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POST MORTEM INVESTIGATION OF THE KANSAS TEST TRACK

NOVEMBER 1979
FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
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16. Abstract

The Kansas Test Track (KTT) was comprised of nine different track systems, which were founded on a designed embankment. The KTT subgrade experienced premature failure in service, and KTT operations were terminated in June 1975 after approximately six months of traffic.

A postmortem investigation of the KTT was carried out in 1975 and 1976. Results of this investigation are presented in two volumes. Summary data, analyses, conclusions, and recommendations are presented in Volume I. Volume II is comprised of five appendixes which document the equipment and procedure used, and data obtained in KTT structures, vibroseismic, penetrometer, trenching, and instrumentation testing.

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PREFACE

This study was authorized by the Department of Transportation (DOT) Federal Railroad Administration (FRA) under Interagency Agreement AR 30025, dated 12 December 1972, and Amendments 3-8 thereto. The work was performed by personnel of the U. S. Army Engineer Waterways Experiment Station (WES), P. O. Box 631, Vicksburg, Mississippi 39180. Dr. R. M. McCafferty of the Office of Rail Safety Research, FRA, monitored the project.

Mr. A. J. Bush III, Pavement Evaluation Branch, Geotechnical Laboratory (GL), carried out the field and laboratory trenching study. Mr. H. C. Greer, Instrumentation Services Division, was responsible for the instrumentation investigation, and Mr. M. A. Vispi, Explorations Branch, GL, accomplished the penetrometer testing. Mr. M. M. Carlson conducted the vibroseismic testing. Mr. S. S. Cooper, Geodynamics Branch (GDB), Earthquake Engineering and Vibrations Division (EE&VD), directed the investigation and prepared this report under the supervision of Mr. R. F. Ballard, Chief, GDB, and Messrs. P. F. Hadala and F. G. McLean, Chief and former Chief, respectively, of EE&VD. The work was performed under the general supervision of Mr. J. P. Sale, Chief, GL.

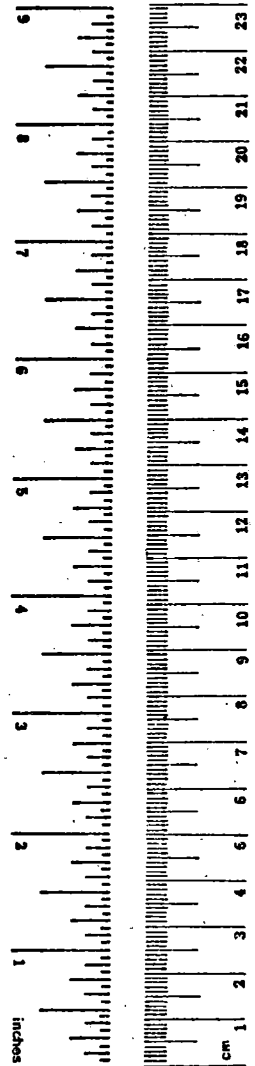
COL G. H. Hilt, CE, and COL J. L. Cannon, CE, were Directors of the WES during this study. Mr. F. R. Brown was Technical Director.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

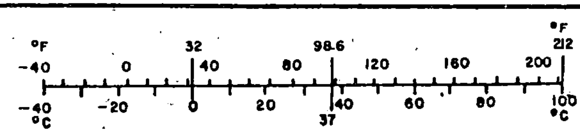


TABLE OF CONTENTS

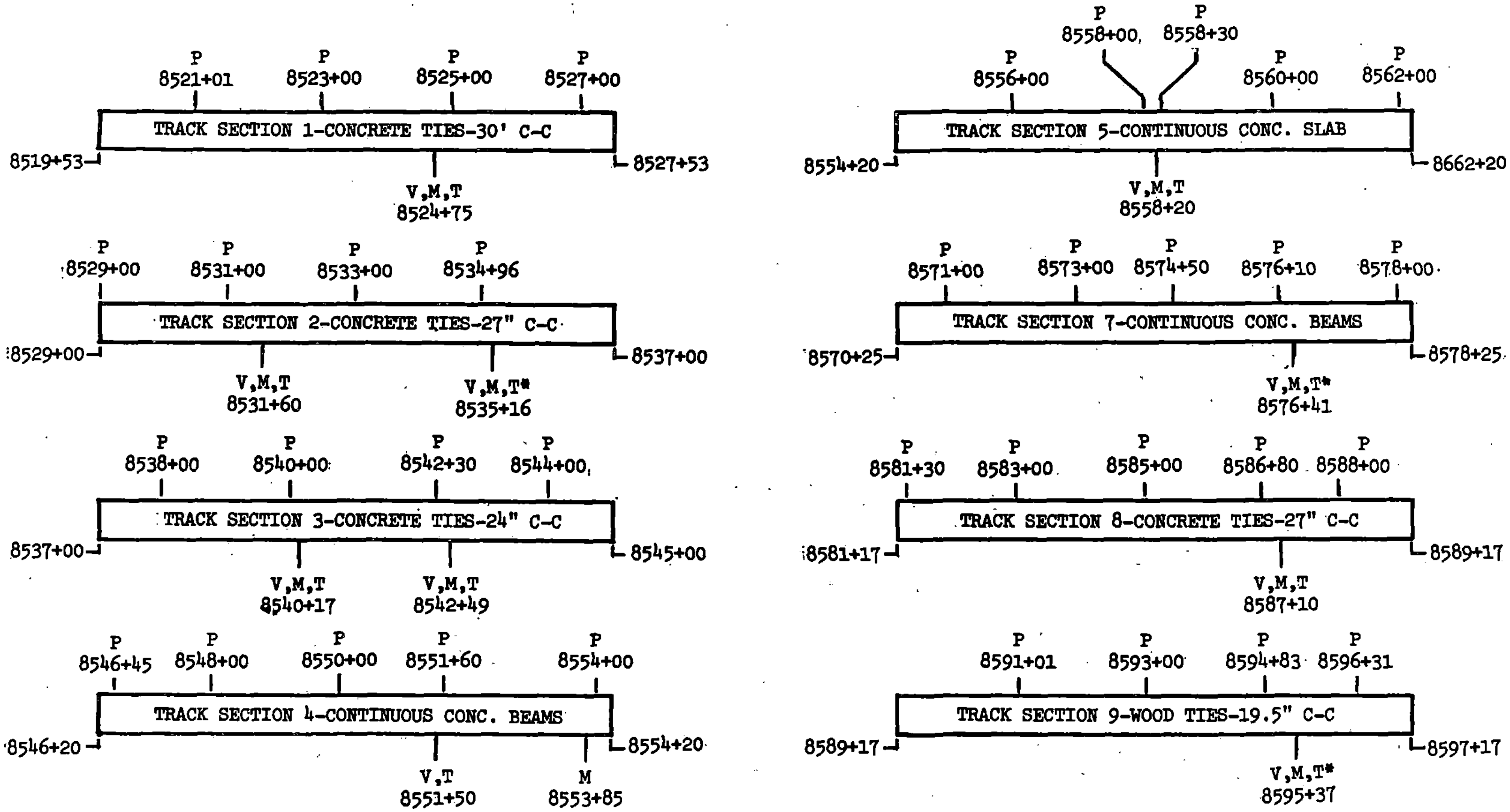
LIST OF TABLES

LIST OF FIGURES

POSTMORTEM INVESTIGATION OF THE KANSAS TEST TRACK, VOLUME II

INTRODUCTION

In consideration of the quantity of data and information generated in KTT Postmortem Investigation, results are presented in two volumes. Volume I describes the postmortem test plan, summarizes results of the field and laboratory tests conducted, and presents analyses, conclusions, and recommendations derived from the test results. Volume II provides detailed descriptions of test equipment and procedures used in the investigation and also documents the original data. Volume II consists of five appendixes, A-E, which refer to the text in Volume I and document the structures, vibroseismic, Dutch cone penetrometer, trenching, and instrumentation studies, respectively. A summary of the U. S. Army Engineer Waterways Experiment Station (WES) test plan is presented in Figure 1 to assist the reader in identifying test locations with in the KTT.



LEGEND

SYMBOL	DESCRIPTION
P	LOCATION OF DUTCH CONE PENETROMETER TEST
V	LOCATION OF VIBROSEISMIC TEST
M	LOCATION OF MECHANICAL IMPEDANCE TEST
T	LOCATION OF TEST TRENCH IN EMBANKMENT
*	LOCATION OF MAIN (BUILT-IN) INSTRUMENTATION ARRAY

FIGURE 1. GRAPHICAL SUMMARY OF WES TEST PLAN

APPENDIX A: STRUCTURES TESTING

General

The Kansas Test Track (KTT) Phase I Postmortem Investigations requested by the Department of Transportation (DOT) were conducted by a U. S. Army Engineer Waterways Experiment Station (WES) field party at the KTT in the period from 15 October - 17 November 1975. The sequence and timing of the various investigations conformed closely to the timetable developed by WES in joint planning with DOT and associated participants. This timetable, which was furnished to all interested parties before field operations commenced, is shown in Figure A-1. Essentially, Phase I field operations included dynamic and static testing to provide data to validate and tune MITRE Corporation analytical models, as well as posttraffic impedance studies of selected track sections. Selection of test locations within the track sections of interest was based on performance summary charts developed by WES from maintenance records furnished by the Atchinson, Topeka, and Santa Fe Railroad (AT&SF) and from an on-site reconnaissance trip performed in late September 1975.

The WES field crew, which consisted of a project engineer and two technicians in the early part of the field operations, was augmented by two WES instrumentation specialists who provided the required expertise in strain gaging and signal conditioning for dynamic testing and data acquisition. The various phases of the investigation were coordinated with AT&SF representatives at the KTT. It should be noted that the decision rendered in the early September meeting at DOT to conduct the balance of the Postmortem Investigation in the spring of 1976 was a sound one because the deterioration in weather conditions after 17 November and other considerations would certainly have prevented completion of the remaining (Phase II) work during the winter season of 1975. A discussion of the structures testing conducted in Phase I is presented in subsequent paragraphs.

Dynamic Testing

The WES project engineer in charge of field operations arrived at the KTT on 15 October 1975. Watering (for the purpose of inducing a pumping condition) on the track sections selected for impedance testing had already commenced. The track was inspected and the timetable for field operations was confirmed in detail. At this time the test locations had already received approximately 4000 gal* of water in 1000-gal increments. Installation of nine vertical (absolute) reference rods was begun on 16 October and was completed 18 October. Details of this installation are shown in Figures A-2 and A-3. During the installation process on 17 October, free water was encountered at the base of Beam 16 (Track Section 4); hence, watering at the impedance test location in Track Section 4 (sta 8546+95) was suspended. Apparently, the water applied to the impedance test location had migrated along the track structure to the structures test location at Beams 14-18 of Track Section 4; this was an undesirable condition for purposes of the planned structures tests. The impedance test location for Track Section 4 was shifted to Beam 78 (sta 8553+95). This location was believed to be of comparable characteristics to the original location and was sufficiently removed so that water migration to the structures test location would not occur. No free water was encountered at Beams 14-18 after the impedance test (watering) location was shifted.

Strain gaging of Beam 16 in accordance with MITRE specifications commenced on 17 October and was completed by 21 October. Figure A-4 shows the strain gage configuration used. During this time, differential motion Linear Variable Differential Transformers (LVDT) and absolute motion film potentiometers were also mounted in the required locations. The train to be used for dynamic loading, consisting of an engine, two loaded ballast cars, and a caboose, arrived at the KTT on the morning of 22 November. After some preliminary slow runs across the test area, it was concluded that the differential motion LVDT's were not behaving properly. Special mounts were fabricated in the field so that the relative motion LVDT's could be replaced with more

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* A table of factors for converting units of measurement is presented on page iv.

sensitive carbon film potentiometers which had been prepared as alternates; excellent results were obtained with the film pots during calibration runs at very slow train speeds (verified by dial gage measurements) and during the ensuing dynamic tests at higher train speed.

Dynamic measurements of the test sections response to 17 train runs at speeds from 10-50 mps were made on 20 October. MITRE representatives were present during this phase of testing. A total of 13 data channels were recorded on tape, including measurements of relative motion (two channels), absolute motion (four channels), acceleration (one channel), particle velocity (two channels), and surface strain (four channels). Playbacks of the taped data onto oscillographs were examined in the field, and all channels, except those from the strain gages at the east of Beam 16, appeared to yield consistent results of good quality. The observed lack of response from the east end strain gages could not be explained at the time, but this phenomenon (after a more thorough examination in conjunction with the overall data picture) may have been due to rail-fastener-beam-load transfer characteristics in the dynamic test configuration since the gages in question did respond more consistently in later (static) testing. No modifications or repairs were made to the gages installed at the east end of the beam. However, another strain gage was added at this location for redundancy and verification during later testing. Oscillograph records and instrumentation details for each run were furnished to MITRE, and the taped data were digitized at WES to MITRE specifications. Delivery of the digitized tapes to MITRE was effected 19 January 1976.

Static Load-Deflection Tests

In planning for the load-deflection tests, the method of attack had been to shift the north rail so that the 1-ton lead weights used for static loading could be stacked on the top surface of Beam 16. To shift the rail the desired amount (3 ft) at Beam 16 would have required releasing 700-1000 ft of rail from the fasteners; however, a powered nut remover which the AT&SF had intended to use for this purpose was inoperative on 7 November because replacement parts had not been received. The time and cost-effective alternative under the circumstances was to cut and remove the north rail; accordingly, a 32-ft section of rail was cut free and lifted from Beams 15, 16, and 17 to facilitate loading and to permit installation of the necessary dial gages. The north rail was also loosened from its fasteners on Beams 12, 13, 14, 18, 19, and 20 so that the response of the beams in the test section would not be affected by load transfer to the rail.

Three load deflection tests were conducted between 10 and 12 November. Results of these tests are shown in Tables A-1-A-7 (deflection measurements made using dial gages) and Figures A-5-A-8 (strain gage data from Beam 16, north rail). The final test, i.e., the second loading on the west end of Beam 16, was omitted with the approval of Dr. James L. Milner of MITRE because highly consistent results had been obtained in the first three tests. As stated previously, strain gage response in the static tests was much more consistent than in the earlier dynamic tests. An additional longitudinal gage, which was installed on the east end of Beam 16 after the dynamic testing, yielded virtually the same response during the static tests as the longitudinal gage originally installed at that location. This suggests that the strain gages performed properly in both the static and dynamic testing, and that response in the dynamic tests was affected by uncontrolled variables, such as rail-fastener-beam-load transfer conditions, which were eliminated in the static tests.

Prior to testing, it was noted that the north rail beams in the test section were canted to the north field side of the track with a slope of about 1:30. This slope, resulting from rail traffic over the KTT, is opposite the 1:40 slope with which the beams were originally placed and indicates an appreciable rotation of the beams about their long axis. Measurements of long axis rotation during the load deflection tests were neither desired nor conducted; however, it is likely that some such rotation did occur.

Plate Bearing Tests

Preparations for performing plate bearing tests on the subgrade beneath Beam 16 included removal of ballast to the depth of the bottom of the beam (18 in.), cutting the gage rods joining Beam 16 and its companion beam under the south rail, and cutting and removing Beam 16 together with 1-1/2 ft of each adjacent beam. The subgrade thus exposed consisted of a 3- to 4-in.-thick layer of ballast material embedded in moist to wet reddish brown clay. During excavation it was noted that the ballast around Beam 16 was fouled with clay to within 1 or 2 in. of its top surface. The surface of the subgrade material beneath north rail Beam 16 also exhibited a pronounced slope to the north field side of the track. No evidence of a lime stabilized layer, which had been placed as the top 6 in. of the embankment, was encountered.

A 40-ft-long flat bed trailer was next hoisted onto the track to span the gap left by removing the beam. This trailer was loaded with 1-ton lead pigs to react the force applied, by means of a hydraulic ram, to the 30-in.-diam plate used in testing the subgrade. Locations of the tests are shown in Figure A-9. The plate bearing tests were conducted in accordance with procedures contained in EM 1110-45-303, and results are shown in Figure A-10-A-12. This testing completed the Phase I KTT Postmortem field operations.

TABLE A-1. STATIC LOAD VERSUS VERTICAL DEFLECTION TEST RESULTS (KTT POSTMORTEM) TEST NO. 1 (CENTER LOADING, BEAM 16, NORTH RAIL, TRACK SECTION 4, 10 NOV 1975)

Static	Absolute Vertical Deflection, in.*									Relative Vertical Deflection, in.*			
Load lb	Dial No. 1	Dial No. 2	Dial No. 3	Dial No. 4	Dial No. 5	Dial No. 6	Dial No. 7	Dial No. 8	Dial No. 9	Dial No. 10	Dial No. 11	Dial No. 12	Dial No. 13
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000	0.0000
4,070	0.000	0.000	0.001	0.006	0.007	0.002	0.002	0.001	0.000	0.0000	0.0020	-0.0070	0.0000
8,140	0.000	0.001	0.002	0.013	0.014	0.005	0.003	0.001	0.000	0.0000	0.0020	-0.0070	0.0000
12,210	0.000	0.002	0.003	0.019	0.025	0.008	0.006	0.001	0.000	-0.0005	0.0070	-0.0180	-0.0001
16,280	0.000	0.002	0.004	0.026	0.033	0.010	0.007	0.001	0.000	-0.0010	0.0100	-0.0220	-0.0002
20,350	0.000	0.002	0.007	0.031	0.042	0.013	0.009	0.002	0.000	-0.0020	0.0115	-0.0290	-0.0002
24,420	0.000	0.002	0.008	0.037	0.049	0.015	0.010	0.002	0.000	-0.0025	0.0135	-0.0320	-0.0001
28,490	0.000	0.002	0.009	0.042	0.056	0.017	0.012	0.002	0.000	-0.0031	0.0143	-0.0375	0.0002
32,560	0.000	0.002	0.011	0.048	0.062	0.019	0.013	0.002	0.000	-0.0040	0.0155	-0.0400	0.0004
24,420	0.000	0.002	0.010	0.045	0.059	0.019	0.014	0.001	0.000	-0.0035	0.0153	-0.0380	0.0004
16,280	0.000	0.002	0.009	0.039	0.050	0.017	0.013	0.001	0.000	-0.0026	0.0145	-0.0320	0.0003
8,140	0.000	0.002	0.007	0.028	0.034	0.014	0.011	0.000	0.000	-0.0018	0.0115	-0.0240	0.0002
0	0.000	0.001	0.003	0.007	0.008	0.009	0.010	0.000	0.000	-0.0004	0.0041	-0.0030	0.0001

* The dial numbers shown refer to locations depicted in Figures A-5-A-8.

TABLE A-2. STATIC LOAD VERSUS VERTICAL DEFLECTION TEST RESULTS (KTT POSTMORTEM) TEST NO. 2 (CENTER LOADING, BEAM 16, NORTH RAIL, TRACK SECTION 4, 11 NOV 1975)

Static Load lb	Absolute Vertical Deflection, in.*									Relative Vertical Deflection, in.*			
	Dial No. 1	Dial No. 2	Dial No. 3	Dial No. 4	Dial No. 5	Dial No. 6	Dial No. 7	Dial No. 8	Dial No. 9	Dial No. 10	Dial No. 11	Dial No. 12	Dial No. 13
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000	0.0000
4,070	0.000	0.000	0.000	0.006	0.008	0.002	0.002	0.000	0.000	0.0000	0.0020	-0.0080	0.0000
8,140	0.000	0.001	0.002	0.017	0.017	0.004	0.003	0.001	0.000	-0.0003	0.0060	-0.0135	-0.0005
12,210	0.000	0.002	0.003	0.023	0.019	0.006	0.005	0.002	0.000	-0.0006	0.0080	-0.0217	-0.0003
16,280	0.000	0.002	0.004	0.030	0.036	0.008	0.006	0.002	0.000	-0.0010	0.0107	-0.0256	-0.0003
20,350	0.000	0.002	0.006	0.035	0.045	0.010	0.008	0.002	0.000	-0.0014	0.0120	-0.0325	-0.0001
24,420	0.000	0.003	0.008	0.042	0.052	0.012	0.010	0.002	0.000	-0.0020	0.0127	-0.0355	0.0000
28,490	0.000	0.003	0.010	0.046	0.059	0.016	0.012	0.003	0.000	-0.0030	0.0130	-0.0403	0.0003
32,560	0.000	0.004	0.012	0.052	0.065	0.018	0.014	0.003	0.000	-0.0037	0.0135	-0.0420	0.0004
24,420	0.000	0.004	0.011	0.049	0.059	0.018	0.013	0.003	0.000	-0.0030	0.0133	-0.0400	0.0003
16,280	0.000	0.003	0.010	0.043	0.050	0.016	0.013	0.003	0.000	-0.0026	0.0130	-0.0360	0.0001
8,140	0.000	0.003	0.007	0.031	0.034	0.013	0.012	0.003	0.000	-0.0014	0.0100	-0.0265	0.0001
0	0.000	0.003	0.003	0.008	0.006	0.008	0.009	0.002	0.000	-0.0003	0.0020	-0.0025	0.0000

* The dial numbers shown refer to locations depicted in Figures A-5-A-8.

TABLE A-3. STATIC LOAD VERSUS VERTICAL DEFLECTION TEST RESULTS (KTT POSTMORTEM) TEST NO. 3 (WEST END LOADING, BEAM 16, NORTH RAIL, TRACK SECTION 4, 12 NOV 1975)

Static Load lb	Absolute Vertical Deflection, in.*									Relative Vertical Deflection, in.*			
	Dial No. 1	Dial No. 2	Dial No. 3	Dial No. 4	Dial No. 5	Dial No. 6	Dial No. 7	Dial No. 8	Dial No. 9	Dial No. 10	Dial No. 11	Dial No. 12	Dial No. 13
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000	0.0000
4,070	0.000	0.000	0.001	0.003	0.009	0.002	0.002	0.000	0.000	0.0000	0.0002	-0.0157	-0.0010
8,140	0.000	0.000	0.001	0.009	0.019	0.004	0.003	0.001	0.000	-0.0002	0.0012	-0.0255	-0.0012
12,210	0.000	0.001	0.001	0.013	0.028	0.009	0.004	0.001	0.000	-0.0004	0.0017	-0.0370	-0.0012
16,280	0.000	0.001	0.002	0.019	0.038	0.012	0.006	0.002	0.001	-0.0008	0.0020	-0.0425	-0.0011
20,350	0.000	0.002	0.003	0.021	0.044	0.018	0.009	0.002	0.001	-0.0009	0.0021	-0.0482	-0.0008
24,420	0.000	0.002	0.003	0.026	0.052	0.023	0.012	0.002	0.001	-0.0011	0.0034	-0.0509	-0.0003
28,490	0.000	0.002	0.004	0.027	0.058	0.031	0.015	0.003	0.001	-0.0013	0.0035	-0.0535	0.0006
32,560	0.000	0.003	0.004	0.032	0.065	0.037	0.018	0.003	0.001	-0.0018	0.0046	-0.0546	0.0013
24,420	0.000	0.003	0.004	0.030	0.061	0.035	0.016	0.003	0.001	-0.0015	0.0040	-0.0543	0.0005
16,280	0.000	0.002	0.004	0.026	0.053	0.028	0.013	0.003	0.001	-0.0011	0.0033	-0.0500	-0.0004
8,140	0.000	0.002	0.003	0.019	0.037	0.019	0.009	0.003	0.001	-0.0005	0.0022	-0.0360	-0.0011
4,070	0.000	0.001	0.002	0.013	0.025	0.015	0.007	0.002	0.001	0.0000	0.0002	-0.0265	-0.0001
0	0.000	0.001	0.001	0.006	0.008	0.010	0.003	0.002	0.000	0.0003	0.0002	-0.003	-0.0002

* The dial numbers shown refer to locations depicted in Figures A-5-A-8.

TABLE A-4. STATIC LOAD VERSUS SURFACE STRAIN TEST RESULTS (KTT POSTMORTEM) TEST NO. 1 (CENTER LOADING, BEAM 16, NORTH RAIL TRACK SECTION 4, 10 NOV 1975)

Static Load lb	Apparent Surface Strain, μin./in. (2 Active Gages)*						
	Gage No. 1	Gage No. 2	Gage No. 3	Gage No. 4	Gage No. 5	Gage No. 6	Gage No. 7
0	0	0	0	0	0	0	0
4,070	-152	-120	-1	58	1	17	-6
8,140	-307	-262	3	42	-10	26	-286
12,210	-338	-311	15	40	-25	49	-313
16,280	-333	-316	23	21	-41	69	-327
20,350	-326	-325	35	-21	-63	96	-331
24,420	-331	-325	40	-58	-88	119	-337
28,490	-329	-332	40	-113	-133	133	-336
32,560	-329	-330	53	-159	-145	137	-336
24,420	-340	-345	38	-252	-124	121	-349
16,280	-341	-357	16	-339	-223	95	-380
8,140	-366	-369	-2	-378	-234	94	-392
0	-378	-388	-39	-435	-265	98	-445

* Divide apparent values by two to get actual surface strain. Gage numbers refer to locations shown in Figure A-4.

TABLE A-5. STATIC LOAD VERSUS SURFACE STRAIN TEST RESULTS (KTT POSTMORTEM) TEST NO. 2 (CENTER LOADING, BEAM 16, NORTH RAIL TRACK SECTION 4, 11 NOV 1975)

Static Load lb	Apparent Surface Strain, μin./in. (2 Active Gages)*						
	Gage No. 1	Gage No. 2	Gage No. 3	Gage No. 4	Gage No. 5	Gage No. 6	Gage No. 7
0	0	0	0	0	0	0	0
4,070	-165	-80	0	35	8	3	-125
8,140	-202	-177	12	64	10	8	-149
12,210	-205	-185	21	70	7	15	-165
16,280	-203	-189	27	79	7	21	-161
20,350	-201	-189	40	85	2	33	-163
24,420	-202	-188	49	74	-11	46	-162
28,490	-208	-192	50	62	-25	54	-173
32,560	-214	-195	57	33	-40	52	-166
24,420	-218	-200	45	10	-46	64	-182
16,280	-218	-208	36	-29	-61	58	-190
8,140	-217	-215	23	-65	-77	52	-209
0	-190	-229	16	-142	-107	46	-194

* Divide apparent values by two to get actual surface strain. Gage numbers refer to locations shown in Figure A-4.

