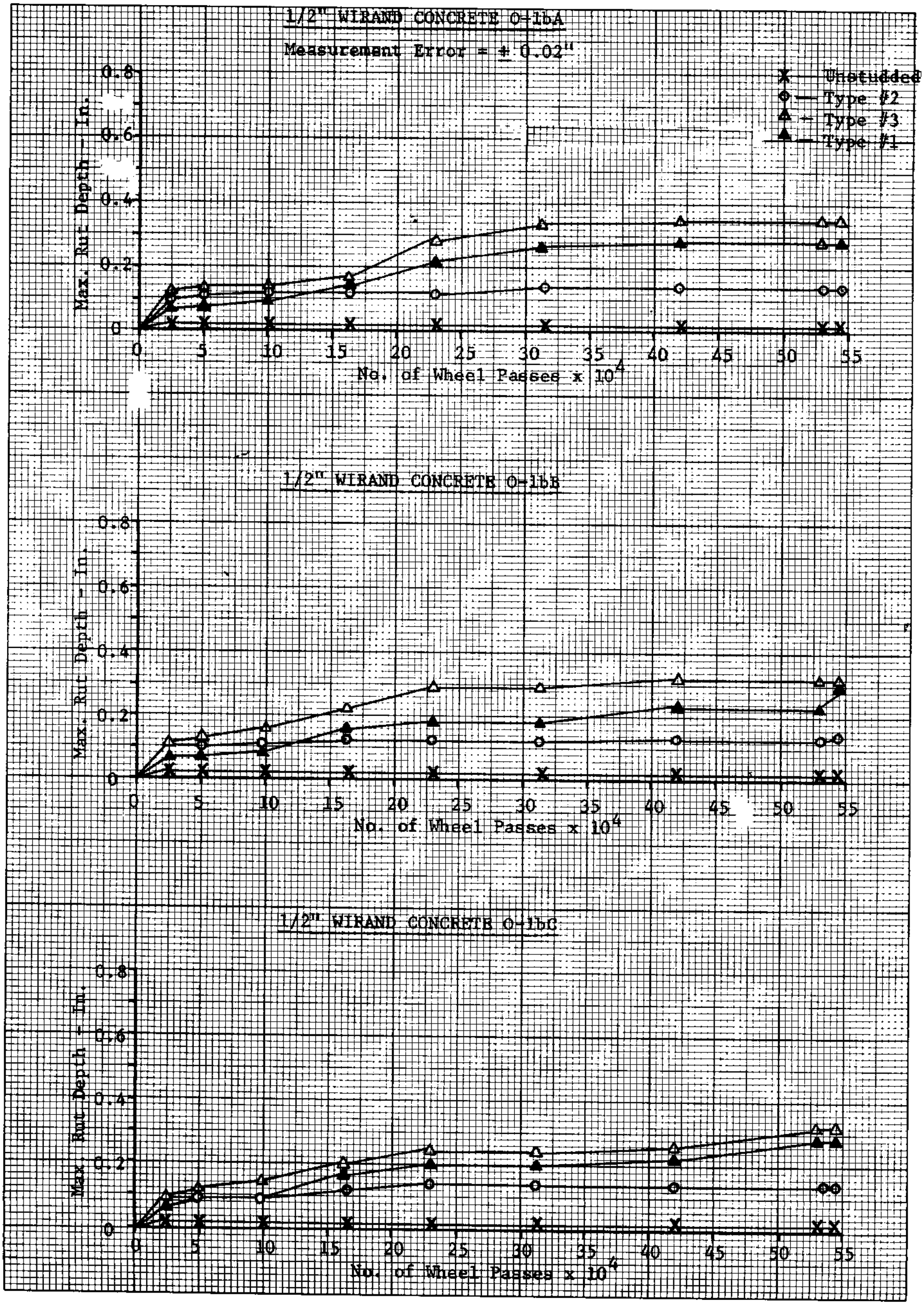

1/2" WIRAND CONCRETE O-1bA
Measurement Error = ± 0.02"
Unstudded
Type #2
Type #3
Type #1
Max. Rut Depth - In.
No. of Wheel Passes x 10^4
1/2" WIRAND CONCRETE O-1bB
Max. Rut Depth - In.
No. of Wheel Passes x 10^4
1/2" WIRAND CONCRETE O-1bC
Max. Rut Depth - In.
No. of Wheel Passes x 10^4