TABLE A-6. STATIC LOAD VERSUS SURFACE STRAIN TEST RESULTS (KTT POSTMORTEM) TEST NO. 3 (WEST END LOADING, BEAM 16, NORTH RAIL, TRACK SECTION 4, 12 NOV 1975)

Static Load lb	Apparent Surface Strain, μin./in. (2 Active Gages)*						
	Gage No. 1	Gage No. 2	Gage No. 3	Gage No. 4	Gage No. 5	Gage No. 6	Gage No. 7
0	0	0	0	0	0	0	0
4,070	100	108	136	-43	-34	18	55
8,140	107	127	2	-42	-36	8	100
12,210	119	155	-7	-37	-35	13	102
16,280	134	174	7	-25	-32	4	112
20,350	126	177	10	-14	-28	7	107
24,420	140	193	41	7	-21	-1	80
28,490	-24	116	38	17	-17	1	124
32,560	-24	63	47	35	-15	-10	100
24,420	7	35	70	34	-13	9	-27
16,280	-44	10	38	30	-10	18	-59
8,140	-40	-9	30	23	-4	37	-70
4,070	-1	5	22	19	-3	43	-87
0	-43	-1	45	28	37	31	-45

* Divide apparent values by two to get actual surface strain. Gage numbers refer to locations shown in Figure A-4.

TABLE A-7. 30-IN.-DIAM. PLATE BEARING TEST RESULTS (KTT POSTMORTEM) ON KTT SUBGRADE (NORTH RAIL, BEAM 16, TRACK SECTION 4)

Location No.	Load psi	Deflection, in. Dial No. 1	Dial No. 2	Dial No. 3	Average	Elapsed Time min*	Date of Test
1**	5	0.035	0.029	0.039	0.034	21	16 Nov
	10	0.051	0.053	0.061	0.055	15	
	15	0.060	0.081	0.087	0.079	15	
	20	0.098	0.119	0.124	0.1137	36	
	25	0.121	0.153	0.156	0.1433	30	
	30	0.138	0.193	0.189	0.1733	33	
	0	0.057	0.076	0.079	0.0706	27	
2**	5	0.024	0.009	0.017	0.0167	9	17 Nov
	10	0.046	0.033	0.037	0.0387	18	
	15	0.070	0.064	0.061	0.065	21	
	20	0.089	0.098	0.085	0.0906	18	
	25	0.109	0.139	0.110	0.119	21	
	30	0.130	0.193	0.143	0.155	30	
	0	0.046	0.049	0.045	0.0467	27	
3**	5	0.051	0.053	0.027	0.0437	15	17 Nov
	10	0.084	0.088	0.043	0.0717	12	
	15	0.116	0.122	0.066	0.101	21	
	20	0.145	0.156	0.083	0.128	21	
	25	0.175	0.184	0.103	0.154	18	
	30	0.210	0.219	0.127	0.185	30	
	0	0.098	0.094	0.037	0.763	45	

* Elapsed time between load application and dial indicator readings - readings made when dial creep was less than 0.001 in. in a 3-min interval.

** Test locations were as follows:
Location No. 1 - West end of Beam 16
Location No. 2 - Center of Beam 16
Location No. 3 - East end of Beam 16

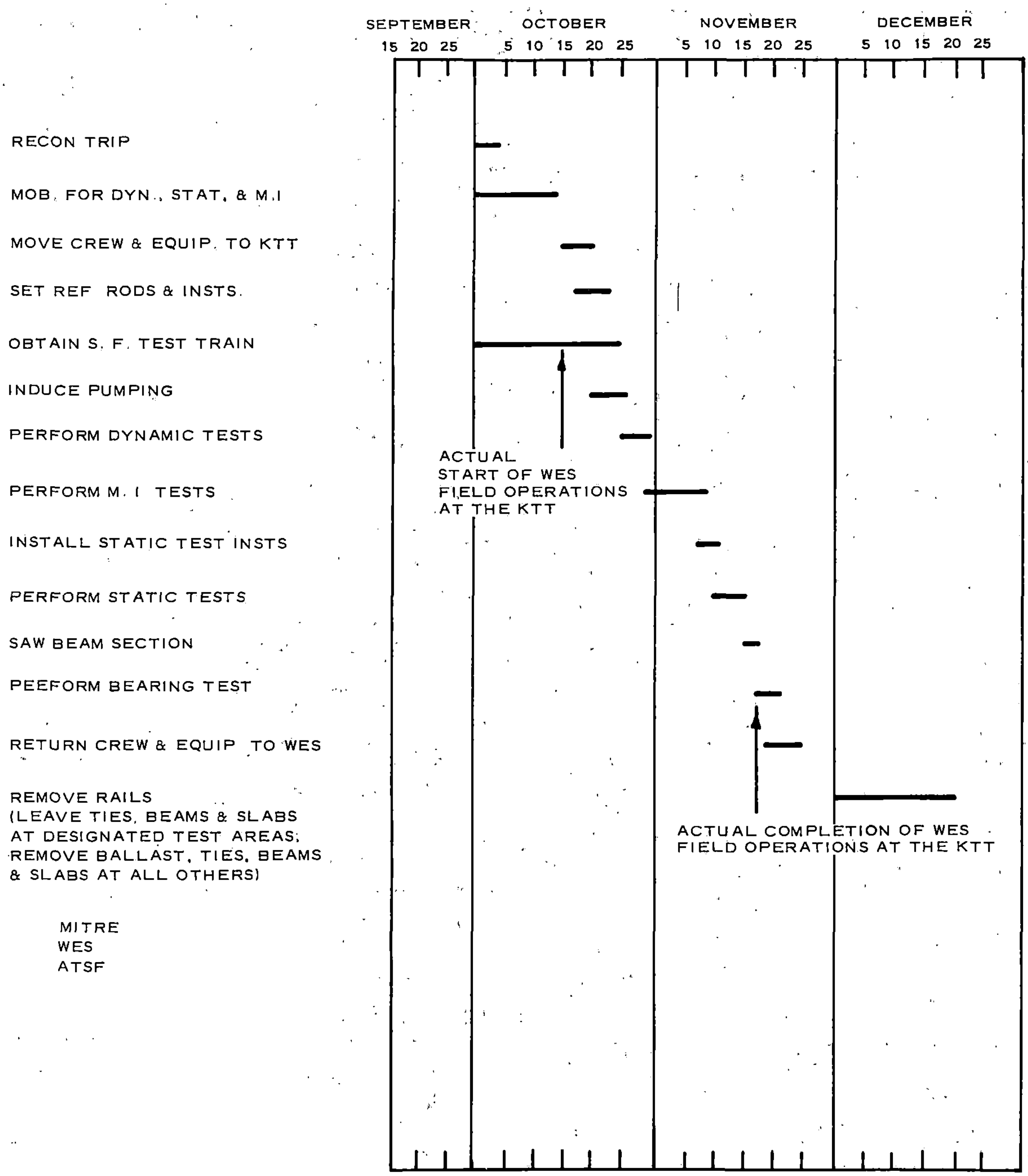
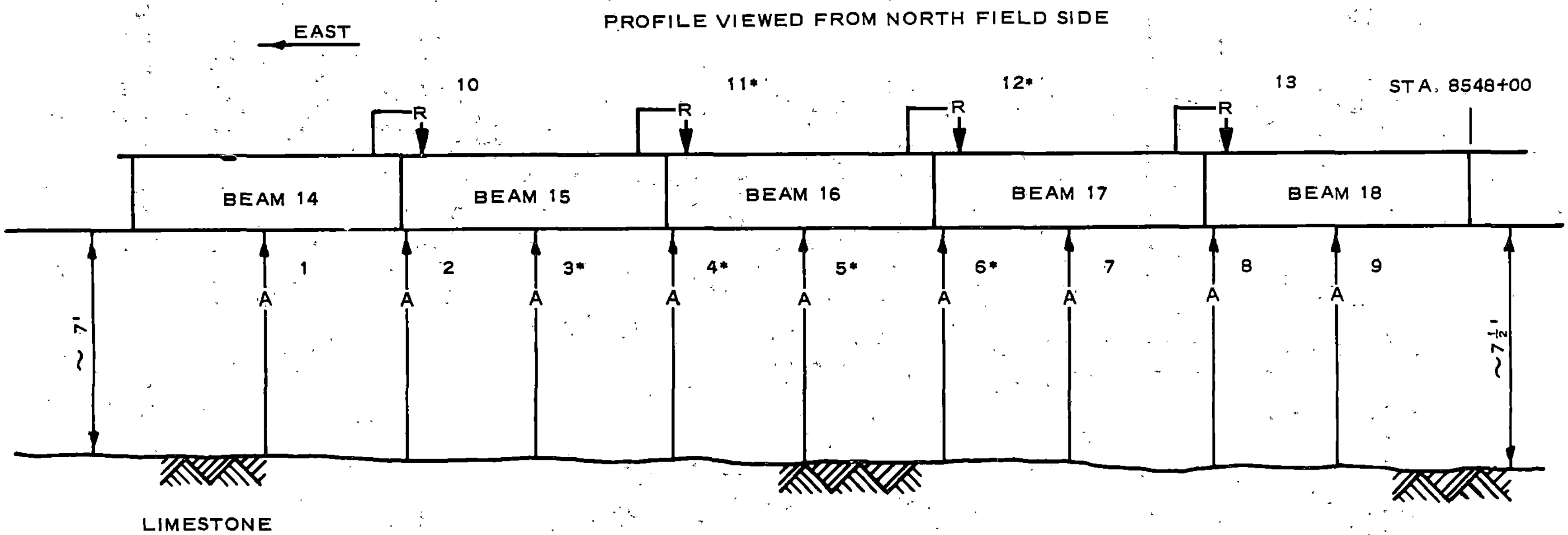


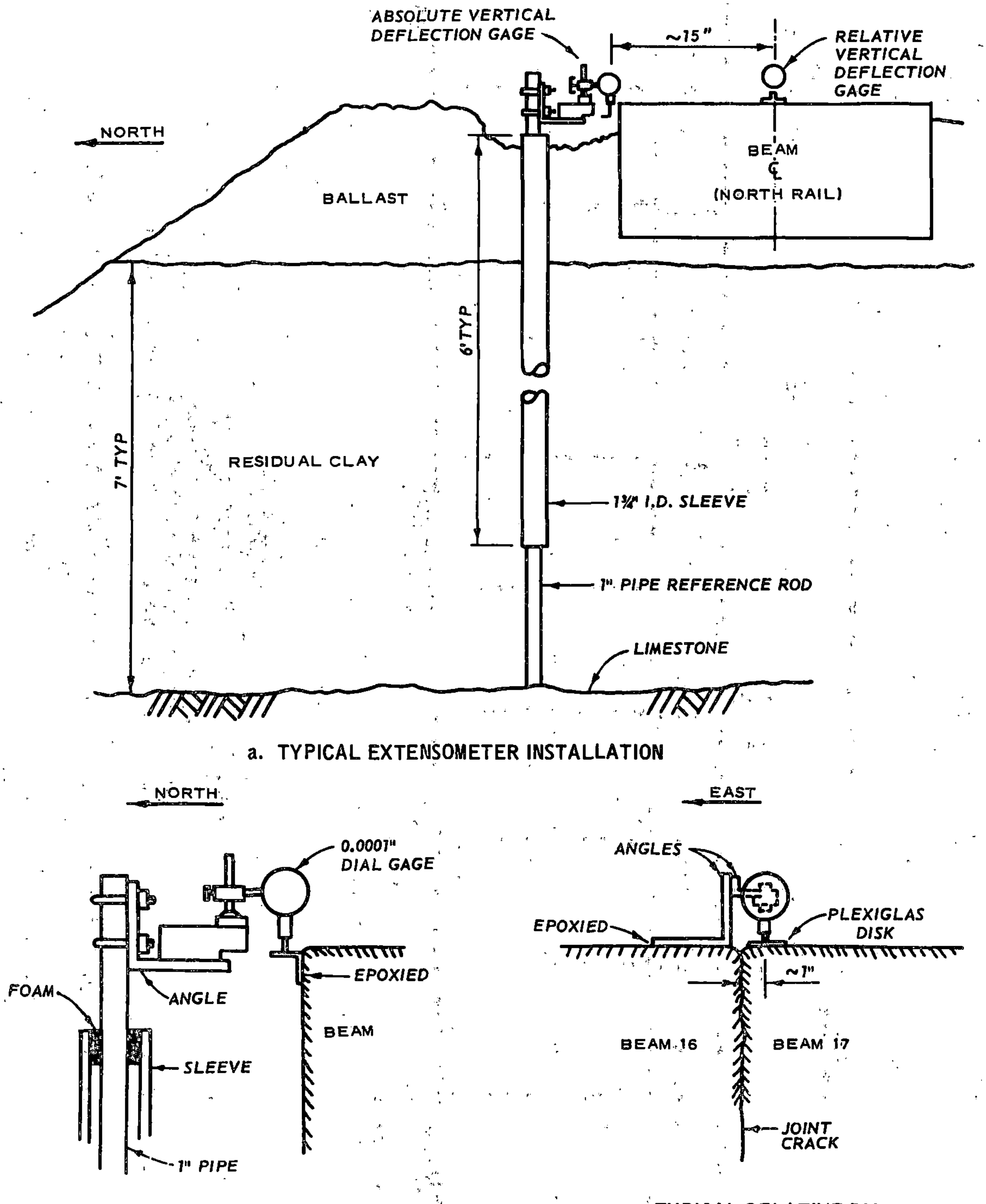
FIGURE A-1. TIME TABLE DEVELOPED FOR WES PHASE I FIELD OPERATIONS



LEGEND

SYMBOL	DESCRIPTION
R	RELATIVE DEFLECTION GAGE
A	ABSOLUTE DEFLECTION GAGE
*	MEASUREMENT LOCATION IN DYNAMIC TESTS

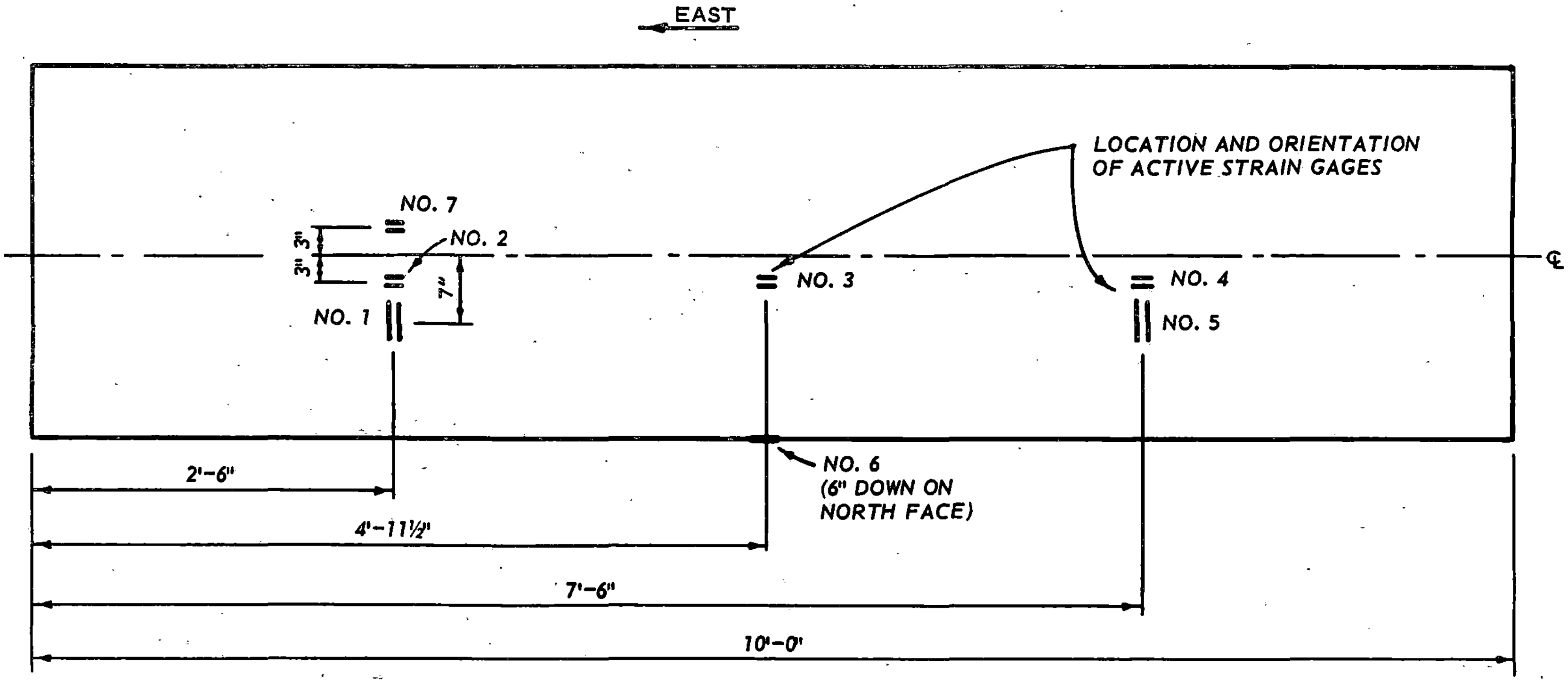
FIGURE A-2. GAGE CONFIGURATION FOR STATIC AND DYNAMIC STRUCTURE TESTS



b. TYPICAL ABSOLUTE DIAL GAGE MOUNTING

c. TYPICAL RELATIVE DIAL GAGE MOUNTING

FIGURE A-3. DETAILS OF DIAL GAGE INSTALLATIONS

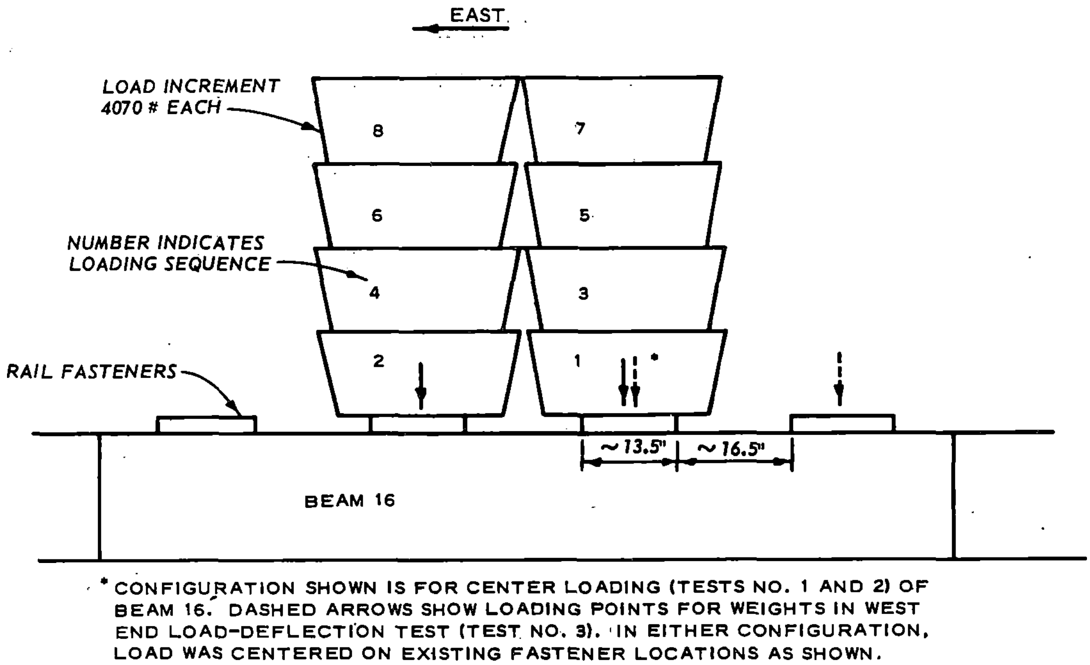


LEGEND

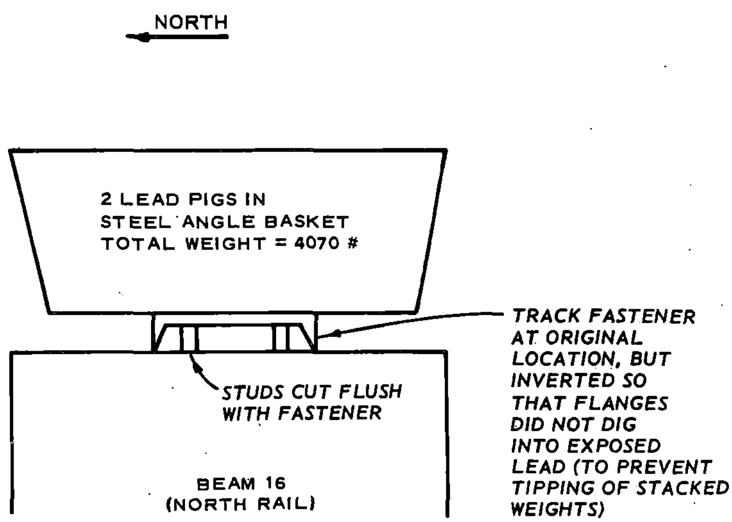
SYMBOL	DESCRIPTION
NO. 1	LATERAL GAGE (2 ACTIVE, FULL BRIDGE) 4" GAGE LENGTH
NO. 2	LONG. GAGE (2 ACTIVE, FULL BRIDGE) 2" GAGE LENGTH
NO. 3	LONG. GAGE (2 ACTIVE, FULL BRIDGE) 2" GAGE LENGTH
NO. 4	LONG. GAGE (2 ACTIVE, FULL BRIDGE) 2" GAGE LENGTH
NO. 5	LATERAL GAGE (2 ACTIVE, FULL BRIDGE) 4" GAGE LENGTH
NO. 6	LONG. GAGE (2 ACTIVE, FULL BRIDGE) 2" GAGE LENGTH
NO. 7	LONG. GAGE (2 ACTIVE, FULL BRIDGE) 2" GAGE LENGTH

PLAN VIEW BEAM 16

FIGURE A-4. STRAIN GAGE INSTRUMENTATION, BEAM 16, NORTH RAIL, TRACK SECTION 4



a. TYPICAL LOADING PROCEDURE



b. DETAILS OF SUPPORT ARRANGEMENT

FIGURE A-5. LOADING CONFIGURATION FOR LOAD-DEFLECTION TESTS

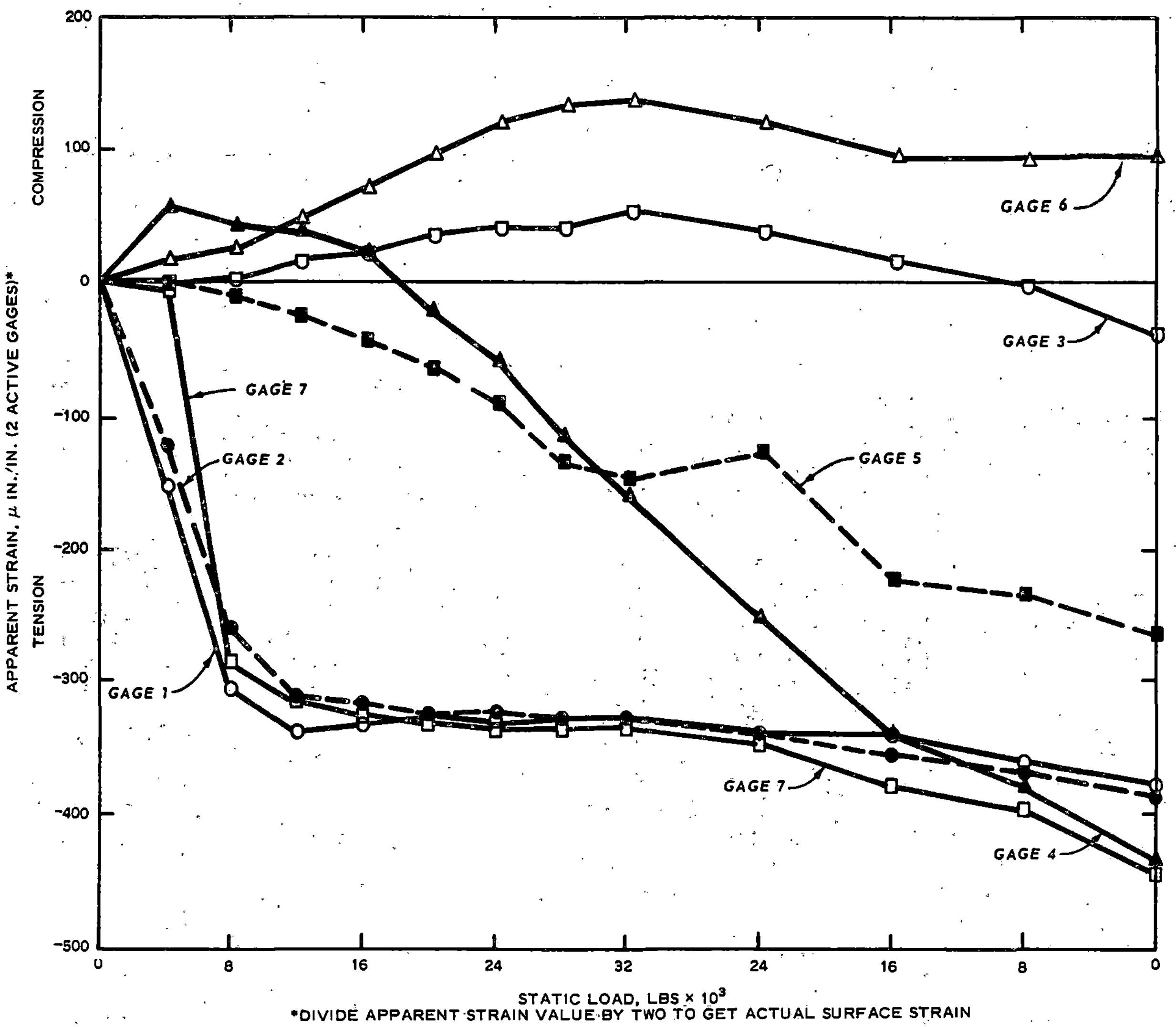
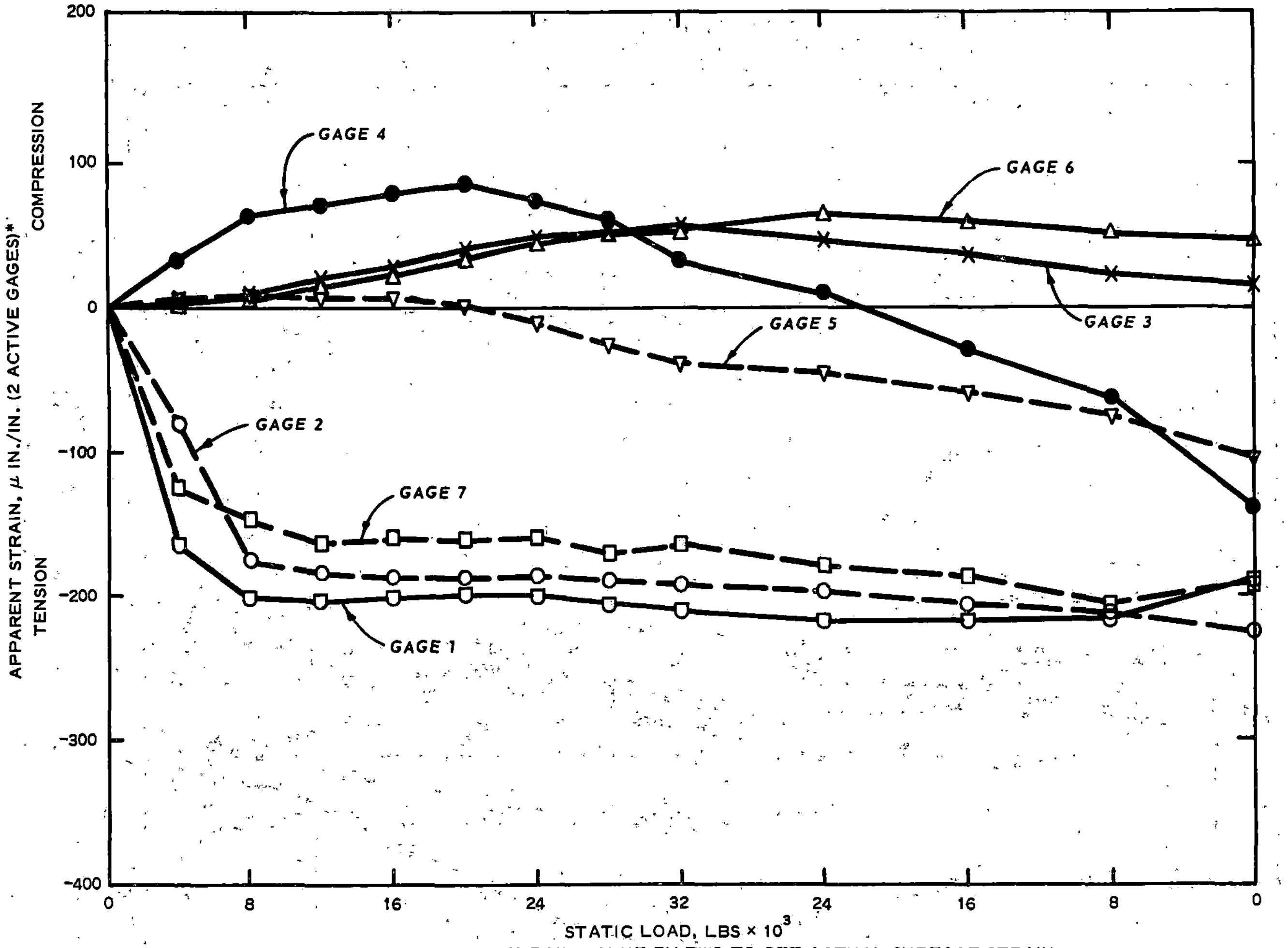


FIGURE A-6. PLOTS OF LOAD VERSUS SURFACE STRAIN FROM LOAD-DEFLECTION TEST 1



*DIVIDE APPARENT STRAIN VALUE BY TWO TO GET ACTUAL SURFACE STRAIN

FIGURE A-7. PLOTS OF LOAD VERSUS SURFACE STRAIN FROM LOAD-DEFLECTION TEST 2

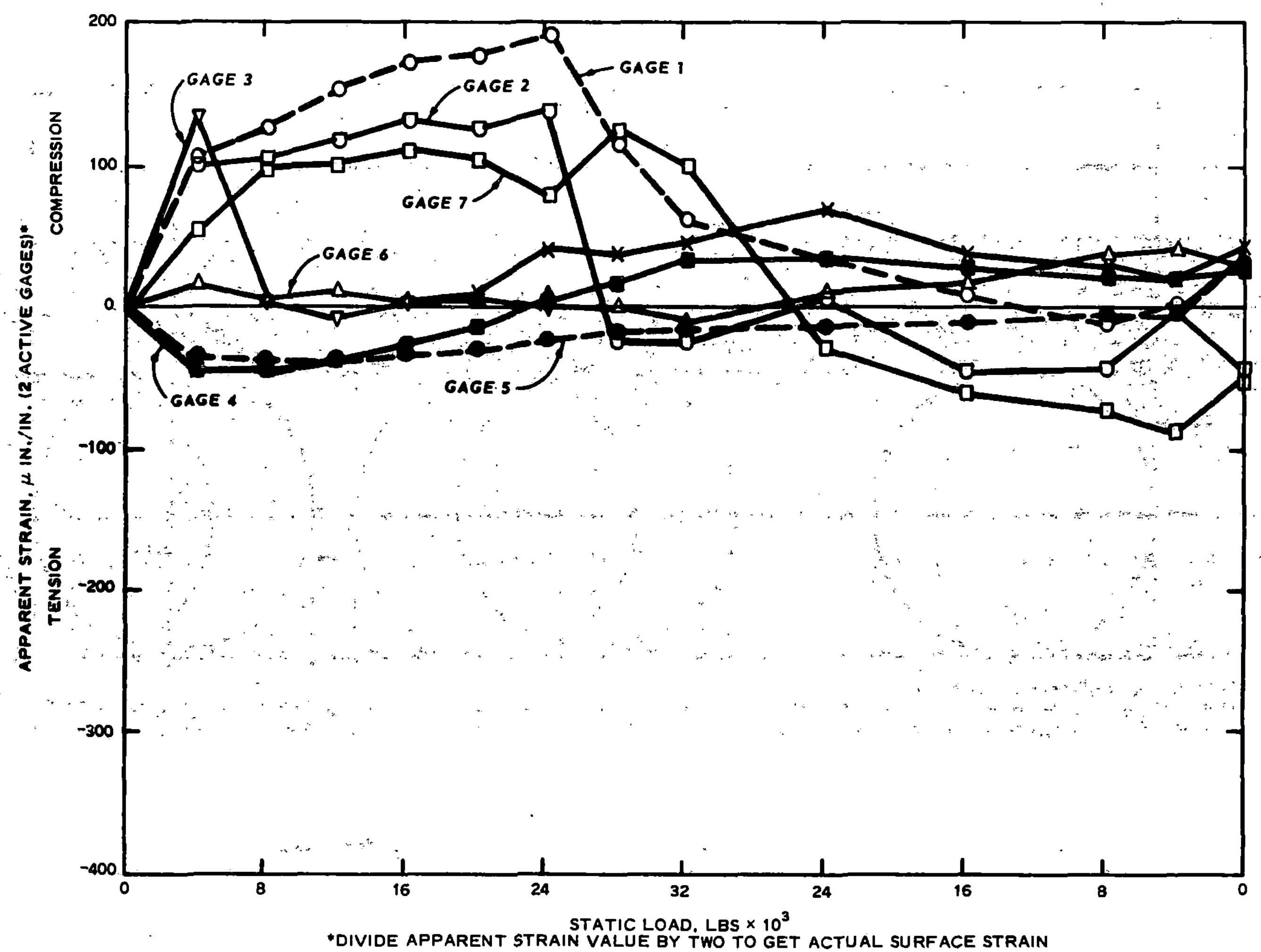


FIGURE A-8. PLOTS OF LOAD VERSUS SURFACE STRAIN FROM LOAD-DEFLECTION TEST 3

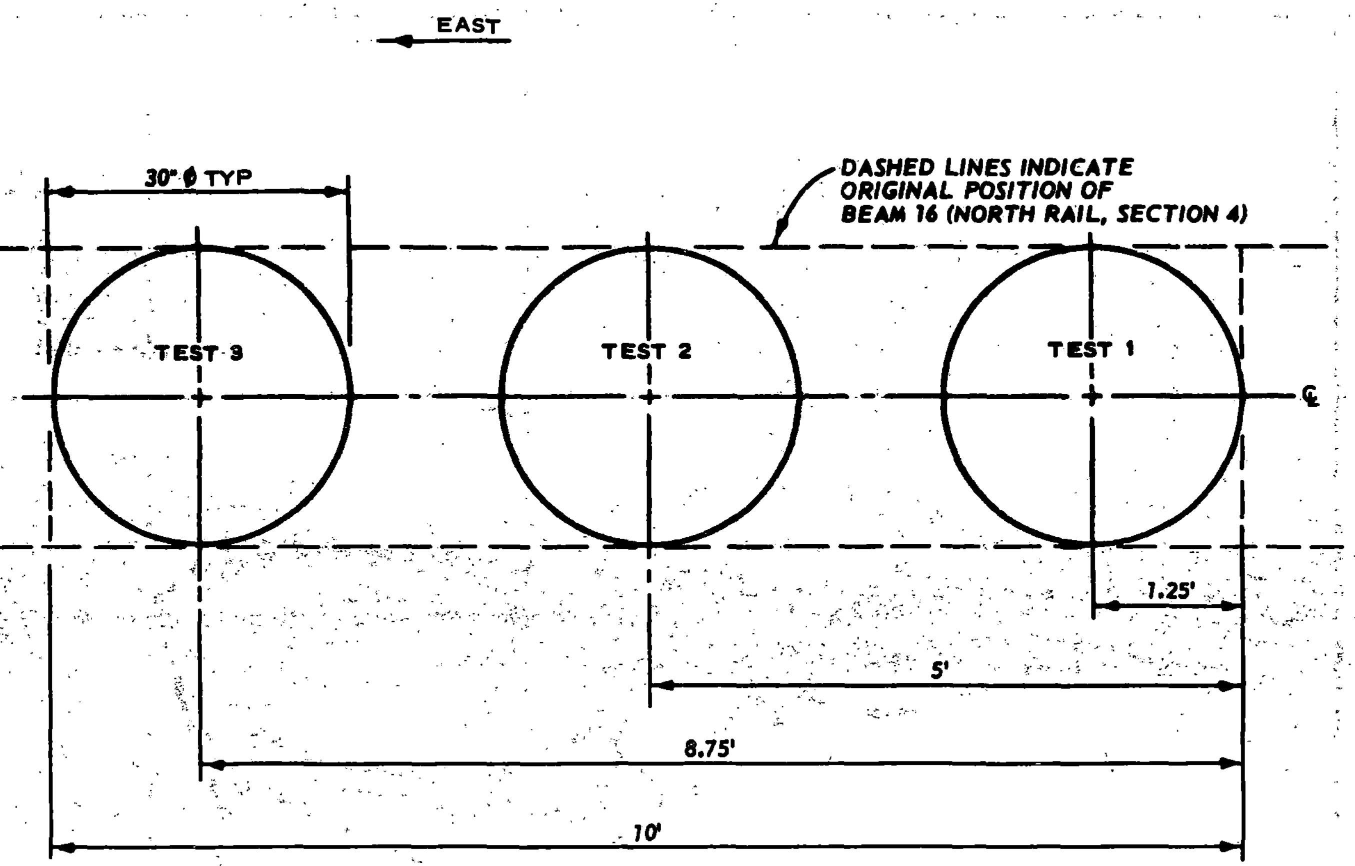


FIGURE A-9. LOCATION OF 30-IN.-DIAM PLATE BEARING TEST ON SUBGRADE

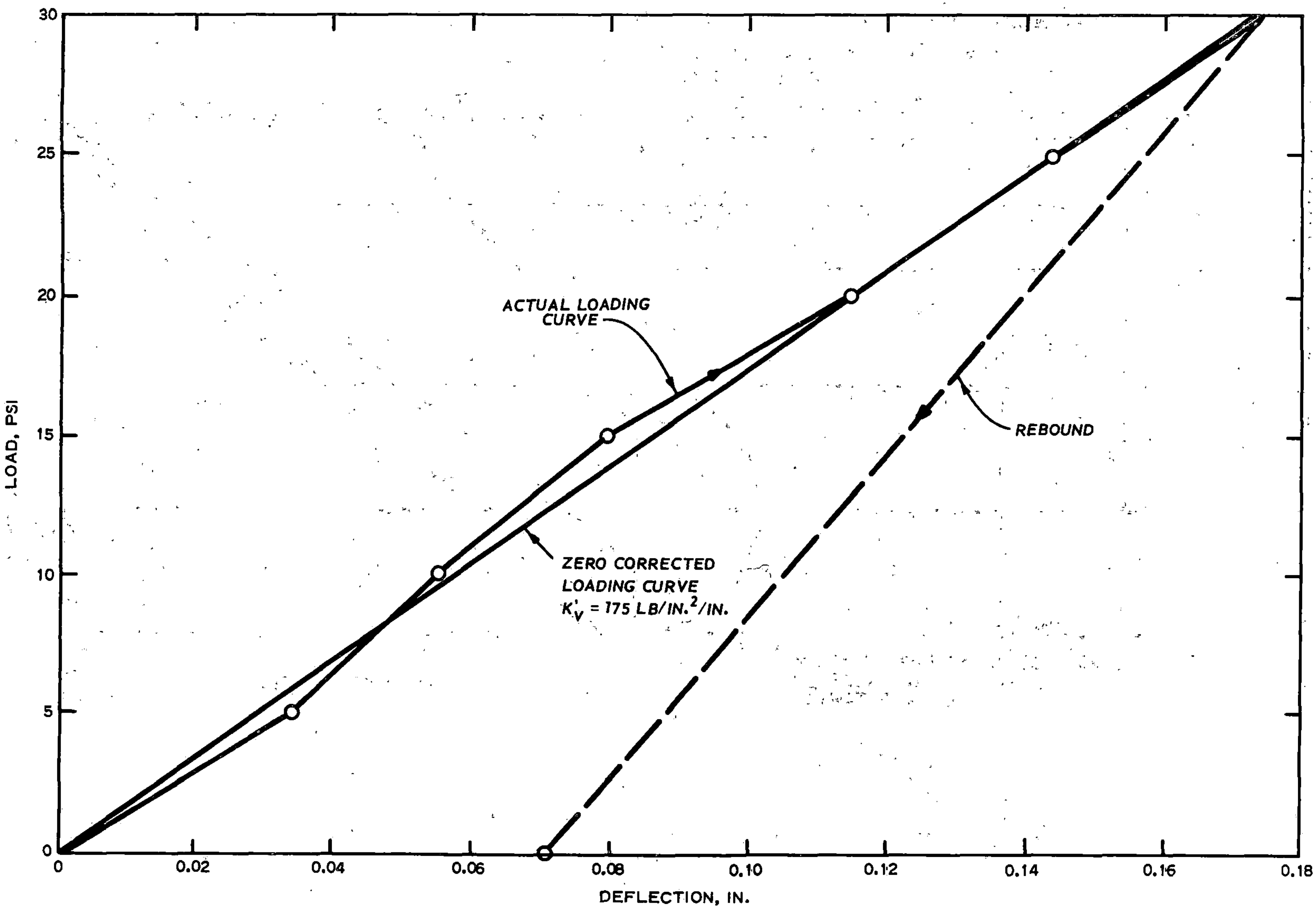


FIGURE A-10. PLATE BEARING TEST RESULTS, LOCATION 1 (WEST END BEAM 16)

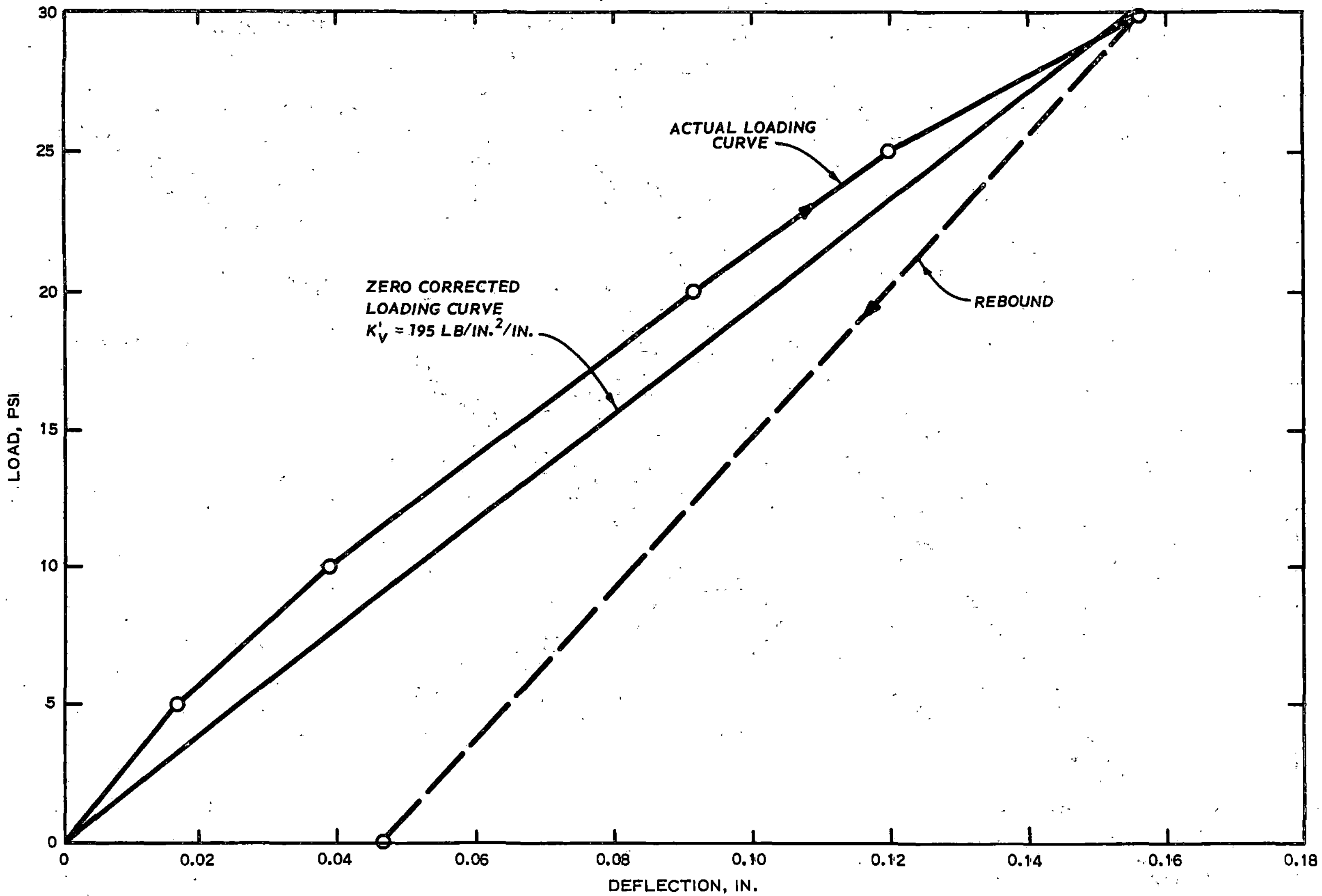


FIGURE A-11. PLATE BEARING RESULTS, LOCATION 2 (CENTER OF BEAM 16)

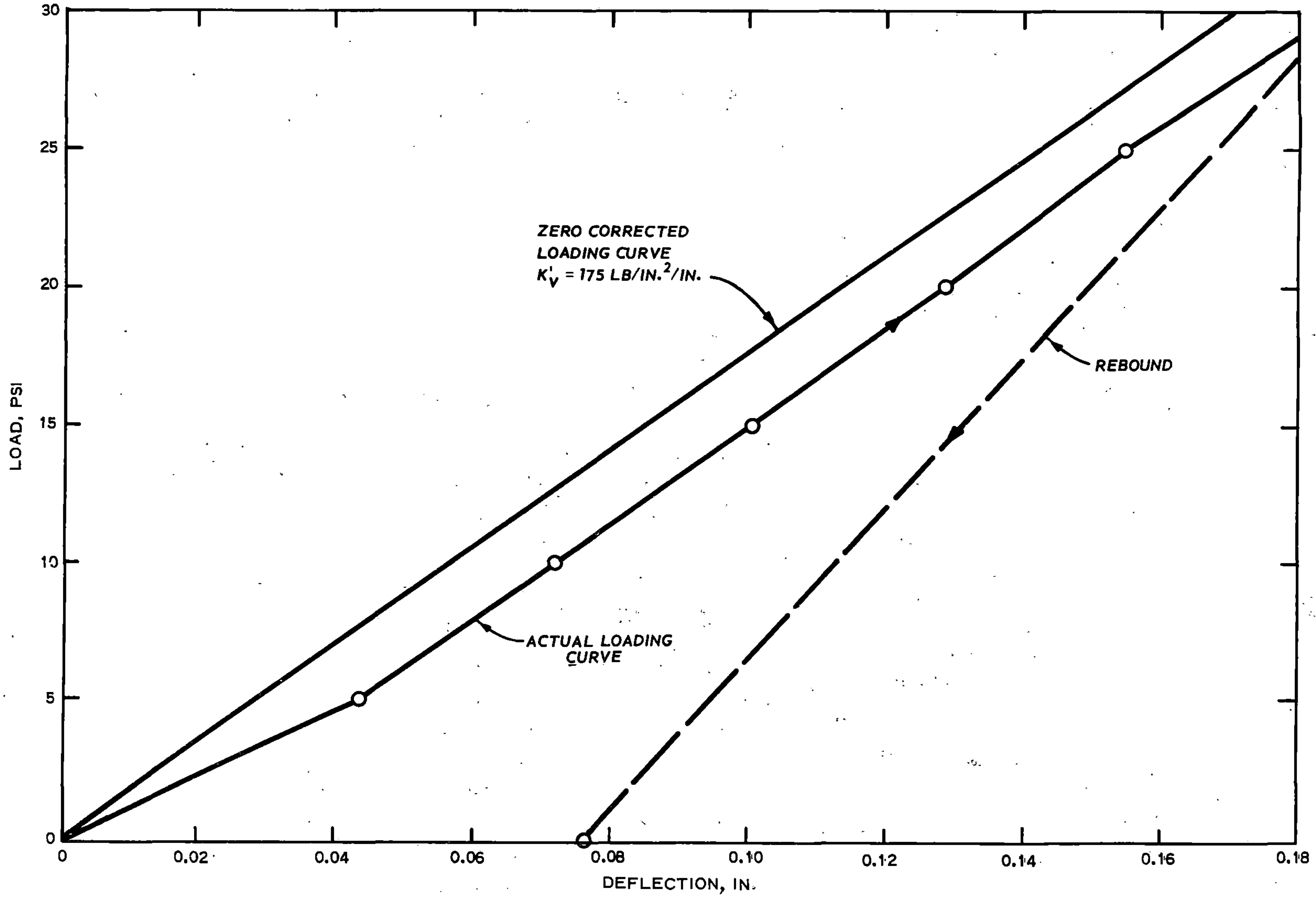


FIGURE A-12. PLATE BEARING TEST RESULTS, LOCATION 3 (EAST END BEAM 16)

APPENDIX B: VIBROSEISMIC STUDY

General

WES vibroseismic tests are used to determine the in situ elastic properties of foundation materials. In the KTT Postmortem Investigation, vibroseismic tests were conducted at 10 preselected locations on the KTT embankment; these locations were also used for studies of embankment strength and material properties. The vibroseismic field work was carried out, as part of the Phase II field operations, by a project engineer and technician in the period 5-15 May 1976.

Test Plan

Vibroseismic tests were conducted for the following purposes:

1. To determine the variation of embankment elastic moduli with depth for the posttraffic (postmortem) test condition.
2. For comparison with 1971 pretraffic vibroseismic test results in order to assess traffic induced changes in embankment strength.

Locations for the vibroseismic tests were selected to typify either "good" or "poor" performance, based on judgements of ATSF maintenance records for the KTT. WES judgements of performance from the ATSF maintenance records are described in Volume I of this report, but may be summarized as follows:

Track Section	Test Location (KTT Control Stations)	Performance
1	8524+75	Poor
2 (A)	8531+60	Poor
(B)	8535+16*	Good
3 (A)	8540+17	Good
(B)	8542+49	Poor
4	8551+50	Poor

* Denotes location of main (built in) KTT instrumentation array.