Figure 9

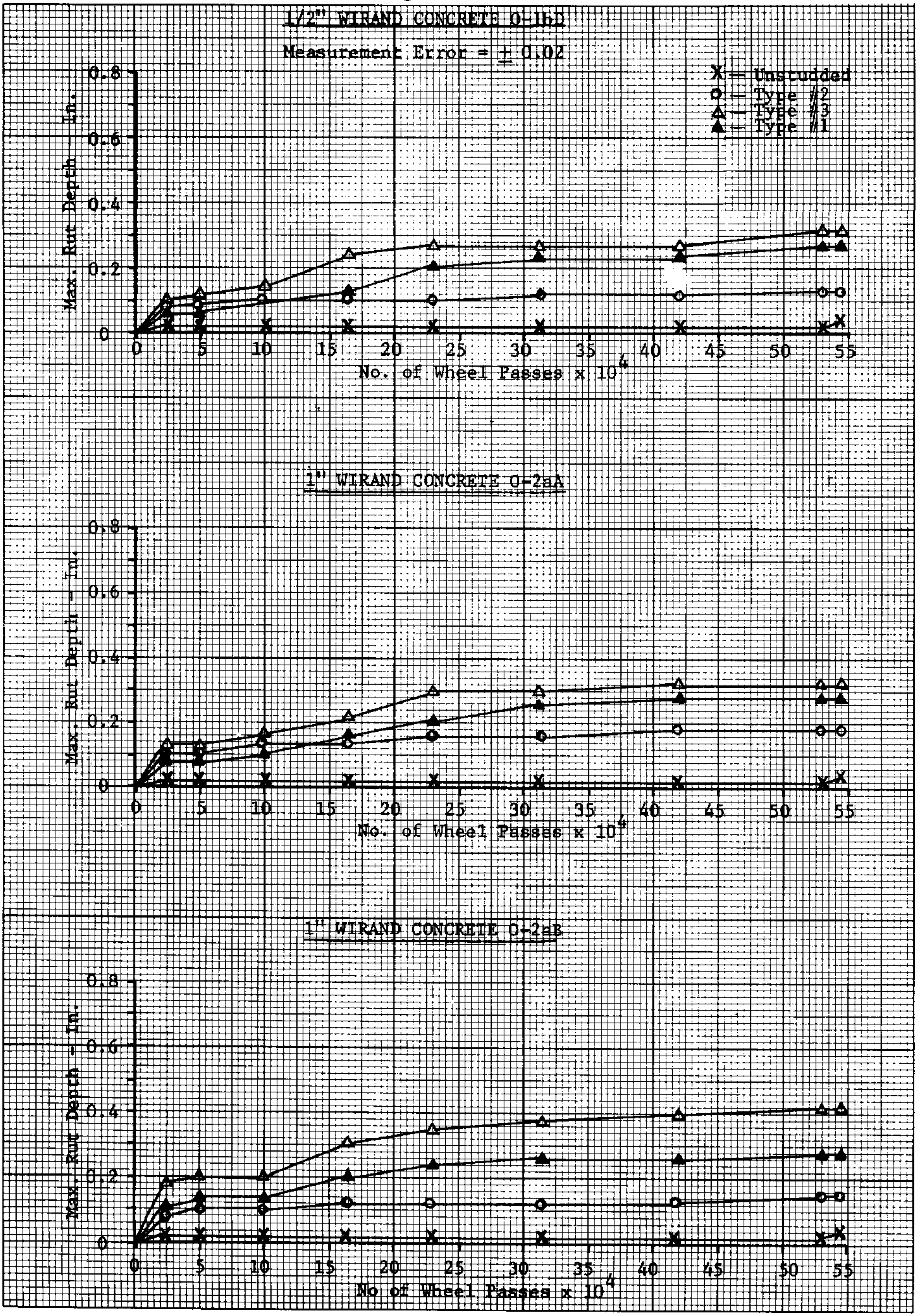

1/2" WIRAND CONCRETE O-1bD
Measurement Error = ± 0.02
X — Unstudded
o — Type #2
△ — Type #3
▲ — Type #1
Max. Rut Depth - In.
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
40
45
50
55
No. of Wheel Passes x 10^4
1" WIRAND CONCRETE O-2aA
Max. Rut Depth - In.
No. of Wheel Passes x 10^4
1" WIRAND CONCRETE O-2aB
Max. Rut Depth - In.
No of Wheel Passes x 10^4