Track Section	Test Location (KTT Control Stations)	Performance
5	8558+20	Poor
7	8576+41*	Poor
8	8587+10	Good
9	8595+37*	Good

* Denotes location of main (built in) KTT instrumentation array.

Field Testing

The vibroseismic tests at each location were carried out in two steps. First, the compression wave velocity in each subsurface layer and the depth to interfaces between layers were determined using refraction seismic techniques. A 16-lb sledge hammer provided the seismic energy source and compression wave arrivals at scaled distances from the source were recorded using a 12-channel seismograph. Seismic waves were generated by striking the sledge hammer on a thick steel disk. Compression wave arrivals were detected with vertical seismic geophones, which were spaced at 2-ft intervals along a line following the north or south rail of the KTT track structures. The track structures had, of course, been removed prior to testing. The ballast was also removed so that the geophones could be placed on the top surface of the embankment. The sledge hammer was struck at either end of the geophone spread so as to obtain both forward and reverse traverses on the subsurface materials. The wave travel times and distances to each detector were used to construct the time-distance plots shown in Figures B-1-B-10. The slope of the line in these plots gives the apparent compression wave velocity of the subsurface material. A change in slope of the line indicates the presence of a subsurface layer with different seismic properties from the overlying material. For a two-layer system, the depth to the interface between layers may be calculated from the following equation:

$$D_1 = \frac{X_1}{2}\sqrt{\frac{V_2 - V_1}{V_2 + V_1}} \qquad \text{(B-1)}$$

where

D_1 = depth from surface to first interface

X_1 = distance from source to change in slope

V_1 = compression wave velocity in upper layer

V_2 = compression wave velocity in lower layer

Since dipping layers will cause different apparent velocities to be recorded for the same material, forward and reverse traverses are used to determine the true compression wave velocity in a layer. The true velocity is obtained using the following equation:

$$V_T = \frac{2V_u V_d}{V_u/V_d} \tag{B-2}$$

where

V_T = true compression wave velocity, LT^{-1}

V_u = apparent velocity updip, LT^{-1}

V_d = apparent velocity downdip, LT^{-1}

The second phase of the vibroseismic investigation is a vibratory test, which is conducted at the same location as the refraction seismic survey. A 25-lb force output electromagnetic vibrator was used for vibration testing at the KTT, and surface waves were detected using the 12-channel seismograph equipment previously described. A typical test setup is shown in Figure B-11. This vibrator and associated instrumentation is described in detail in WES Miscellaneous Paper (MP) 4-691, entitled Determination of Soil Shear Moduli at Depths by In Situ Vibratory Techniques, Dec 1964, and in A Procedure for Determining Elastic Moduli of In Situ Soils by Dynamic Techniques, an excerpt from the 1967 Proceedings of the International Symposium on Wave Propagation and Dynamic Properties of Earth Material.

The vibratory test consists of determining the wavelength of surface (Rayleigh) waves generated by a vibrator operating at a discrete frequency. A number of different frequencies are used to cover the frequency domain of interest, and wave velocity is computed from the following equation:

$$V = \lambda f \tag{B-3}$$

where

V = wave velocity, LT^{-1}

λ = wave length, L

f = frequency of vibration, T^{-1}

An example plot of this type is shown in Figure B-12.

Computation of Poisson's Ratio and Elastic Moduli

Shear wave velocity and Rayleigh wave velocity are related by Poisson's ratio. For homogenous materials, having Poisson's ratios in the range from 0.20 to 0.50, the difference between shear and Rayleigh wave velocities is less than 9 percent. For practical purposes, shear and Rayleigh waves may be taken to have the same velocity. The wave velocities measured in the vibratory test may therefore be used to compute shear moduli from

$$G = \rho V_s^2 \tag{B-4}$$

where

G = shear modulus of soil, FL^{-2}

V_s = shear wave velocity, LT^{-1}

ρ = mass density of soil, $\gamma w/g$, $GL^{-4}T^2$

γ_w = wet unit weight of soil, FL^{-3}

g = acceleration due to gravity, LT^2

Assuming that shear and compression wave velocities were determined for the same material, Poisson's ratio can be determined using the velocity ratio

$$V_r = \frac{V_c}{V_s} \tag{B-5}$$

where

V_r = velocity ratio

V_c = compression wave velocity, LT^{-1}

V_s = shear wave velocity, LT^{-1}

Poisson's ratio ν is calculated from elastic theory using the relationship

$$\nu = \frac{V_r^2 - 2}{2\left(V_r^2 - 1\right)} \tag{B-6}$$

Young's E modulus is similarly derived from the equation

$$E = 2G\left(1 + \nu\right) \tag{B-7}$$

WES experience indicates that shear wave velocity and E and G moduli derived in this way correlate well with results of conventional exploration methods if the derived values are assigned to a depth equal to one-half the surface wave length measured in the vibratory tests. Results presented herein conform with the above practice and are summarized in Table B-1. Plots of shear wave velocity versus depth in the embankment for each test location are shown in Figures B-13-B-22. Corresponding plots of E and G moduli with depth are shown in Figures B-23-B-32. A summary plot showing the average variation in E and G moduli with depth is shown in Figure B-33. These moduli should be considered as upper bound values since they were derived from tests conducted at very low stress levels.

TABLE B-1. RESULTS OF VIBROSEISMIC SURVEY

Wet Unit Weight γ_m^{2} pcf	P-Wave Velocity V_c fps	Depth d, ft	Frequency f, Hz	Wave Length λ, ft	Depth d, ft	R-Wave Velocity V_s, fps	Poission Ratio γ	Modulus, 10^3 psi Shear G	Young's E
				Test Section 1					
107	1075	0+	400	0.70	0.35	265	0.47	1.6	4.70
			350	0.80	0.40	280	0.46	1.8	5.30
			300	1.00	0.50	310	0.45	2.2	6.40
			250	1.60	0.80	400	0.42	3.7	10.50
			200	1.90	1.00	390	0.42	3.5	9.90
			150	3.20	1.60	480	0.38	5.3	14.60
120			100	6.70	3.40	670	0.18	11.6	27.90
			80	8.40	4.20	670	0.18	11.6	27.90
			70	8.60	4.30	600	0.27	9.3	23.30
			50	11.50	5.80	580	0.29	8.7	22.50
				Test Section 2A					
107	1075	0+	250	2.00	1.00	510	0.36	6.0	16.30
			200	2.60	1.30	520	0.35	6.2	16.70
			150	3.80	1.90	570	0.31	7.5	19.70
120			100	6.00	3.00	600	0.28	9.3	23.80
			80	6.30	3.20	505	0.36	6.6	18.00
			70	7.60	3.80	530	0.34	7.3	19.60
			50	10.00	5.00	500	0.37	6.5	17.80
			45	14.50	7.30	655	0.23	11.1	27.30
			40	18.80	9.40	750	0.04	14.6	30.40

(Continued)

(Sheet 1 of 5)

TABLE B-1 (Continued)

Wet Unit Weight γ_m[2] pcf	P-Wave Velocity V_c fps	Depth d, ft	Frequency f, Hz	Wave Length λ, ft	Depth d, ft	R-Wave Velocity V_s, fps	Poission Ratio γ	Modulus, 10^3 psi Shear G	Young's E
				Test Section 2B					
107	1090	0+	300	1.70	0.85	510	0.36	6.0	16.30
			250	2.10	1.00	520	0.35	6.2	16.70
			200	2.70	1.30	530	0.35	6.5	17.60
			150	4.30	2.10	640	0.24	10.6	26.30
			100	5.40	2.70	540	0.34	7.6	20.40
			80	6.30	3.10	500	0.39	6.5	18.10
			70	8.30	4.10	580	0.30	8.7	22.60
			50	10.80	5.40	540	0.34	7.6	20.40
				Test Section 3A					
107	1150	0+	300	1.70	0.87	520	0.37	6.2	17.00
			250	1.90	0.94	470	0.40	5.1	14.30
120			200	2.60	1.30	510	0.38	6.7	18.50
			150	3.70	1.80	550	0.35	7.8	21.10
			100	5.70	2.80	570	0.34	8.4	22.50
			80	6.00	3.00	480	0.39	6.0	16.70
			70	7.60	3.80	530	0.37	7.3	20.00
			50	12.80	6.40	640	0.28	10.6	27.10
				Test Section 3B					
107	1150	0+	300	2.00	1.00	610	0.30	8.6	22.40
			250	2.20	1.10	550	0.35	7.0	18.90

(Continued)

(Sheet 2 of 5)

TABLE B-1 (Continued)

Wet Unit Weight γ_m,[2] pcf	P-Wave Velocity V_c fps	Depth d, ft	Frequency f, Hz	Wave Length λ, ft	Depth d, ft	R-Wave Velocity V_s, fps	Poission Ratio γ	Modulus, 10^3 psi Shear G	Young's E
				Test Section 3B (Continued)					
			200	2.50	1.30	500	0.38	6.5	17.90
120			150	3.40	1.70	510	0.38	6.7	18.50
			100	5.00	2.50	500	0.38	6.5	17.90
			80	5.50	2.80	440	0.41	5.0	14.10
			70	7.00	3.50	490	0.39	6.2	17.20
			50	12.20	6.10	620	0.26	10.0	25.80
			40	12.50	6.30	500	0.38	6.5	17.90
				Test Section 4					
107	1040	0+	400	1.10	0.55	450	0.38	4.7	13.00
			350	1.20	0.56	400	0.41	3.7	10.40
			300	1.30	0.63	375	0.43	3.2	9.20
			250	1.50	0.73	365	0.43	3.1	8.90
			200	1.90	0.93	375	0.43	3.2	9.20
			150	2.40	1.20	360	0.43	3.0	8.60
			100	3.70	1.90	370	0.43	3.2	9.20
120			80	5.50	2.80	440	0.39	5.0	13.90
			70	6.30	3.10	440	0.39	5.0	13.90

(Continued)

TABLE B-1 (Continued)

Wet Unit Weight γ_m pcf	P-Wave Velocity V_c, fps	Depth d, ft	Frequency f, Hz	Wave Length λ, ft	Depth d, ft	R-Wave Velocity V_s, fps	Poission Ratio γ	Modulus, 10^3 psi Shear G	Young's E
				Test Section 5					
107	1075	0-5.1	400	0.85	0.40	340	0.45	2.7	7.80
	4750	5.1+	350	0.97	0.50	340	0.45	2.7	7.80
			300	1.10	0.60	340	0.45	2.7	7.80
			250	1.30	0.70	325	0.45	2.4	7.00
			200	1.60	0.80	315	0.45	2.3	6.80
			150	2.00	1.00	300	0.46	2.1	6.10
			100	3.20	1.60	320	0.45	2.4	7.00
120			80	4.40	2.20	350	0.44	3.2	9.20
			70	4.70	2.40	330	0.45	2.8	8.10
			50	6.80	3.40	340	0.44	3.0	8.60
			40	11.80	5.40	470	0.50	5.7	17.10
			35	17.10	8.60	600	0.48	9.3	27.50
				Test Section 7					
107	1100	0-4.4	400	1.10	0.60	440	0.40	4.5	12.60
	1955	4.4+	350	1.50	0.80	525	0.35	6.3	17.00
			300	1.80	0.90	540	0.34	6.7	18.00
			250	2.00	1.00	500	0.37	5.8	15.90
			200	2.50	1.30	510	0.36	5.9	16.10
			150	3.40	1.70	510	0.36	6.7	18.20
			100	6.00	3.00	600	0.29	9.3	24.00
120			80	5.90	3.00	475	0.39	5.8	16.10
			70	7.40	3.70	515	0.36	6.8	18.50
			50	11.60	5.80	580	0.45	8.7	25.20
			40	13.50	6.80	540	0.46	7.6	22.20
			35	17.00	8.50	595	0.44	9.2	26.50

(Continued)

(Sheet 4 of 5)

TABLE B-1 (Concluded)

Wet Unit Weight γ_m^2 pcf	P-Wave Velocity V_c, fps	Depth d, ft	Frequency f, Hz	Length λ, ft	Depth d, ft	R-Wave Velocity V_s, fps	Poission Ratio γ	Modulus, 10^3 psi Shear G	Young's E
				Test Section 8					
107	1100	0-2.8	300	1.40	0.70	410	0.42	3.9	11.10
	1740	2.8+	250	1.80	0.90	450	0.40	4.7	13.20
			200	2.60	1.30	520	0.36	6.2	16.90
120			150	3.50	1.70	520	0.36	7.0	19.00
			100	5.60	2.80	560	0.44	8.1	23.30
			80	7.50	3.70	600	0.43	9.3	26.60
			70	8.00	4.00	560	0.44	8.1	23.30
			50	12.50	6.30	630	0.42	10.3	29.30
			40	18.30	9.20	730	0.39	13.8	38.40
			35	26.00	13.00	910	0.31	21.4	56.10
				Test Section 9					
107	1140	0+2.4	400	1.00	0.50	380	0.44	3.3	8.80
	1710	+2.4	350	1.40	0.60	400	0.43	3.7	10.60
			300	1.60	0.80	480	0.39	5.3	14.70
			250	2.10	1.00	520	0.37	6.2	17.00
			200	2.50	1.30	500	0.38	5.8	16.00
120			150	3.60	1.80	540	0.36	7.5	20.40
			100	5.70	2.80	565	0.44	8.3	23.90
			80	7.00	3.50	560	0.44	8.1	23.30
			70	8.40	4.20	590	0.43	9.0	25.70
			50	13.20	6.60	660	0.41	11.3	31.90
			40	22.50	11.30	900	0.31	21.0	55.00
			35	28.00	14.00	995	0.24	25.6	63.50

(Sheet 5 of 5)

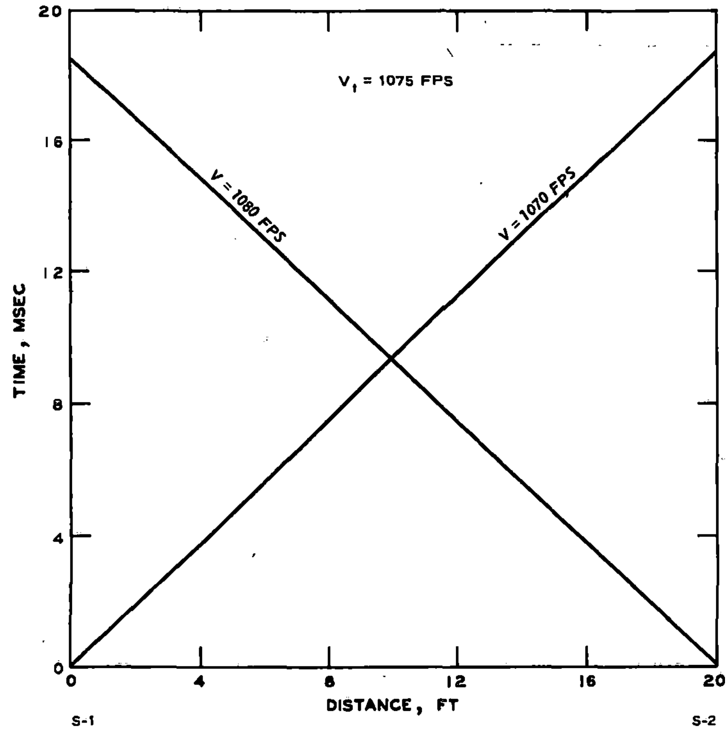


FIGURE B-1. POSTTRAFFIC REFRACTION SEISMIC TEST RESULTS, TRACK SECTION 1, STA 8534+75 (KTT EMBANKMENT)

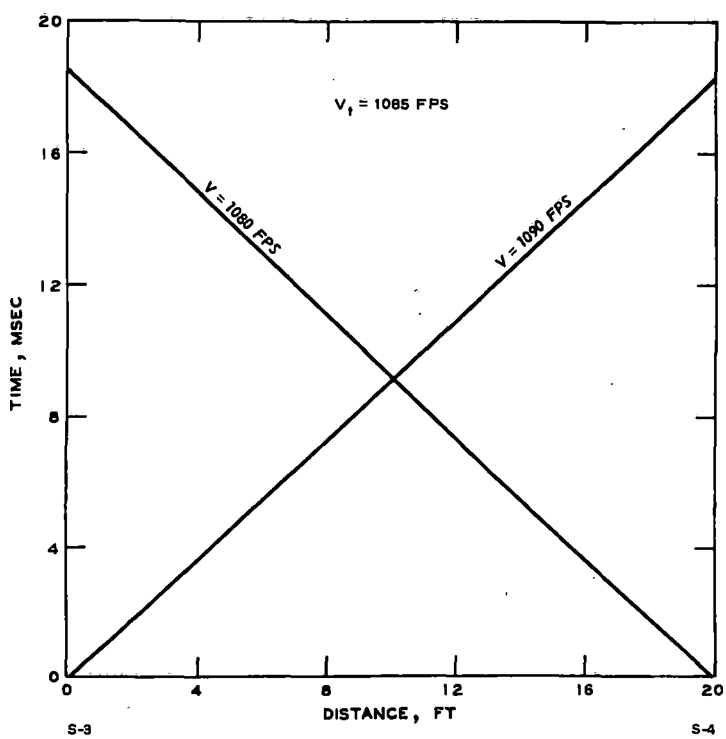


FIGURE B-2. POSTTRAFFIC REFRACTION SEISMIC TEST RESULTS, TRACK SECTION 2, STA 8531+62.5 (TEST LOCATION 2A, KTT EMBANKMENT)

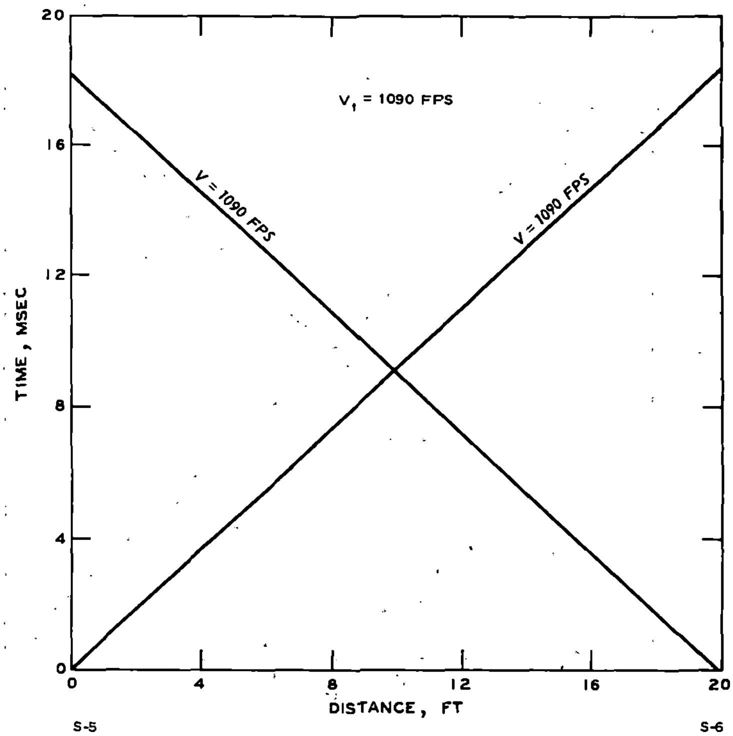


FIGURE B-3. POSTTRAFFIC REFRACTION SEISMIC TEST RESULTS, TRACK SECTION 2, STA 8535+15 (TEST LOCATION 2B, KTT EMBANKMENT)

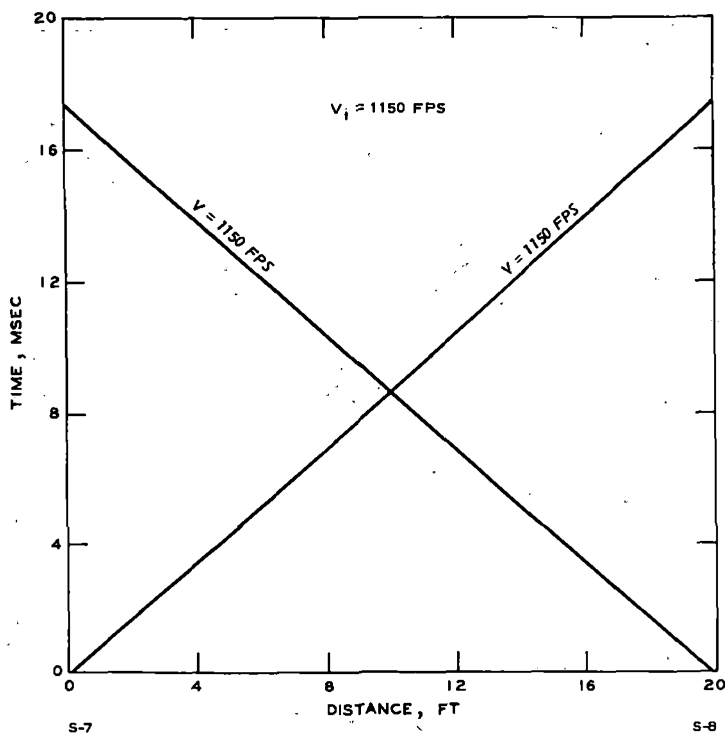


FIGURE B-4. POSTTRAFFIC REFRACTION SEISMIC TEST RESULTS, TRACK SECTION 3, STA 8540+19 (TEST LOCATION 3A, KTT EMBANKMENT)

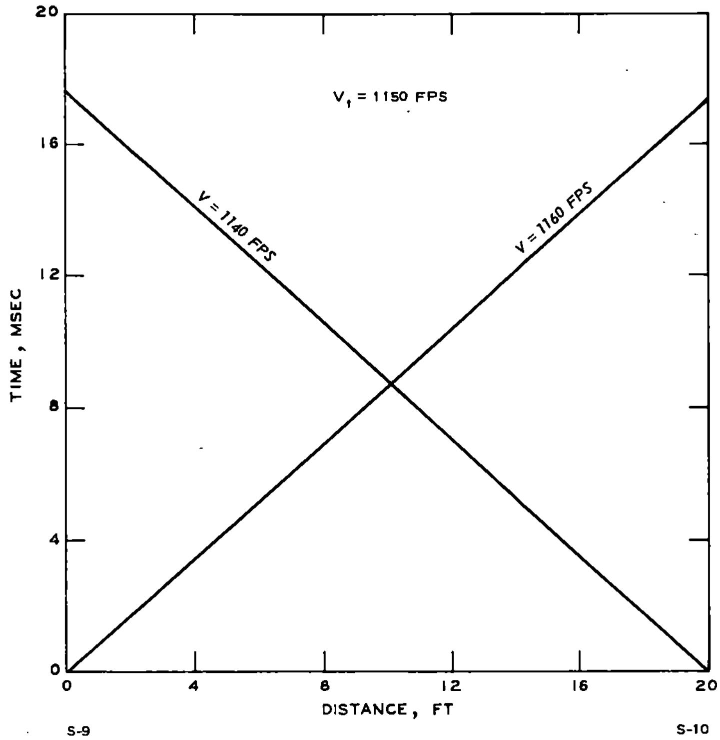


FIGURE B-5. POSTTRAFFIC REFRACTION SEISMIC TEST RESULTS, TRACK SECTION 3, STA 8542+50 (TEST LOCATION 3B, KTT EMBANKMENT)

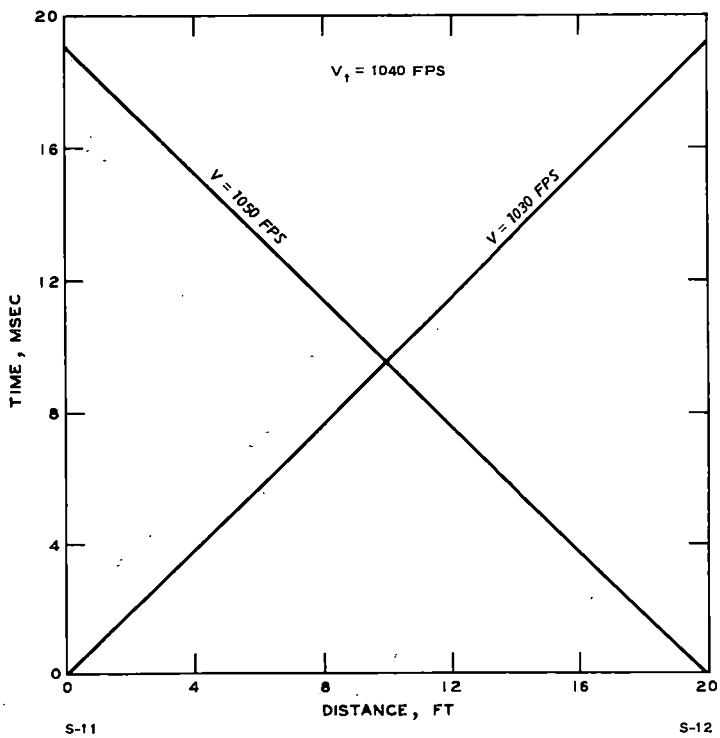


FIGURE B-6. POSTTRAFFIC REFRACTION SEISMIC TEST RESULTS, TRACK SECTION 4, STA 8547+79 (KTT EMBANKMENT)

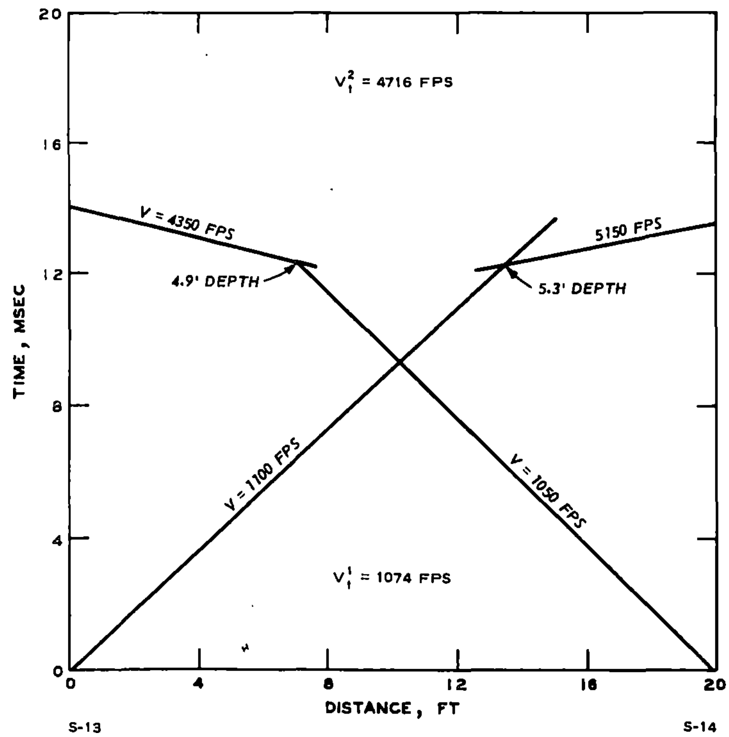


FIGURE B-7. POSTTRAFFIC REFRACTION SEISMIC TEST RESULTS, TRACK SECTION 5, STA 8558+30 (KTT EMBANKMENT)

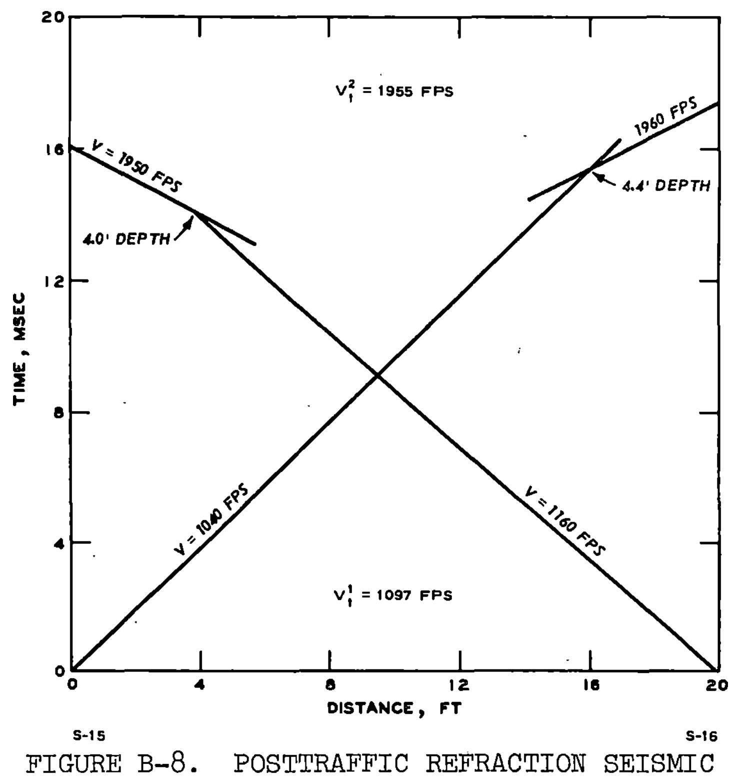


FIGURE B-8. POSTTRAFFIC REFRACTION SEISMIC TEST RESULTS, TRACK SECTION 7, STA 8576+42 (KTT EMBANKMENT)

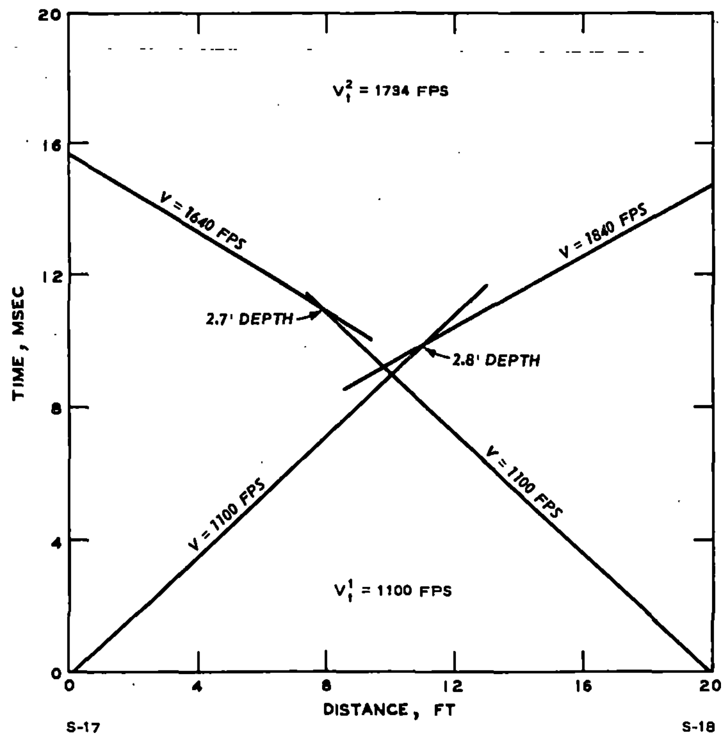


FIGURE B-9. POSTTRAFFIC REFRACTION SEISMIC TEST RESULTS, TRACK SECTION 8, STA 8587+00 (KTT EMBANKMENT)

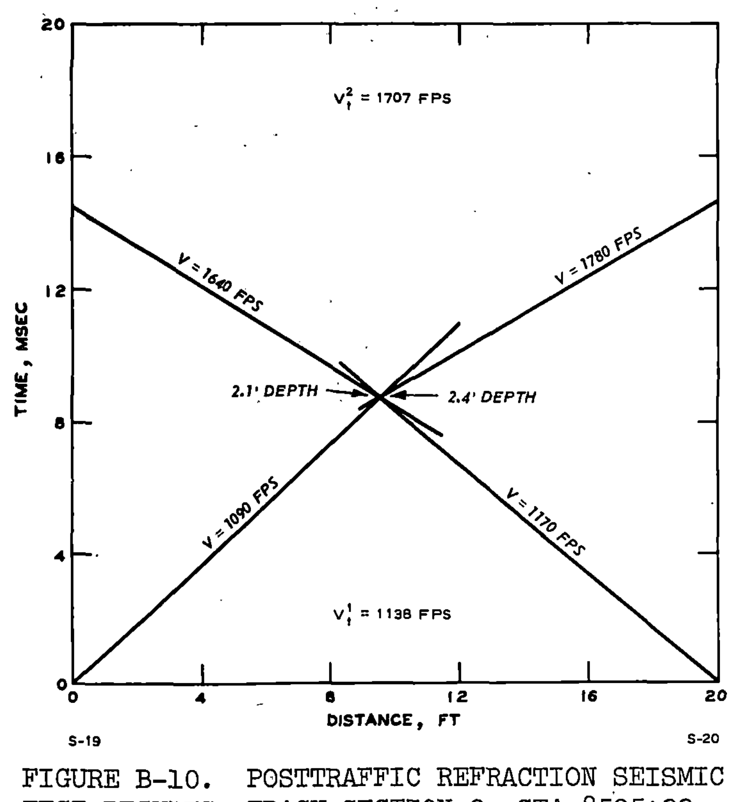


FIGURE B-10. POSTTRAFFIC REFRACTION SEISMIC TEST RESULTS, TRACK SECTION 9, STA 8595+33 (KTT EMBANKMENT)

FIGURE B-11. TYPICAL VIBROSEISMIC TEST CONFIGURATION

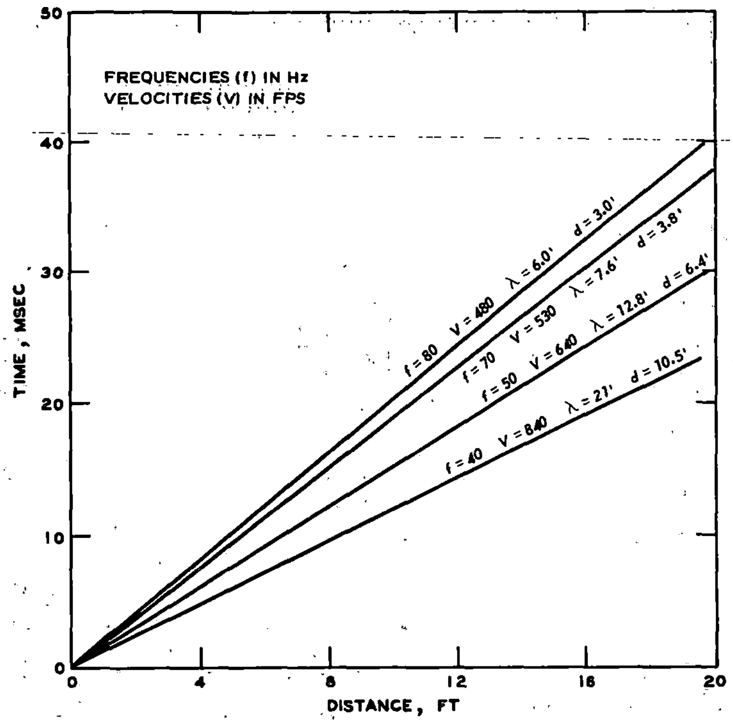


FIGURE B-12. TYPICAL VELOCITY DETERMINATIONS FROM VIBRATION TEST, POSTTRAFFIC, TRACK SECTION 3, STA 8540+09 (TEST LOCATION 3A, KTT EMBANKMENT)

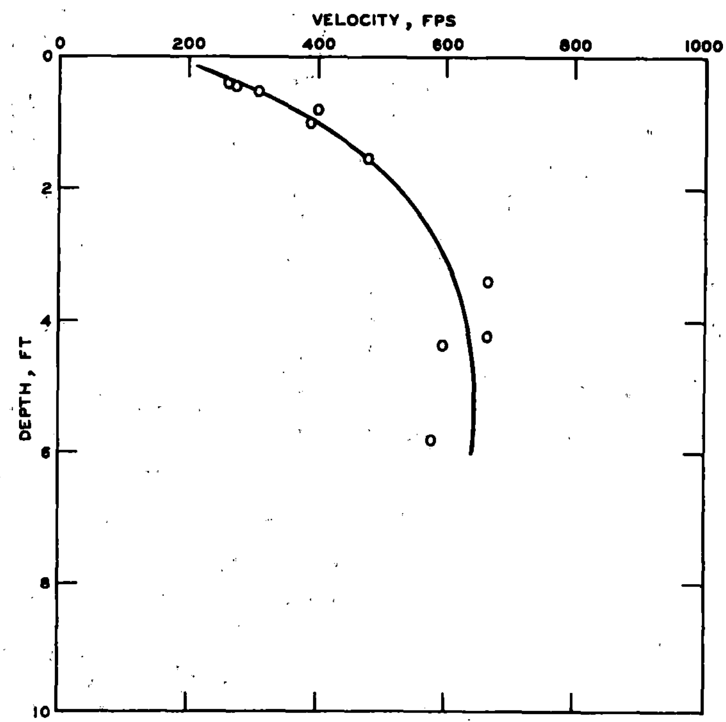


FIGURE B-13. POSTTRAFFIC SHEAR-WAVE VELOCITY RESULTS, TRACK SECTION 1, STA 8524+75 (KTT EMBANKMENT)

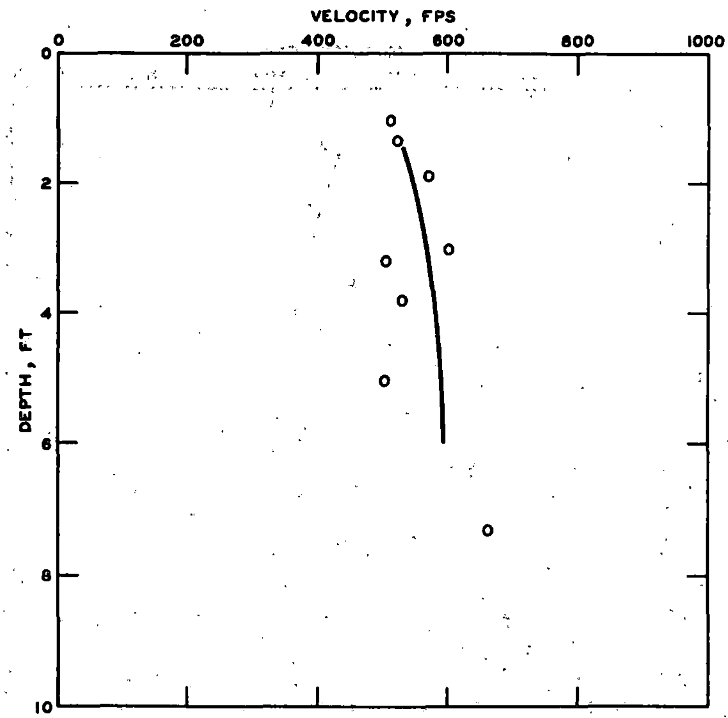


FIGURE B-14. POSTTRAFFIC SHEAR-WAVE VELOCITY RESULTS, TRACK SECTION 2, STA 8531+62.5 (TEST LOCATION 2A, KTT EMBANKMENT)

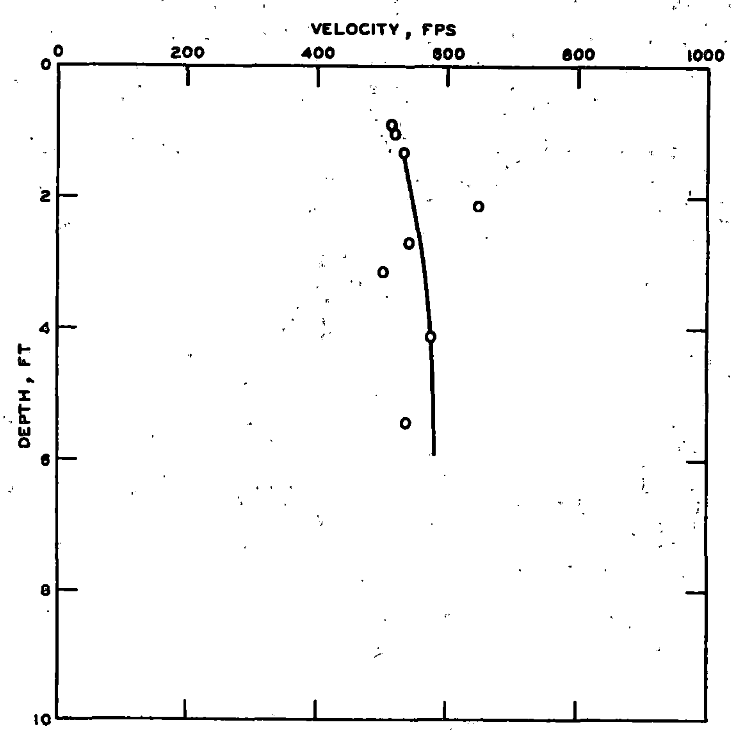


FIGURE B-15. POSTTRAFFIC SHEAR-WAVE VELOCITY RESULTS, TRACK SECTION 2, STA 8535+15 (TEST LOCATION 2B, KTT EMBANKMENT)

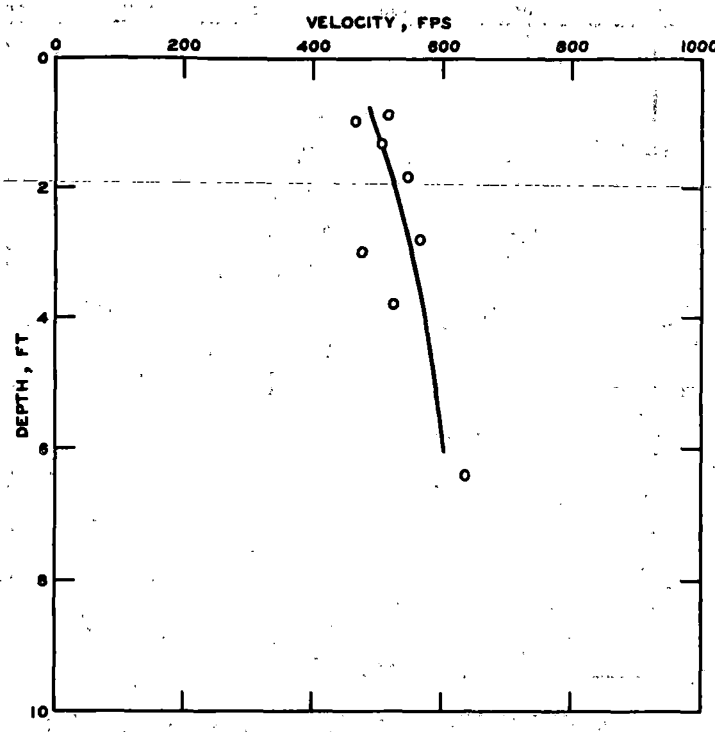


FIGURE B-16. POSTTRAFFIC SHEAR-WAVE VELOCITY RESULTS, TRACK SECTION 3, STA 8540+09 (TEST LOCATION 3A, KTT EMBANKMENT)

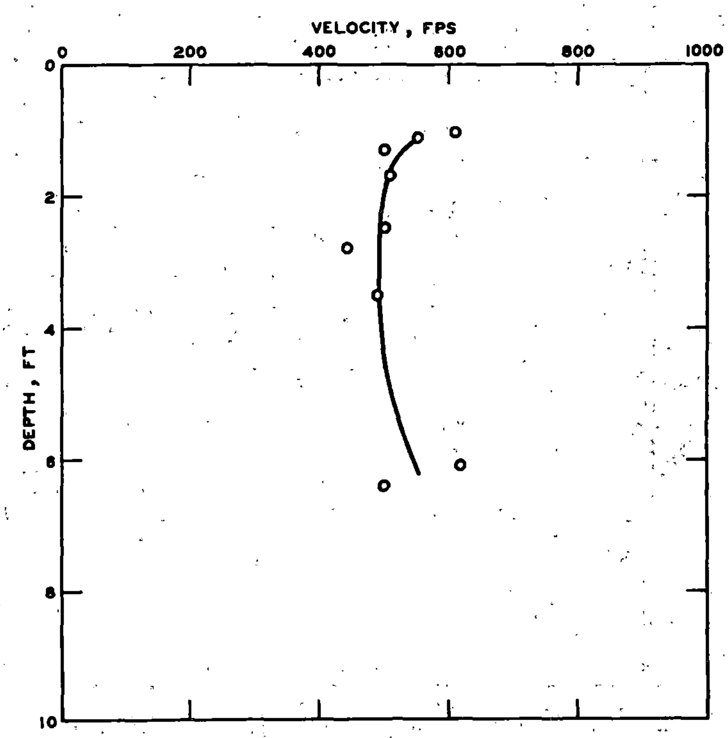


FIGURE B-17. POSTTRAFFIC SHEAR-WAVE VELOCITY RESULTS, TRACK SECTION 3, STA 8542+05 (TEST LOCATION 3B, KTT EMBANKMENT)

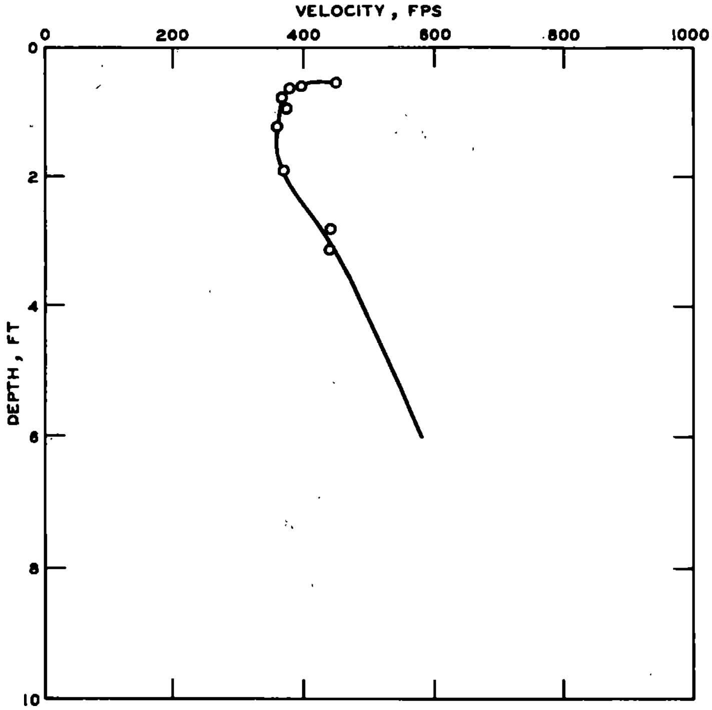


FIGURE B-18. POSTTRAFFIC SHEAR-WAVE VELOCITY RESULTS, TRACK SECTION 4, STA 8547+79 (KTT EMBANKMENT)

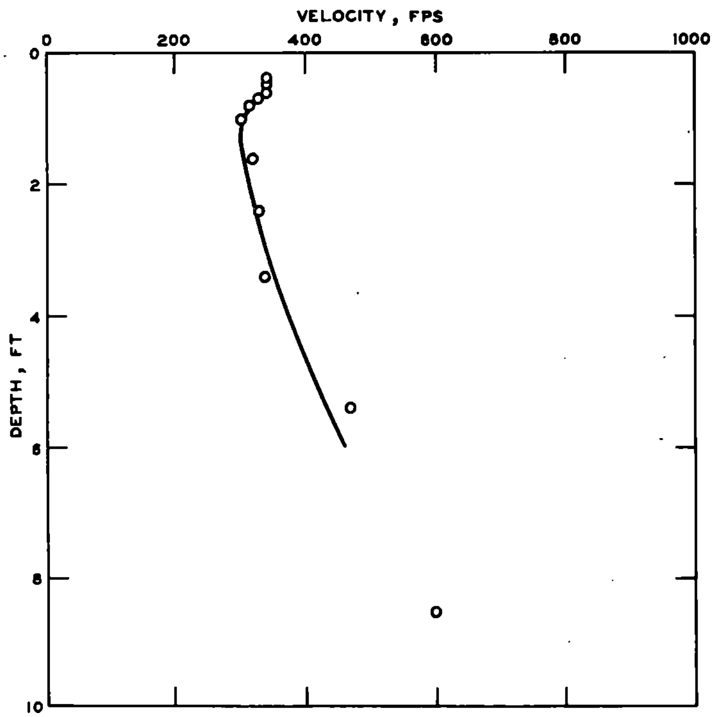


FIGURE B-19. POSTTRAFFIC SHEAR-WAVE VELOCITY RESULTS, TRACK SECTION 5, STA 8558+30 (KTT EMBANKMENT)

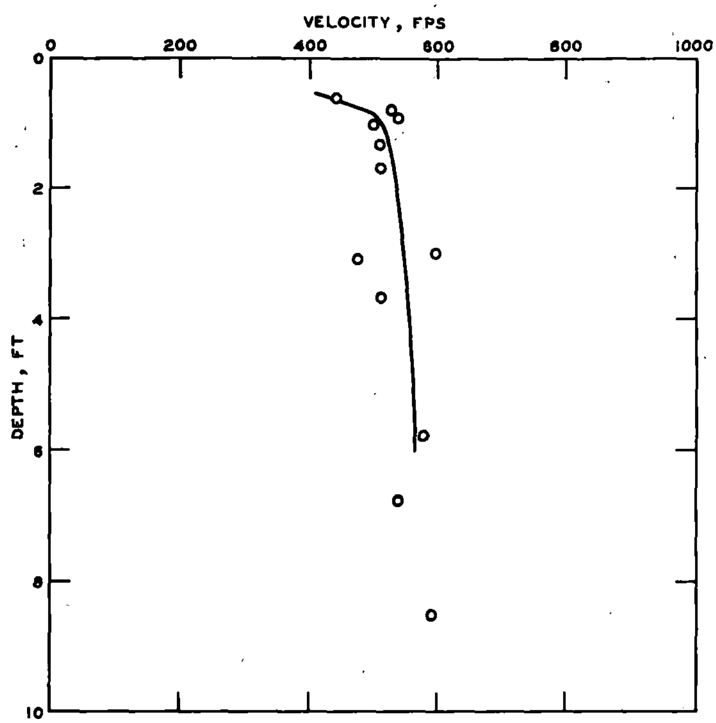


FIGURE B-20. POSTTRAFFIC SHEAR-WAVE VELOCITY RESULTS, TRACK SECTION 7, STA 8576+42 (KTT EMBANKMENT)

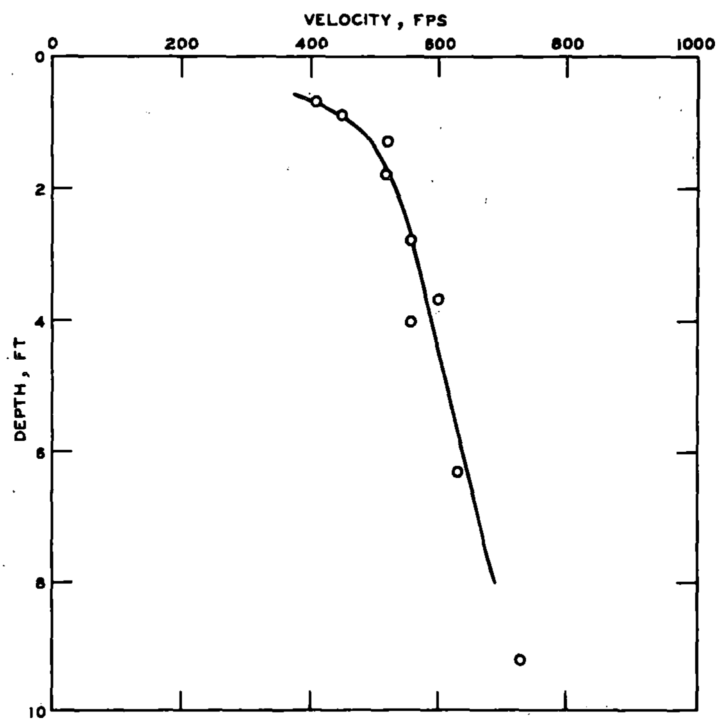


FIGURE B-21. POSTTRAFFIC SHEAR-WAVE VELOCITY RESULTS, TRACK SECTION 8, STA 8587+00 (KTT EMBANKMENT)