Figure 10

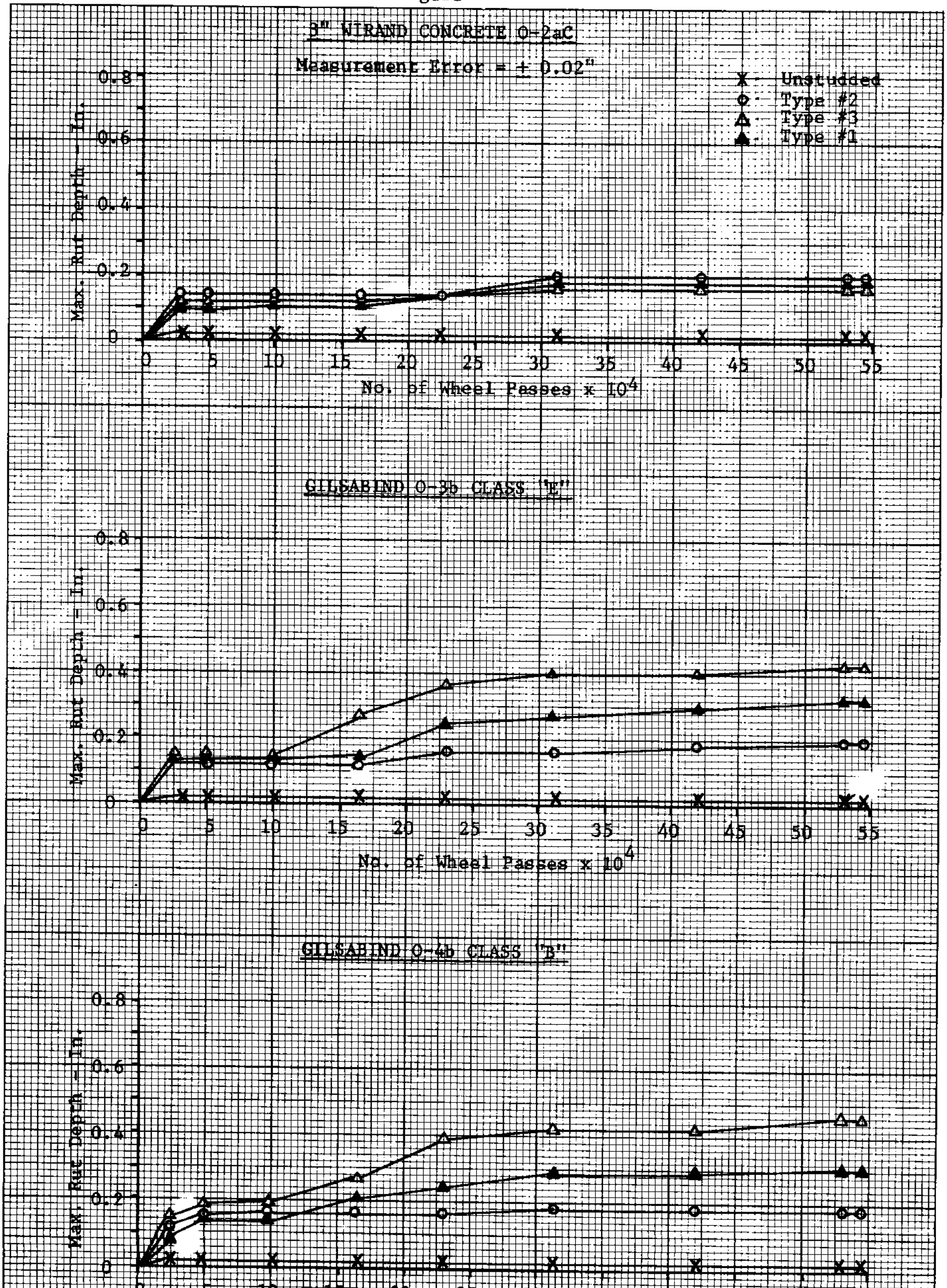
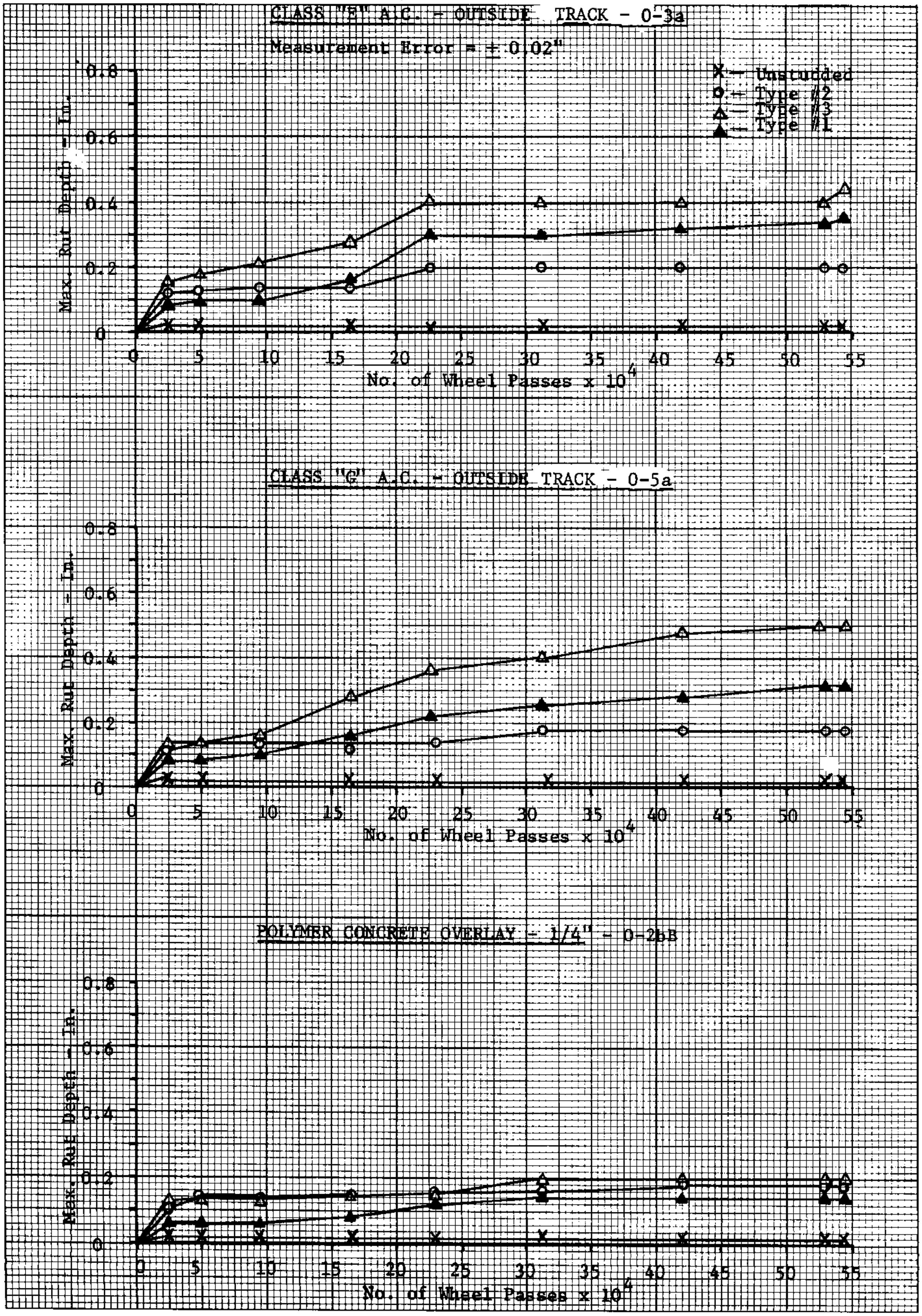

3" WIRAND CONCRETE 0-2aC
Measurement Error = ± 0.02"
X - Unstudded
O - Type #2
△ - Type #3
▲ - Type #1
Max. Rut Depth - In.
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
40
45
50
55
No. of Wheel Passes x 10^4
GILSABIND 0-3b CLASS "E"
Max. Rut Depth - In.
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
40
45
50
55
No. of Wheel Passes x 10^4
GILSABIND 0-4b CLASS "B"
Max. Rut Depth - In.
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
40
45
50
55
No. of Wheel Passes x 10^4

Figure 11


CLASS "E" A.C. - OUTSIDE TRACK - 0-3a
Measurement Error = ± 0.02"
X — Unstudded
o — Type #2
△ — Type #3
▲ — Type #1
Max. Rut Depth - In.
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
40
45
50
55
No. of Wheel Passes x 10^4
CLASS "G" A.C. - OUTSIDE TRACK - 0-5a
Max. Rut Depth - In.
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
40
45
50
55
No. of Wheel Passes x 10^4
POLYMER CONCRETE OVERLAY - 1/4" - 0-2bB
Max. Rut Depth - In.
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
40
45
50
55
No. of Wheel Passes x 10^4