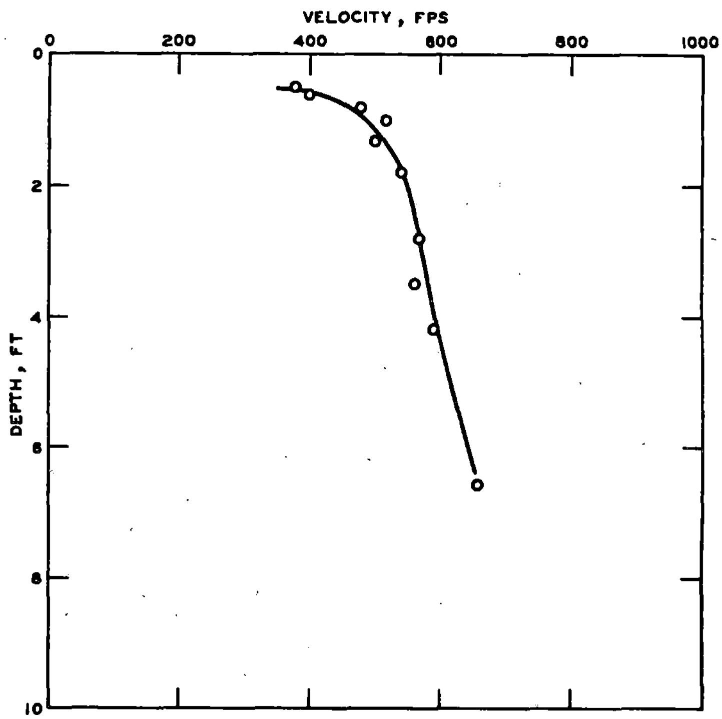


FIGURE B-22. POSTTRAFFIC SHEAR-WAVE VELOCITY RESULTS, TRACK SECTION 9, STA 8595+33 (KTT EMBANKMENT)

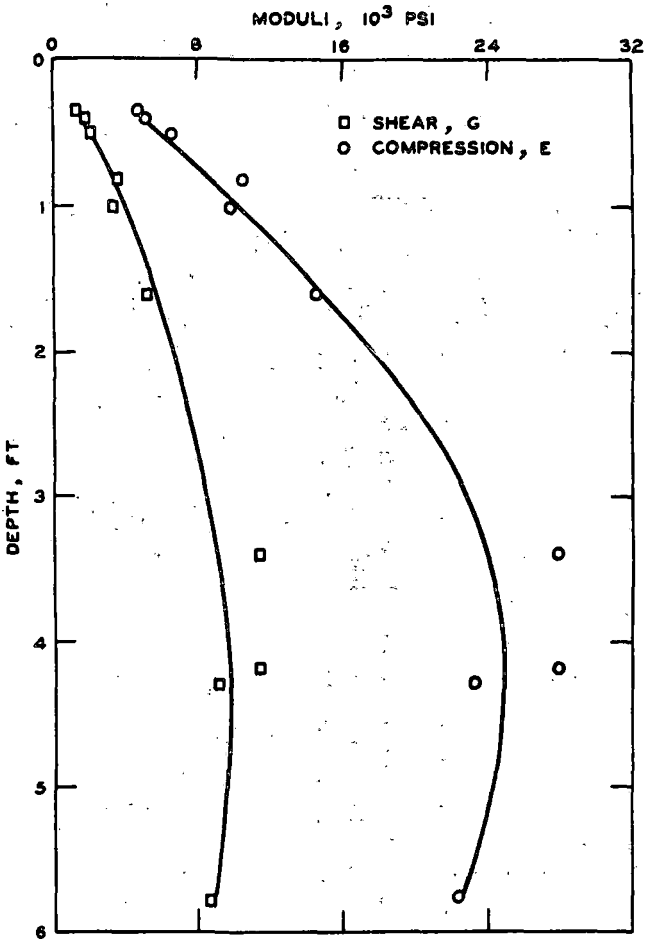


FIGURE B-23. POSTTRAFFIC PLOTS OF ELASTIC MODULI VERSUS DEPTH, TRACK SECTION 1, STA 8524+75 (KTT EMBANKMENT)

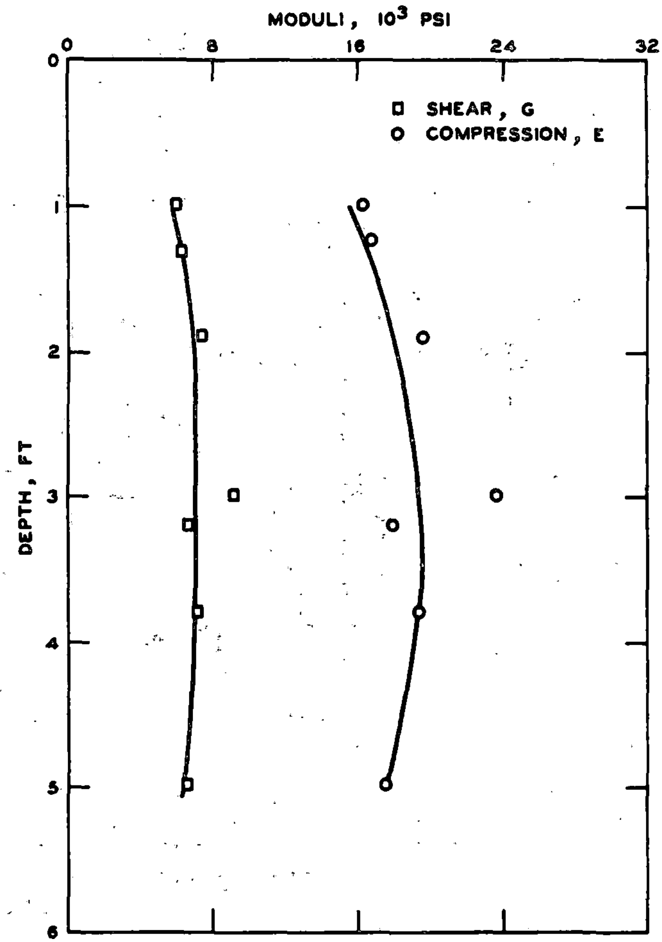


FIGURE B-24. POSTTRAFFIC PLOTS OF ELASTIC MODULI VERSUS DEPTH, TRACK SECTION 2, STA 8531+62.5 (TEST LOCATION 2A, KTT EMBANKMENT)

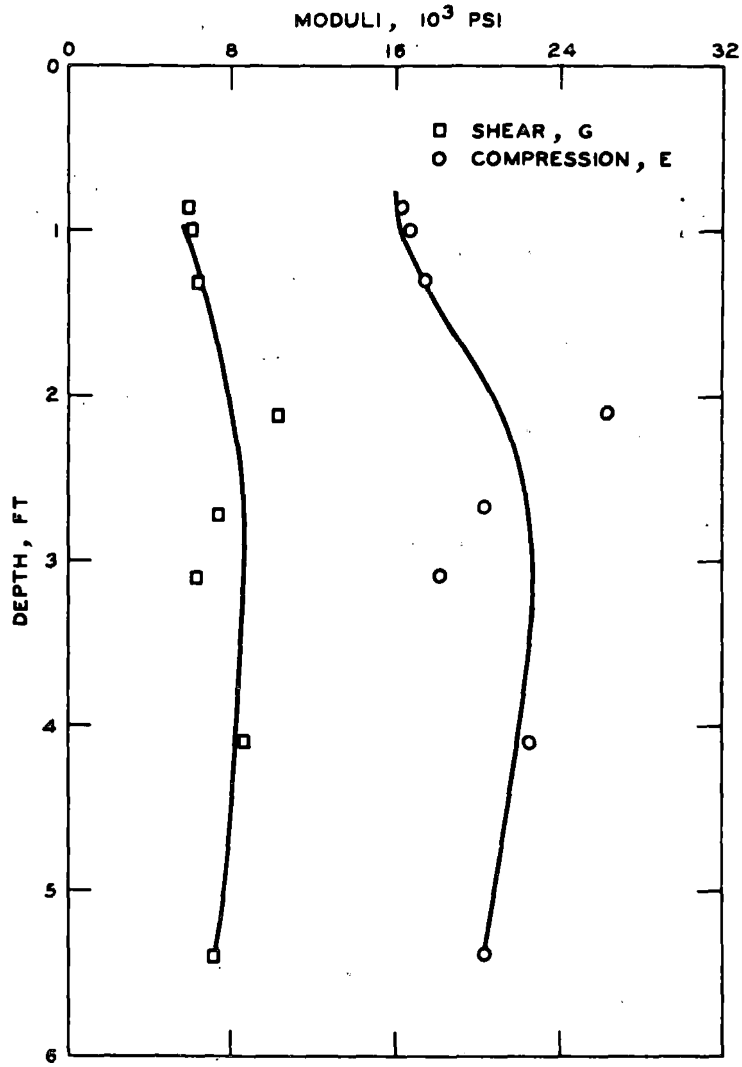


FIGURE B-25. POSTTRAFFIC PLOTS OF ELASTIC MODULI VERSUS DEPTH, TRACK SECTION 2, STA 8535+15 (TEST LOCATION 2B, KTT EMBANKMENT)

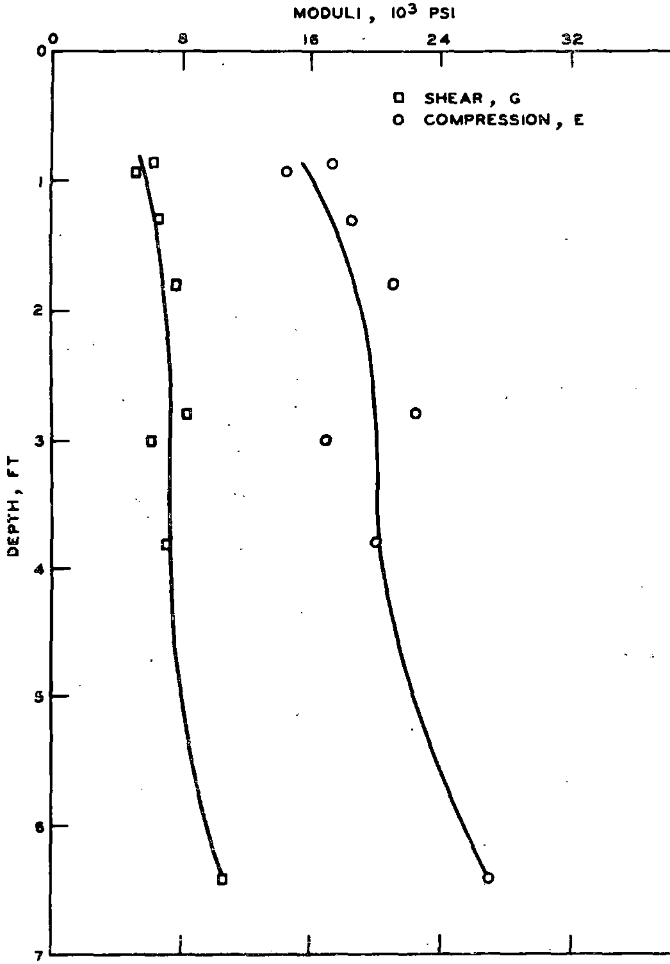


FIGURE B-26. POSTTRAFFIC PLOTS OF ELASTIC MODULI VERSUS DEPTH, TRACK SECTION 3, STA 8540+19 (TEST LOCATION 3A, KTT EMBANKMENT)

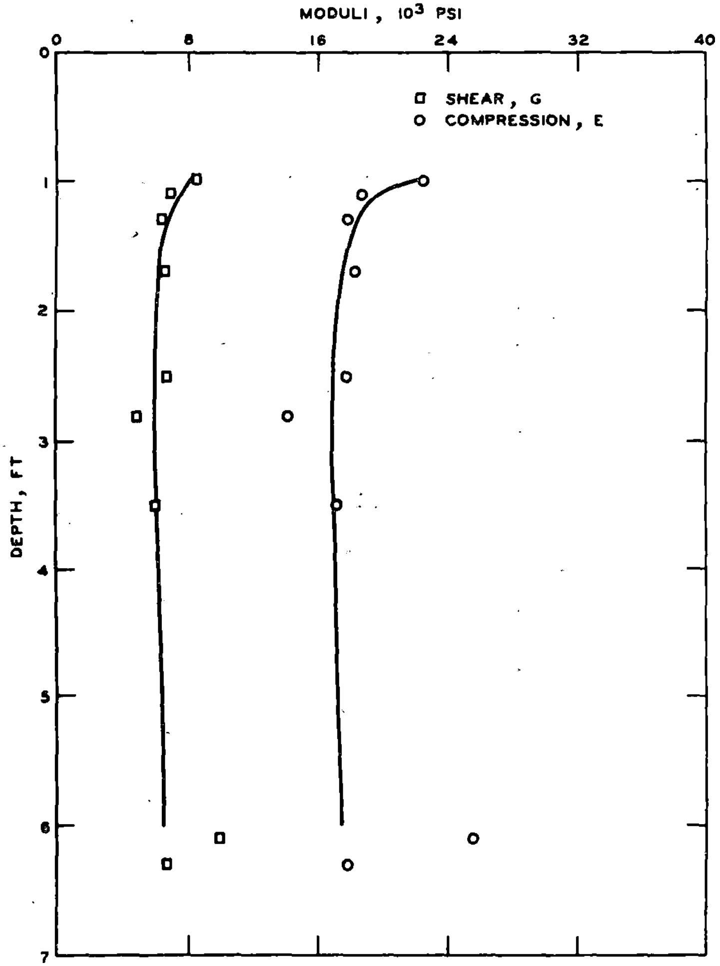


FIGURE B-27. POSTTRAFFIC PLOTS OF ELASTIC MODULI VERSUS DEPTH, TRACK SECTION 3, STA 8542+50 (TEST LOCATION 3B, KTT EMBANKMENT)

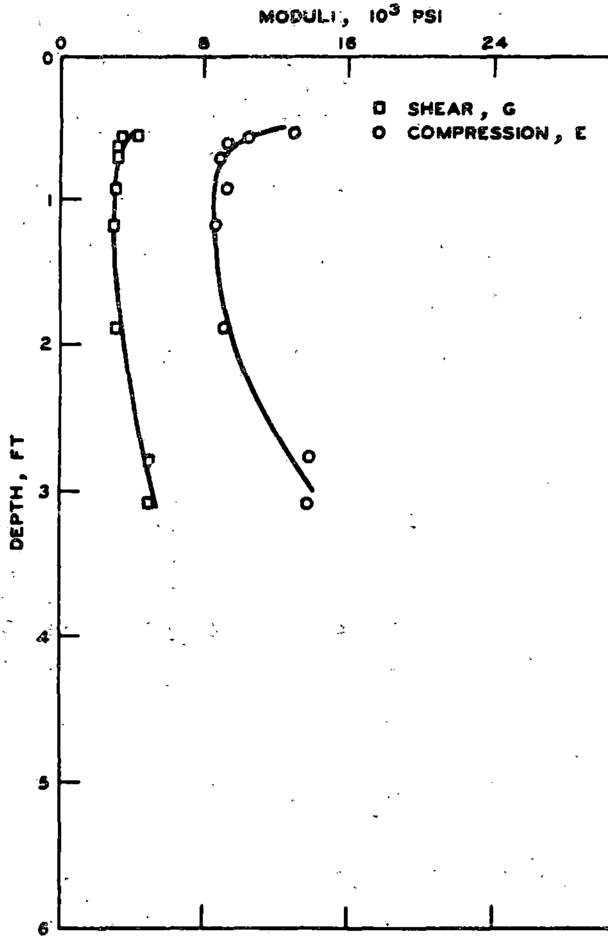


FIGURE B-28. POSTTRAFFIC PLOTS OF ELASTIC MODULI VERSUS DEPTH, TRACK SECTION 4, STA 8547+79 (KTT EMBANKMENT)

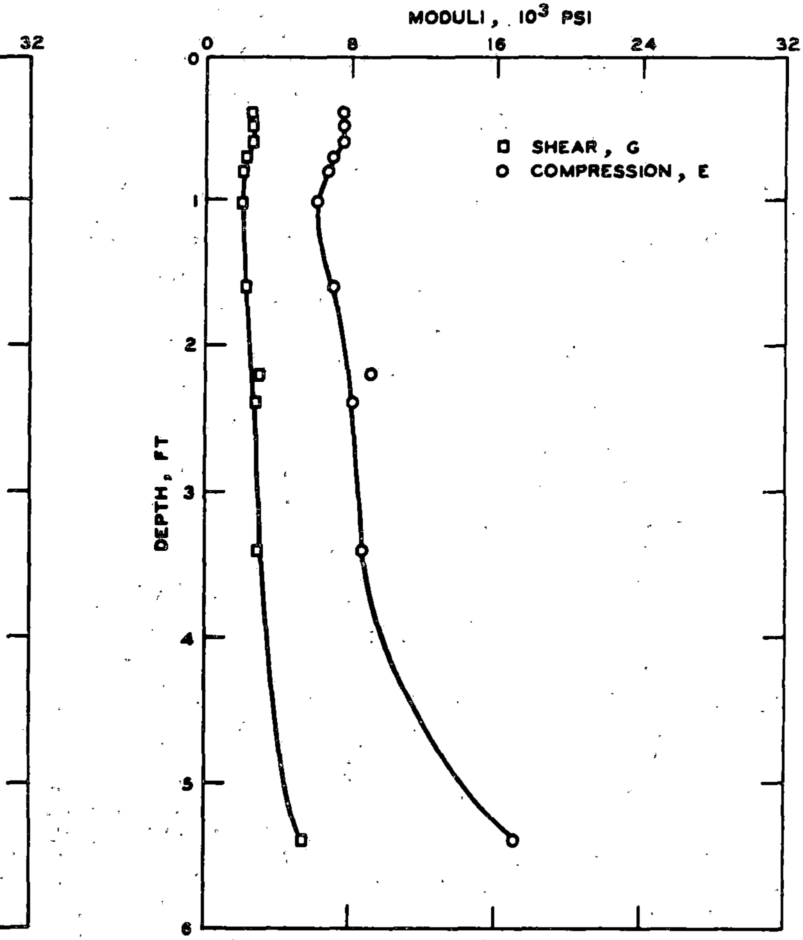


FIGURE B-29. POSTTRAFFIC PLOTS OF ELASTIC MODULI VERSUS DEPTH, TRACK SECTION 5, STA 8558+30 (KTT EMBANKMENT)

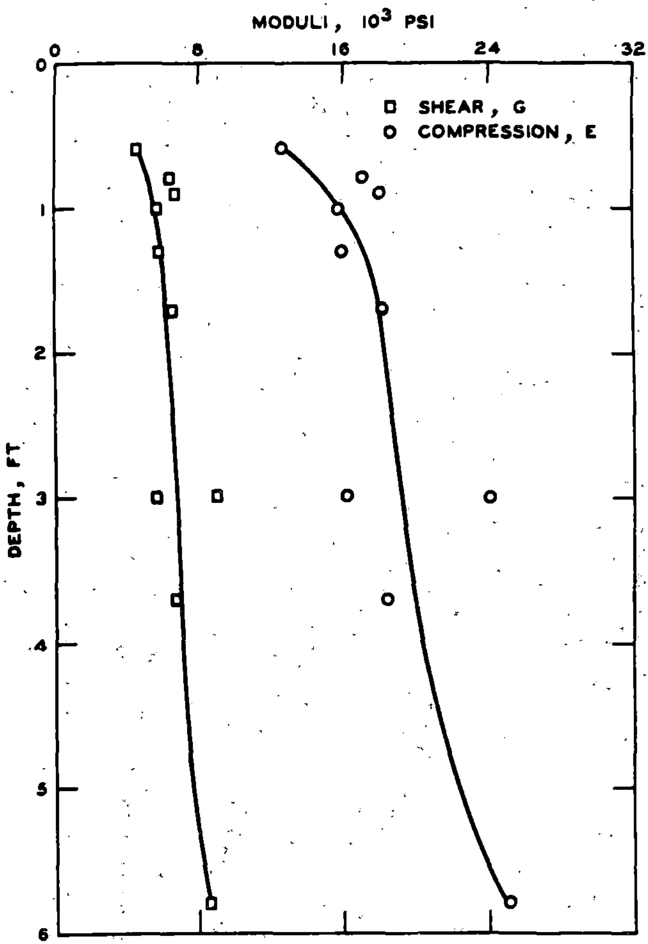


FIGURE B-30. POSTTRAFFIC PLOTS OF ELASTIC MODULI VERSUS DEPTH, TRACK SECTION 7, STA 8576+42 (KTT EMBANKMENT)

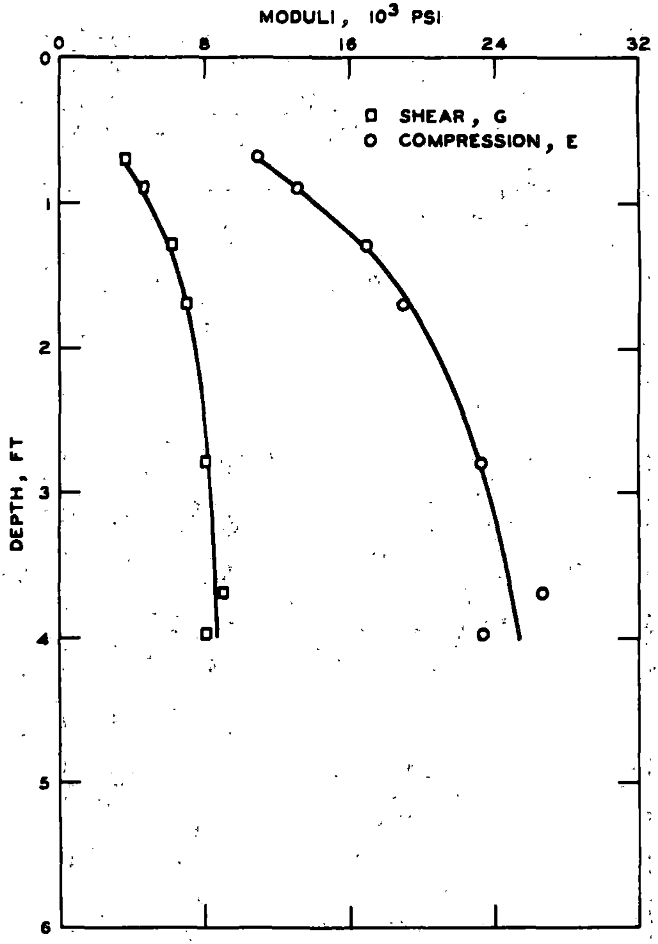


FIGURE B-31. POSTTRAFFIC PLOTS OF ELASTIC MODULI VERSUS DEPTH, TRACK SECTION 8, STA 8587+00 (KTT EMBANKMENT)

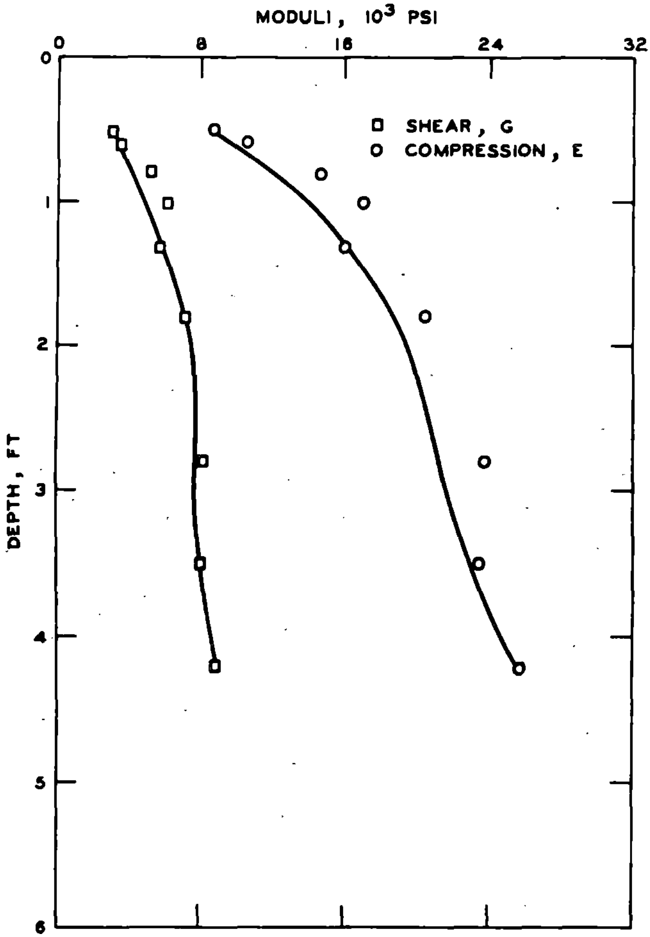


FIGURE B-32. POSTTRAFFIC PLOTS OF ELASTIC MODULI VERSUS DEPTH, TRACK SECTION 9, STA 8595+33 (KTT EMBANKMENT)

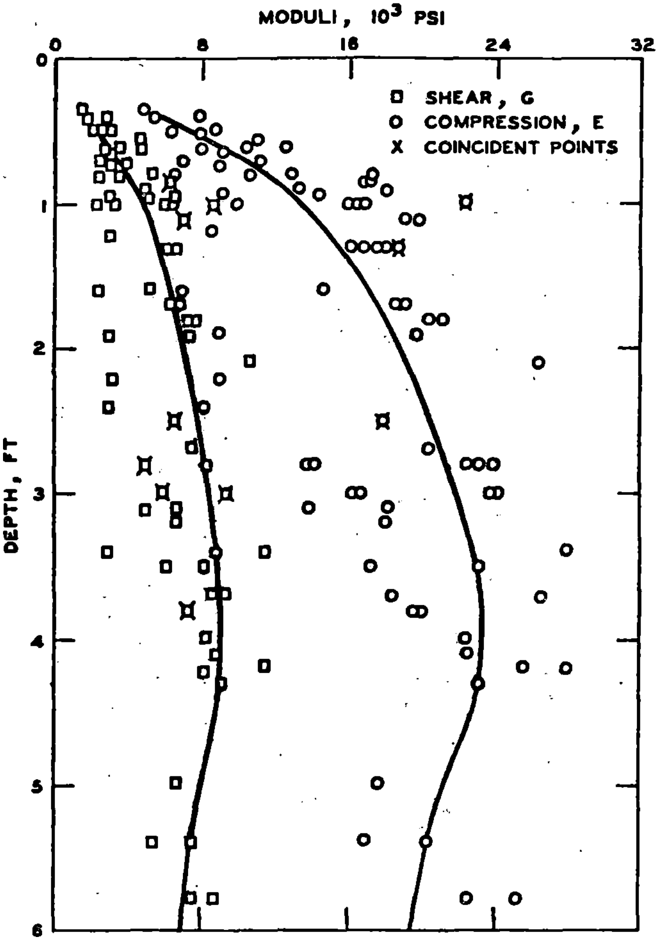


FIGURE B-33. POSTTRAFFIC PLOTS OF ELASTIC MODULI VERSUS DEPTH, TRACK SECTIONS 1 THROUGH 9 (KTT EMBANKMENT)

APPENDIX C: DUTCH CONE PENETROMETER TESTS

General

The Dutch cone penetrometer provides a measure of foundation strength in terms of penetration resistance versus depth. For purposes of the KTT Postmortem Investigation, a total of 97 subgrade soundings were made at intervals along the length of the KTT embankment. This work was accomplished in the period 5-13 May 1976.

Test Plan

Measurements of penetration resistance in the embankment were made for the following purposes:

1. To provide an index of embankment uniformity throughout its length.
2. To determine whether soil conditions, measured in terms of penetration resistance, would reflect the variations in strength believed to exist beneath the track structures.

In order to assess embankment uniformity, soundings were made at intervals of approximately 200 ft throughout the length of the KTT. At each test location, two or three soundings were made in a pattern selected to typify soil conditions in highly stressed, moderately stressed, and/or relatively unstressed areas of the subgrade beneath each track structure. For example, the subgrade beneath the rail seats of crossties or control joints of beam and slab structures would be subjected to higher traffic induced stresses than other areas of the foundation.

Field Testing

A standard friction jacket Dutch cone, whose penetrating action is shown in Figure C-1, was used throughout. This cone permits readings of both point and friction jacket resistances for each penetration drive increment. Both point and friction resistances were recorded, but only point resistance data will be presented. The skid-mounted, portable Dutch cone penetrometer used in the KTT work is shown in Figure C-2. The thrust to push the cone is provided by a hydraulic ram which is powered by a gasoline engine driven hydraulic pump. The engine, pump, and ram are skid mounted in one unit. The ram is fitted with a drivehead, which contains force measurement gages. Operation of the cone is controlled using an inner rod and outer casing system. Both the inner rods and outer casings are in 1-m lengths. The inner rods transfer force to the cone point, which after 1.5 in. of travel engages the friction sleeve. The sleeve and point move together for a further 1.5 in. of travel, at which time the drive is complete. The cone and cone-sleeve travel is continuous at a rate of 2 cm/sec. The outer casing is used to telescope the cone and sleeve, which are then advanced to the next test depth. This unit was designed to be used with soil anchors, which react the uplift forces generated during sounding. This configuration was not suitable for purposes of the KTT investigation, which involved relatively shallow, but numerous, penetrations. Instead, the skid unit was adapted to a platform which included two 2000-lb lead weights, intended to function as reaction masses during penetration. A forklift was used to transport the apparatus to each test location in the conventional (tie) track sections as shown in Figure C-3. A crane was used to position the penetrometer in the nonconventional track sections (the rail fastener studs projecting from the structures in Track Sections 4, 5, and 7 interfered with the forklift).

At each test location the ballast material was first removed by a tractor-mounted backhoe. The Dutch cone apparatus was next positioned over the desired location, and readings of penetration resistance were made at 6-in. intervals from the ballast-subgrade interface to 6 ft in depth. Measurements of penetration resistance were made electronically rather than by reading the force gages supplied with the penetrometer. The force required to push the cone was measured with a calibrated force transducer which was mounted in the penetrometer drivehead. Vertical displacement of the cone was measured with a linear potentiometer, which was attached to the drivehead and referenced to the frame of the apparatus. Both force and displacement were recorded on an X-Y plotter.

Data Reduction

The average drive force, in pounds, required to push the cone 1.5 in. at each penetration depth was picked from the X-Y plot. This force was divided by the projected cross-sectional area of the cone, and the result, in pounds per square inch, was converted to tons per square foot. Figures C-4-C-41 present results of the penetrometer soundings in plots of penetration resistance versus depth in the embankment. Sounding locations are given in terms of both track section and KTT survey station.

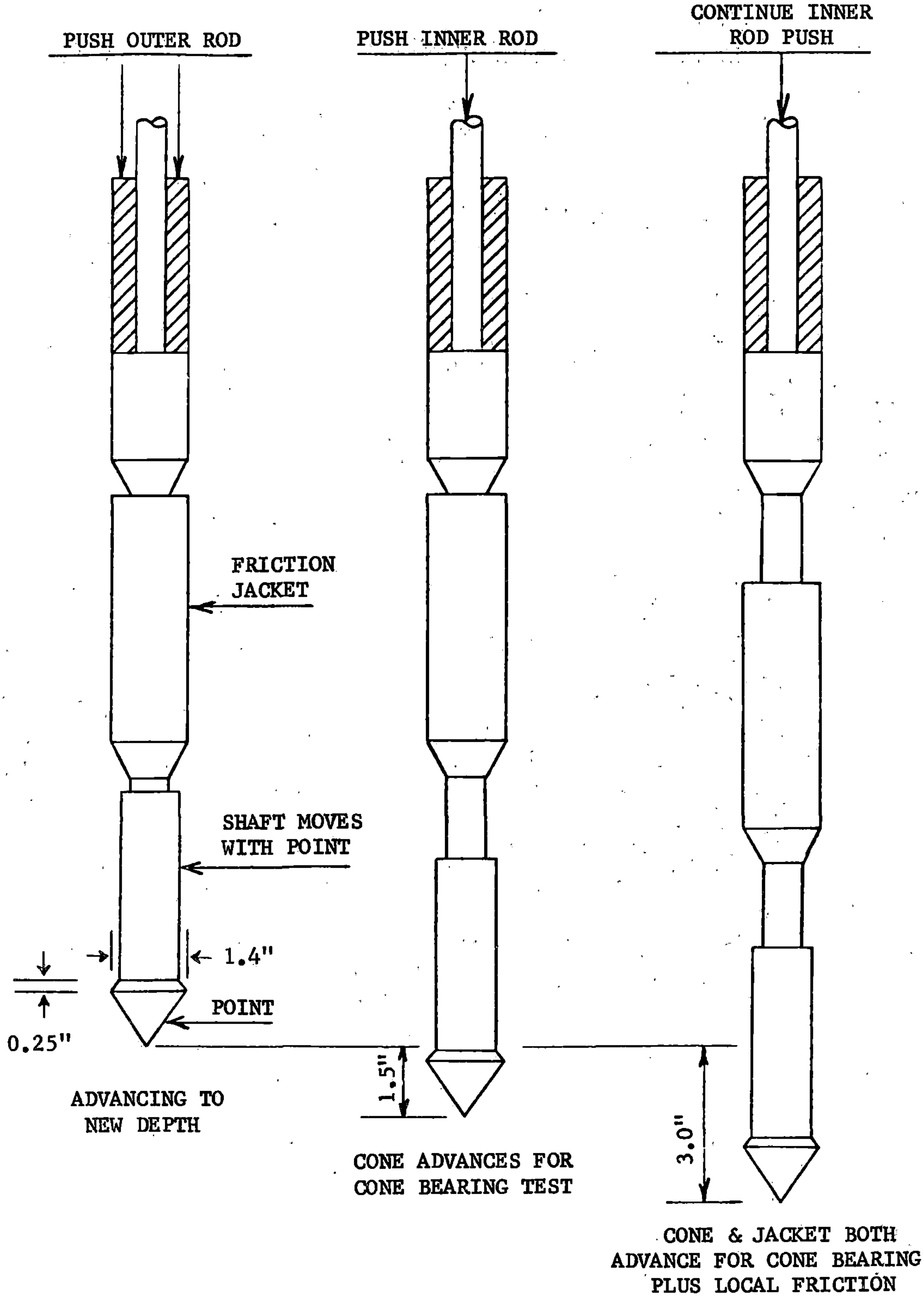


FIGURE C-1. ACTION OF FRICTION JACKET CONE

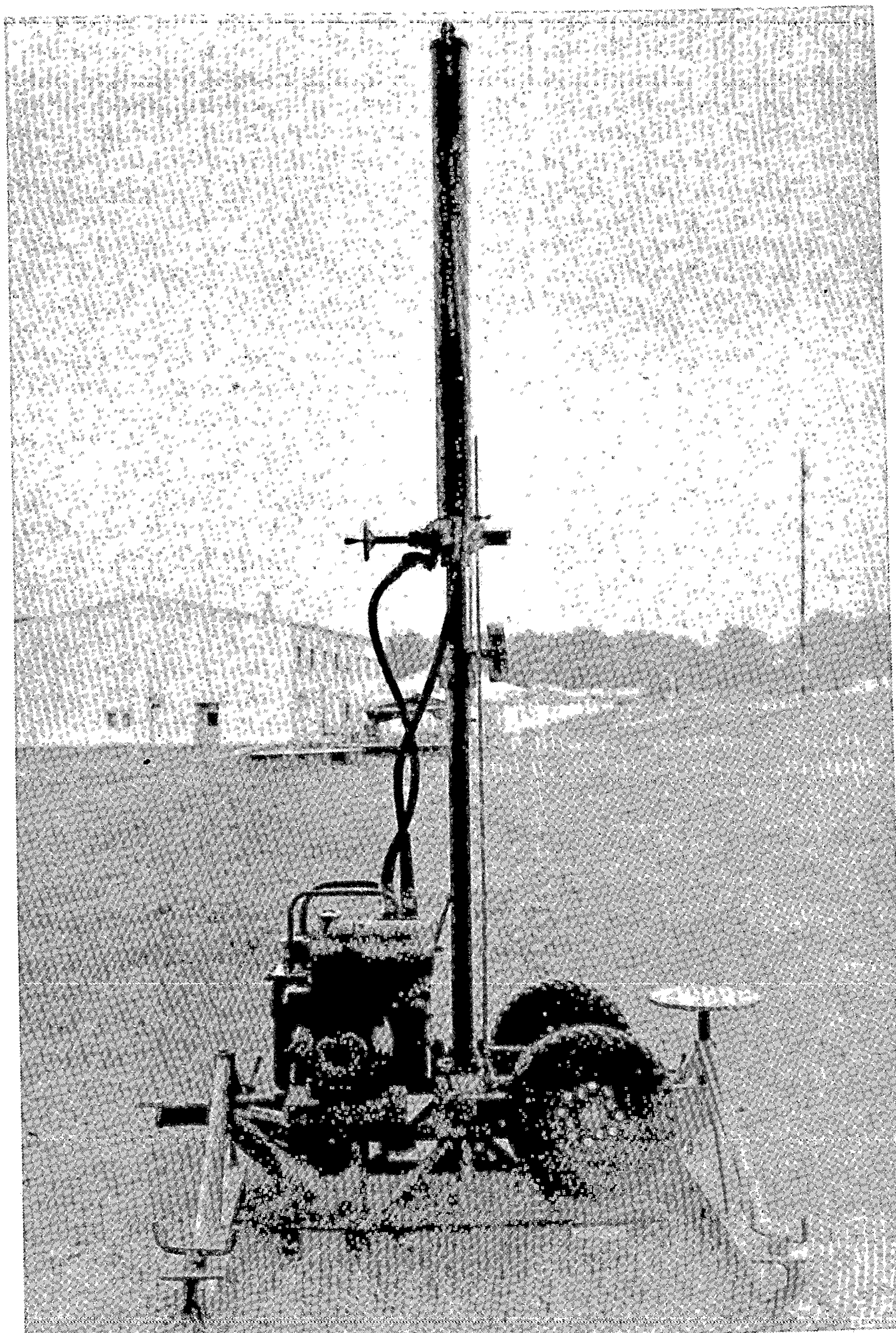


FIGURE C-2. PORTABLE DUTCH CONE PENETROMETER

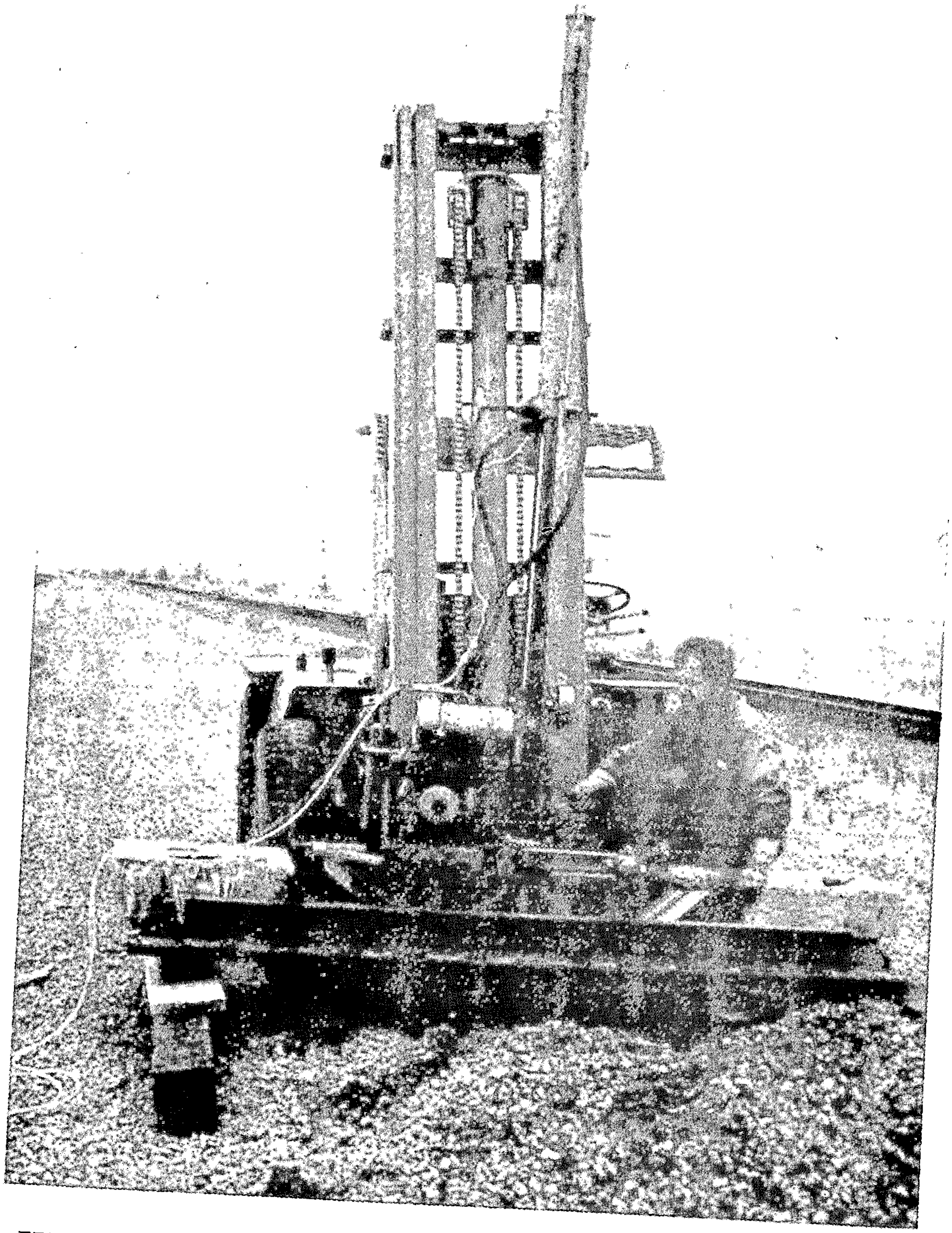


FIGURE C-3. MODIFIED DUTCH CONE PENETROMETER AT TEST LOCATION IN TRACK SECTION 3

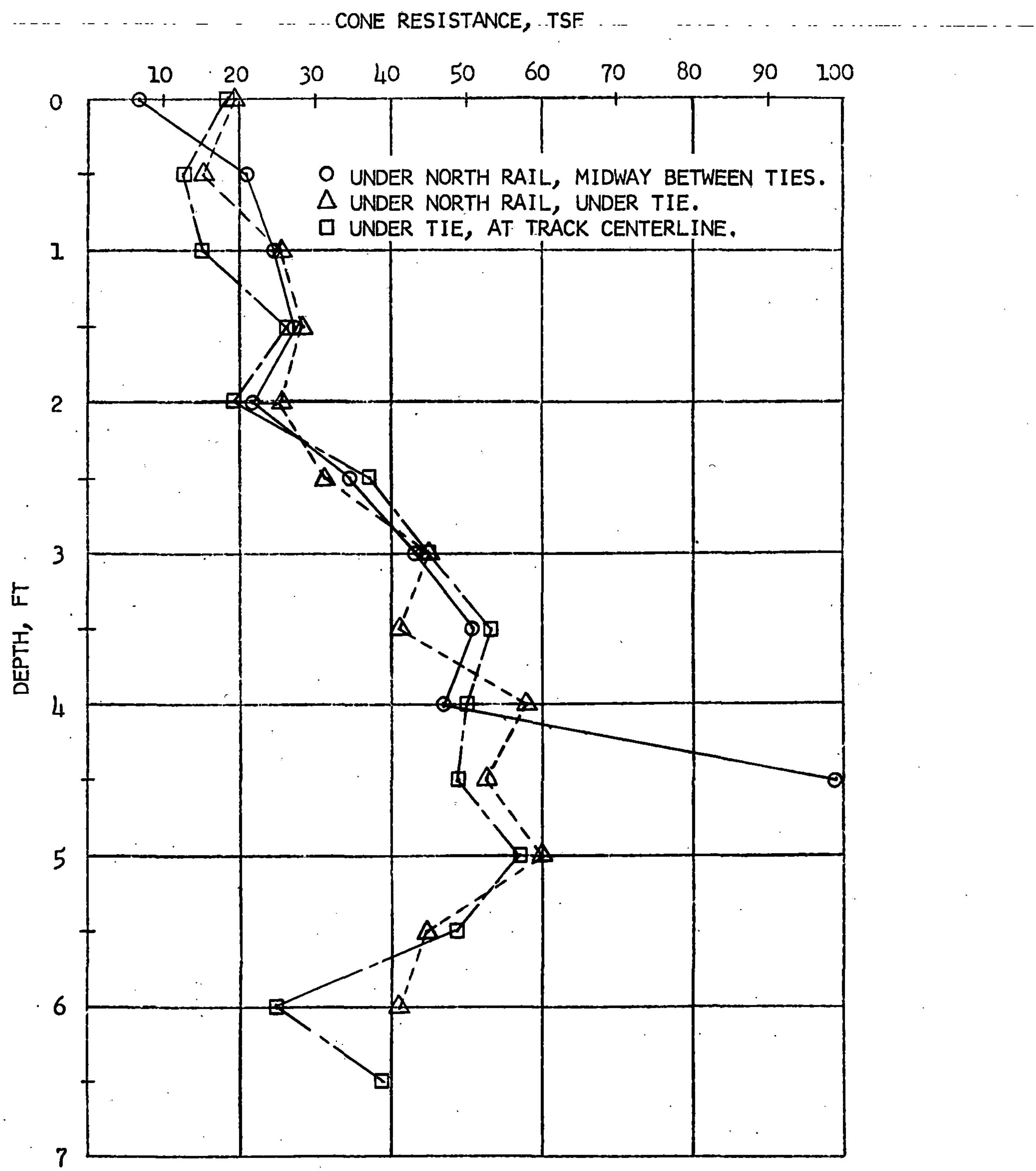


FIGURE C-4. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 1, STA 8521+01

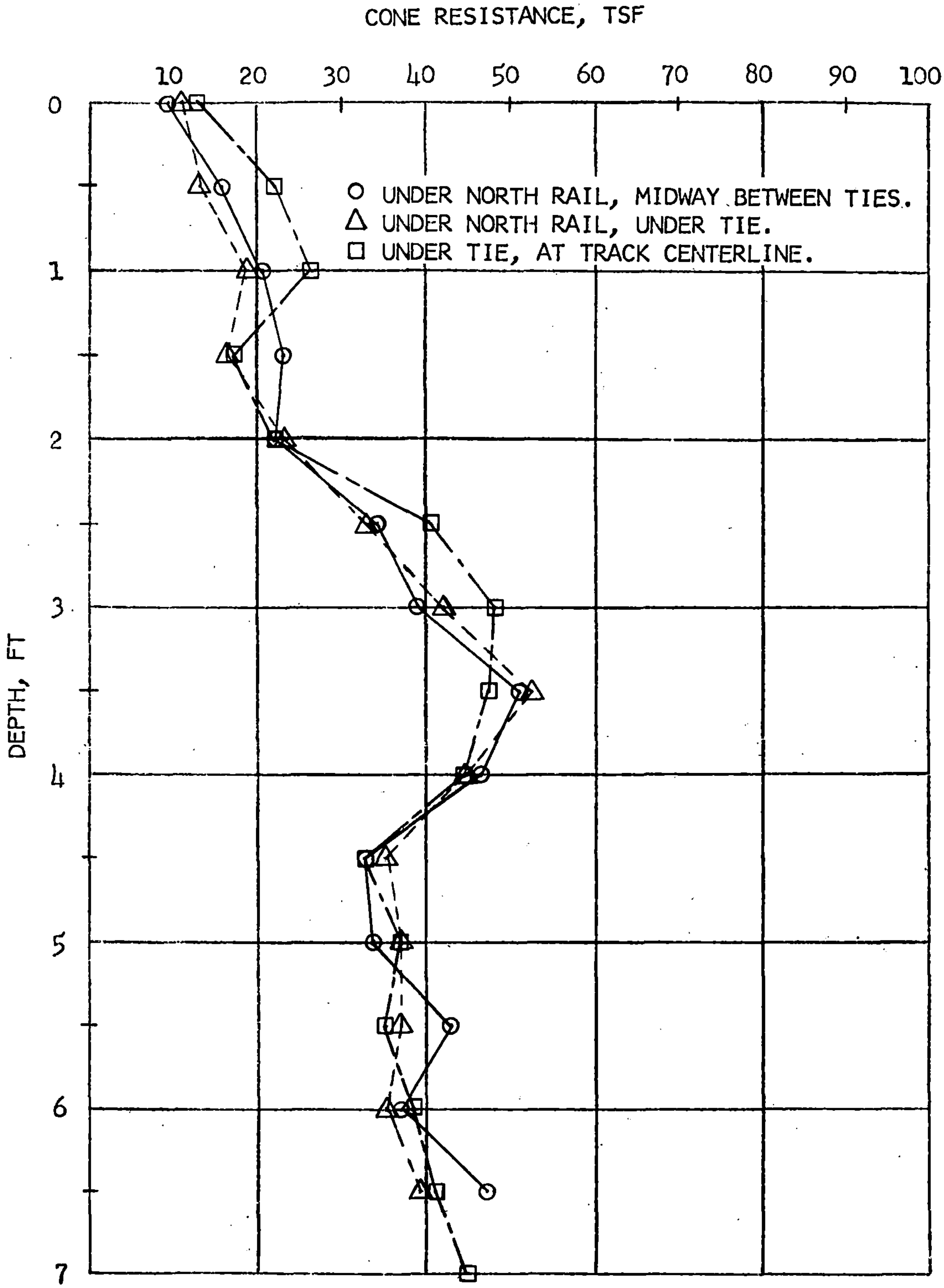


FIGURE C-5. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 1, STA 8523+00

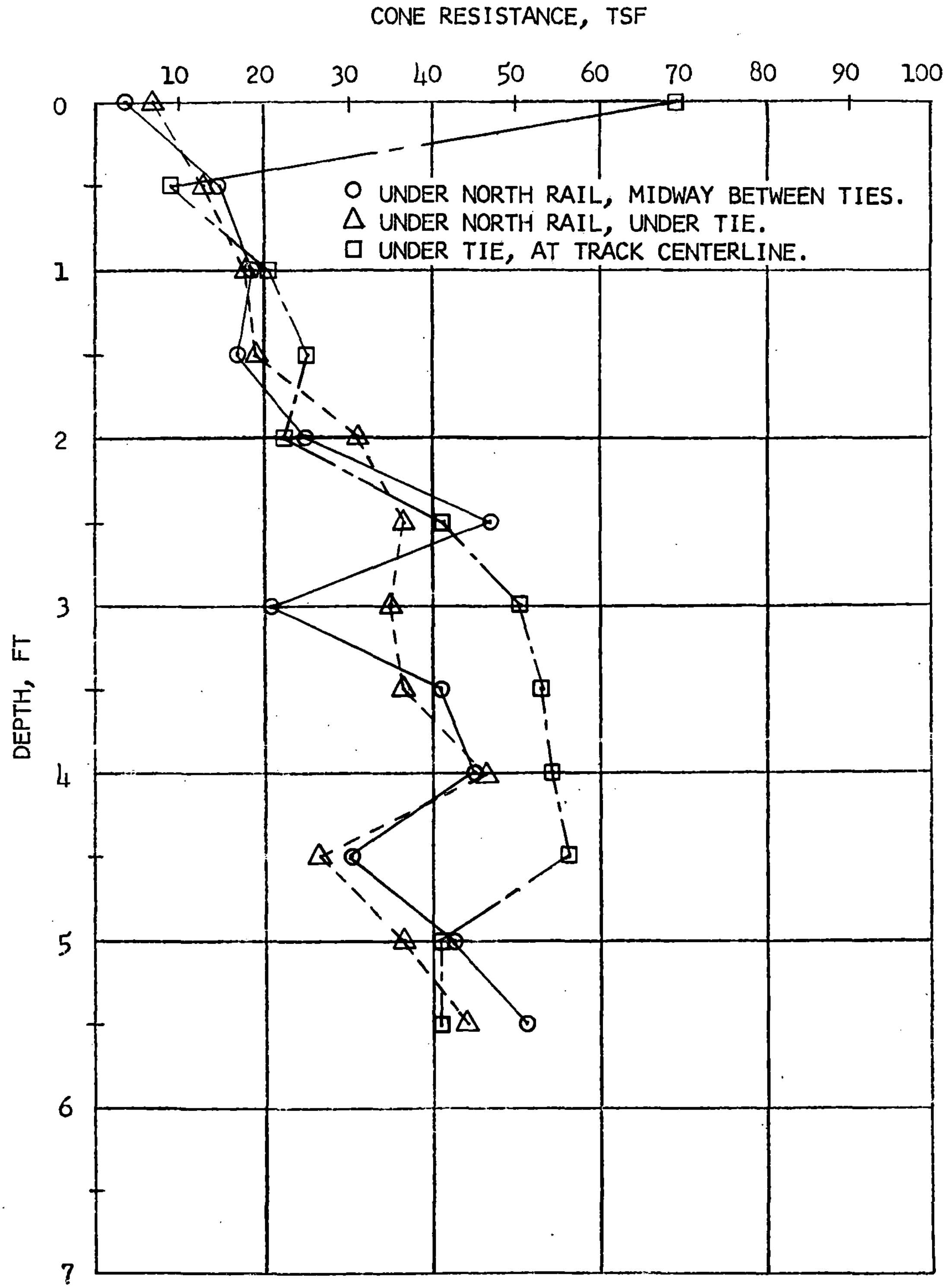


FIGURE C-6. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 1, STA 8525+00

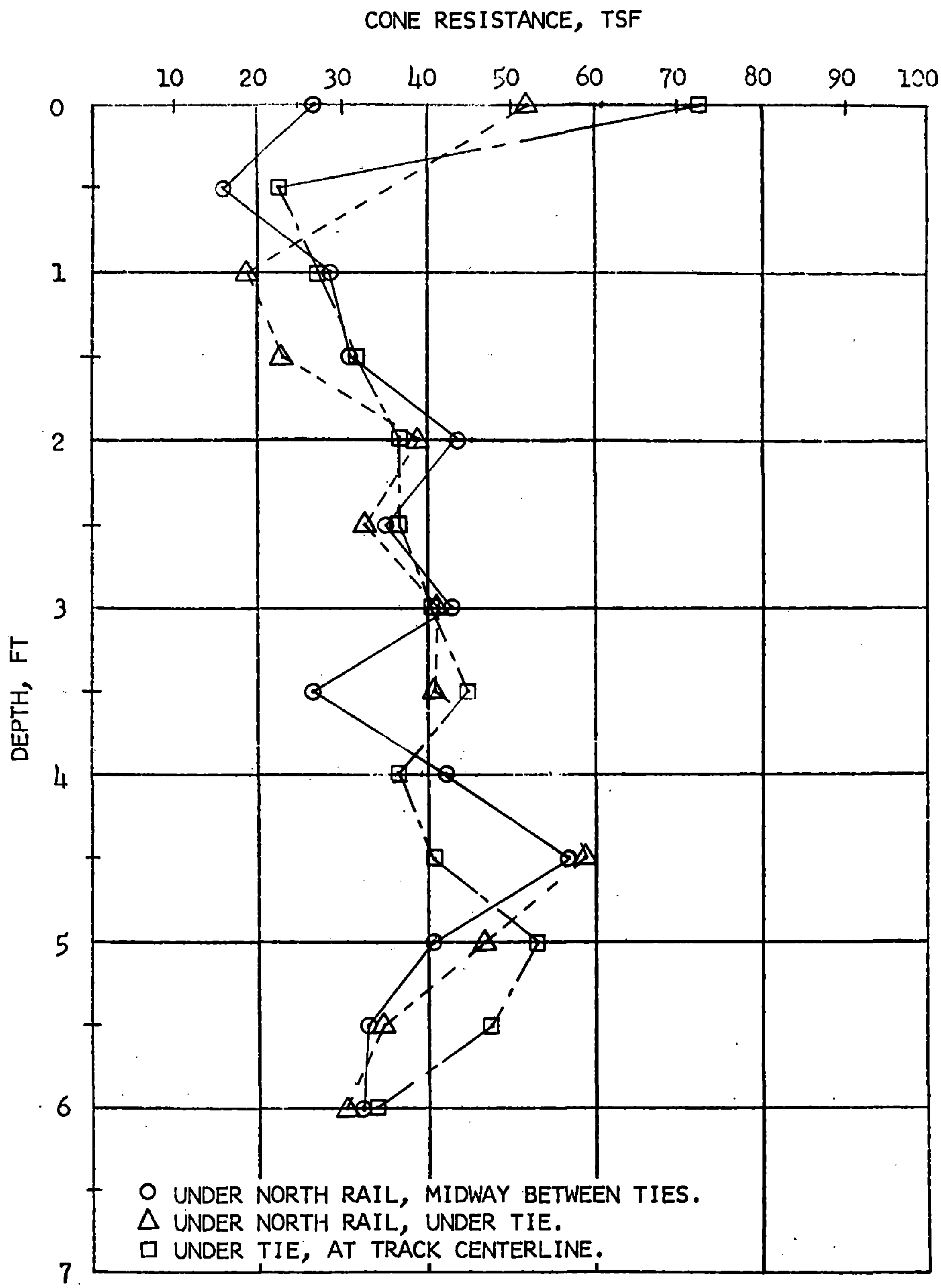


FIGURE C-7. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 1, STA 8527+00

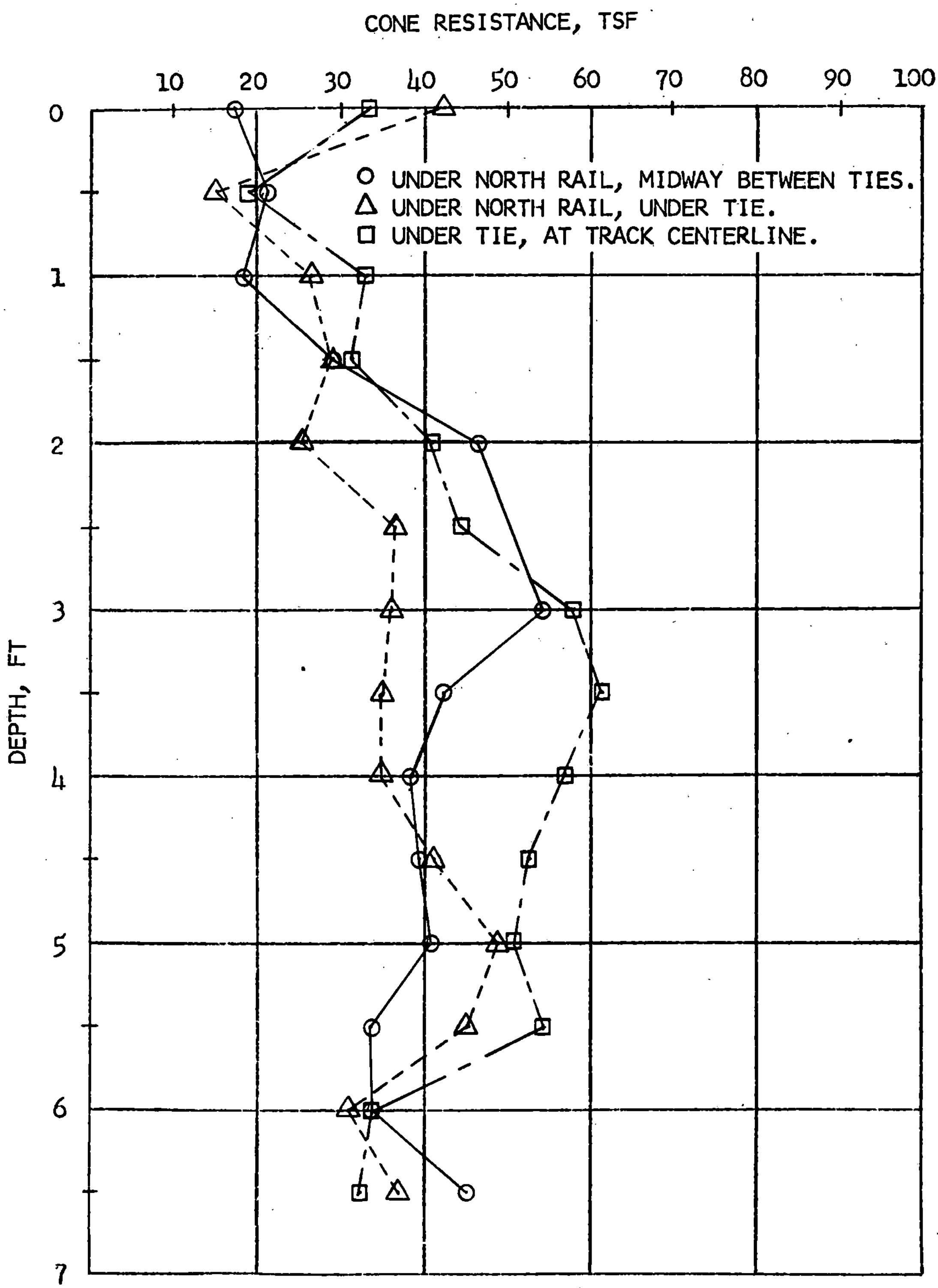


FIGURE C-8. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 2, STA 8529+00

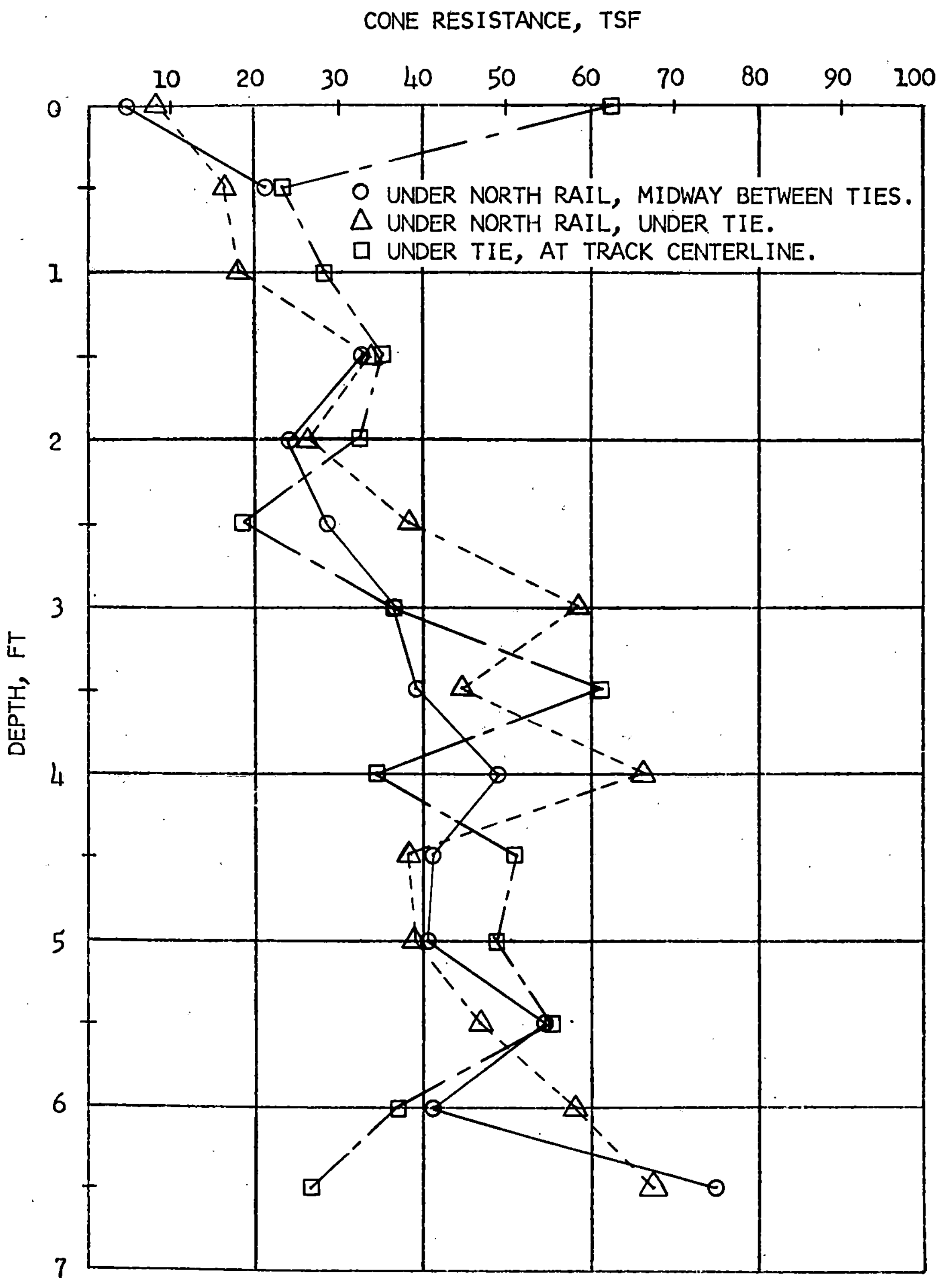


FIGURE C-9. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 2, STA 8531+00

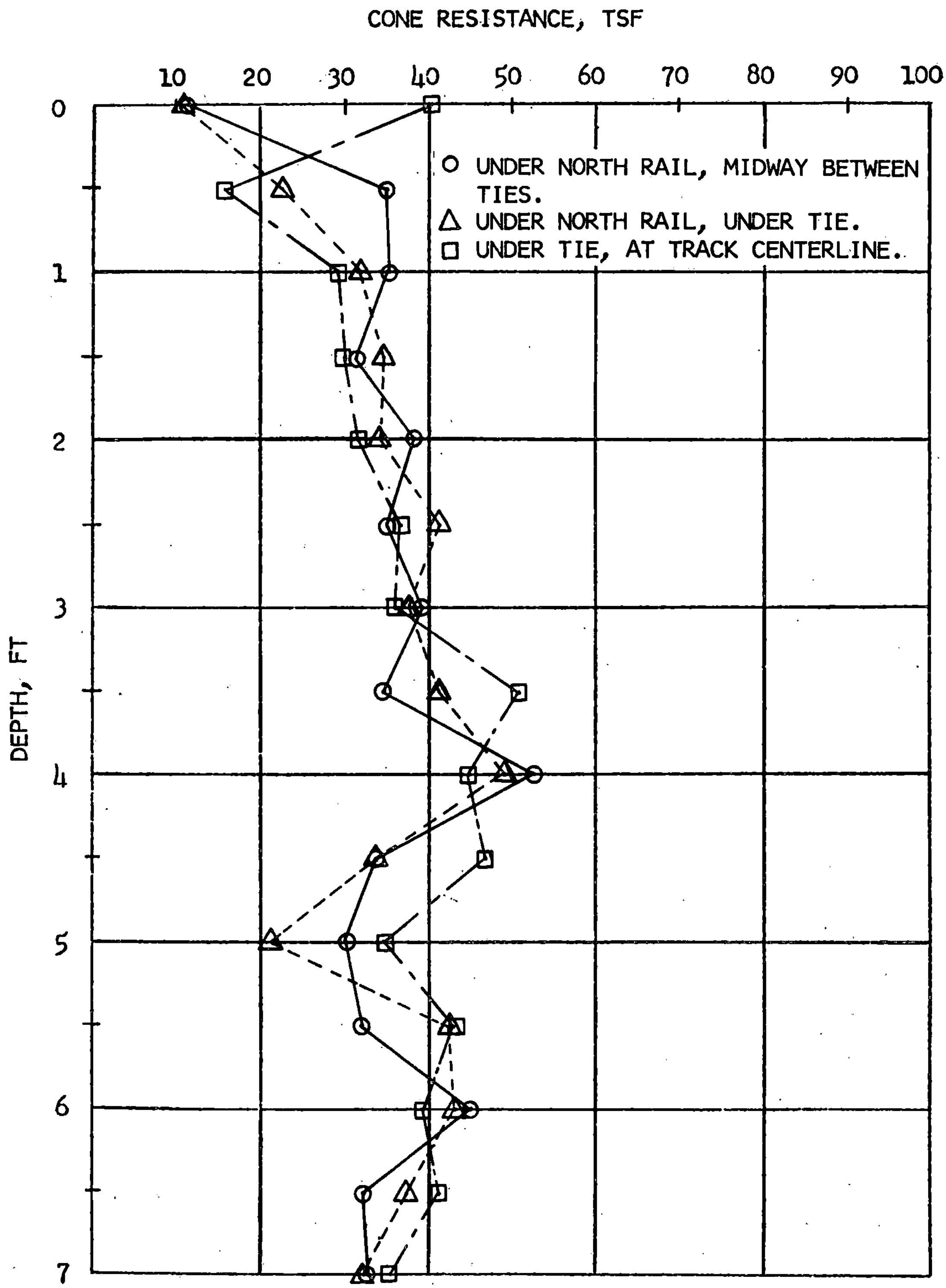


FIGURE C-10. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 2, STA 8533+00

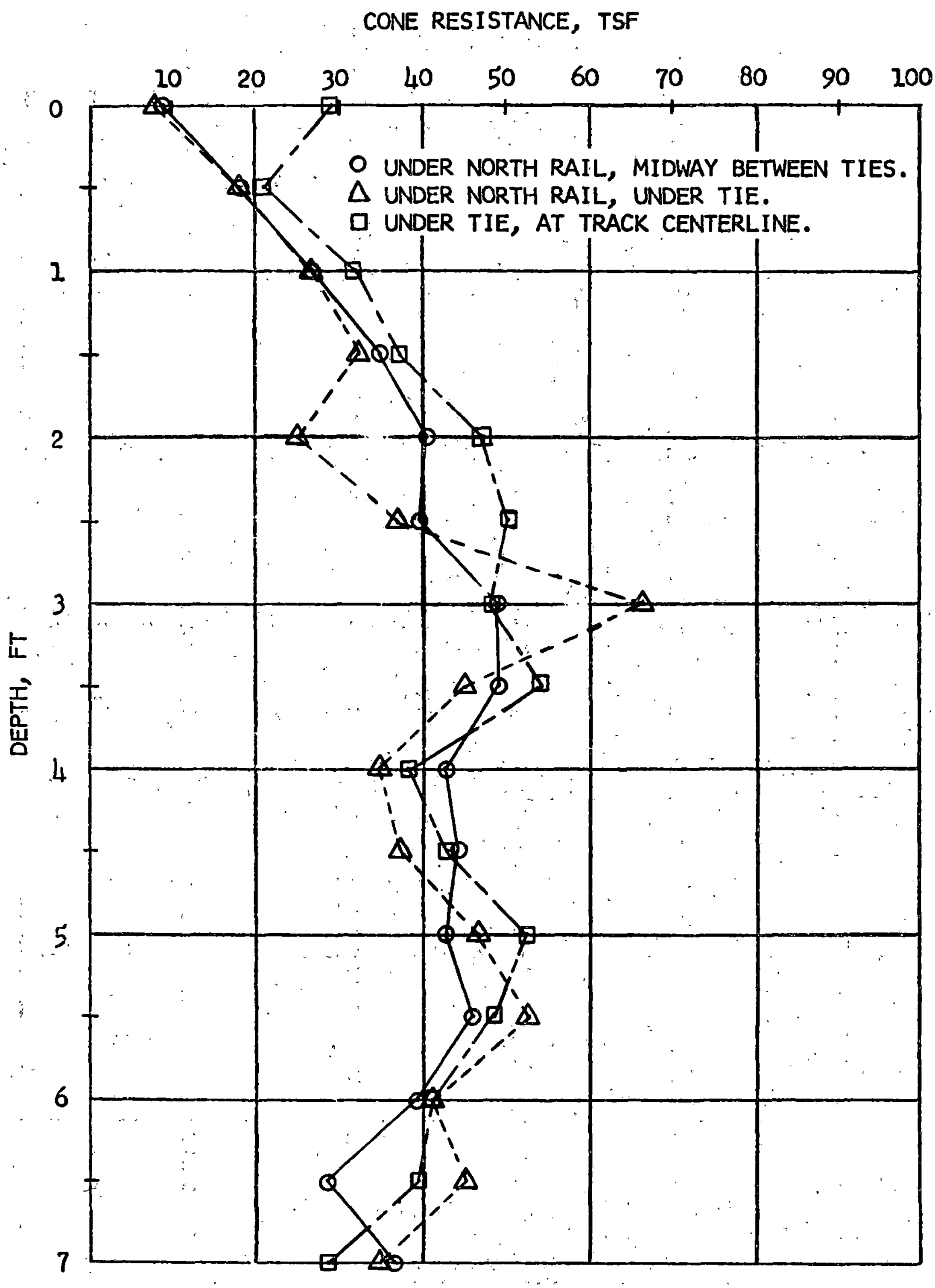


FIGURE C-11. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 2, STA 8534+96

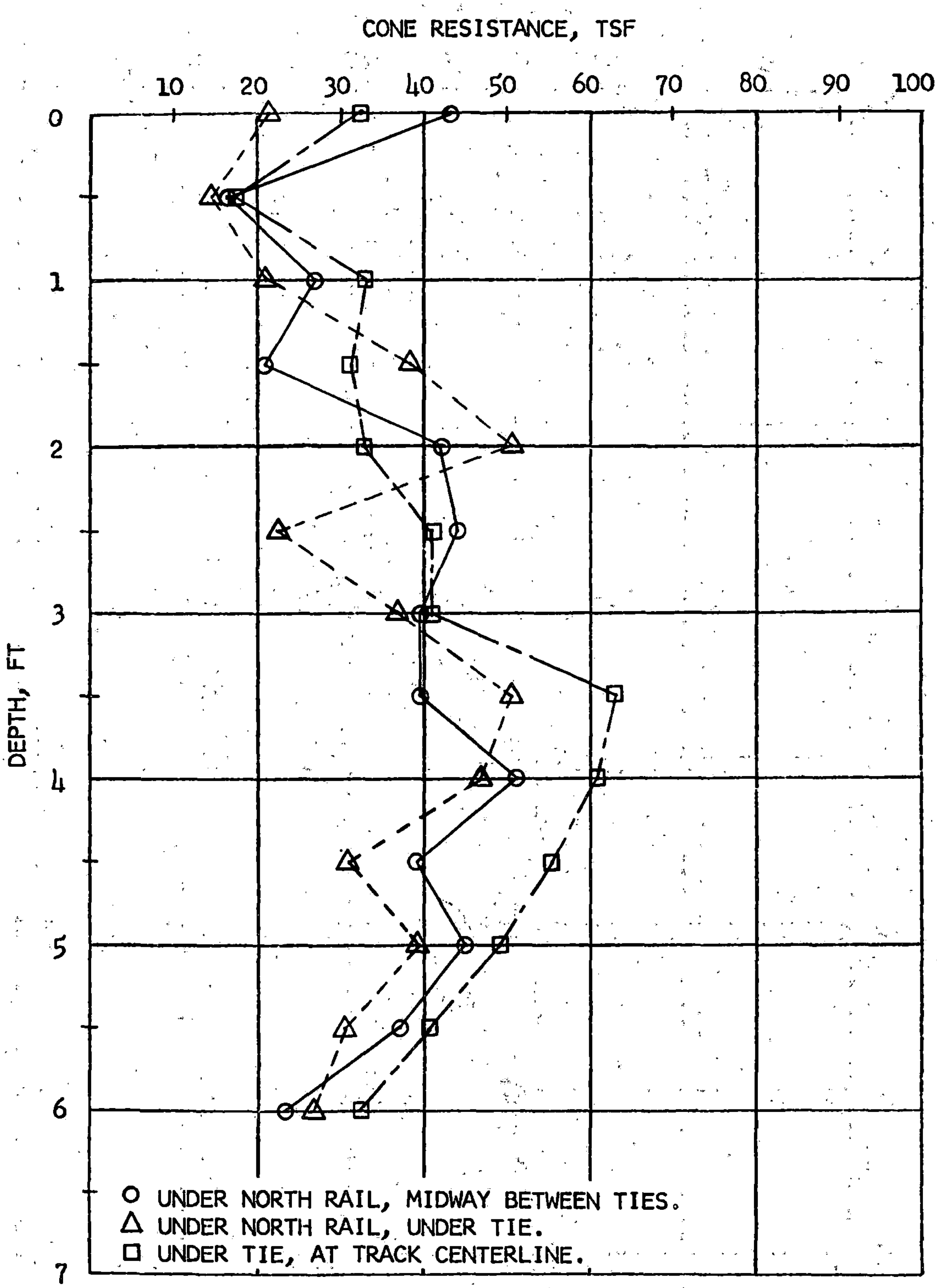


FIGURE C-12. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 3, STA 8538+00

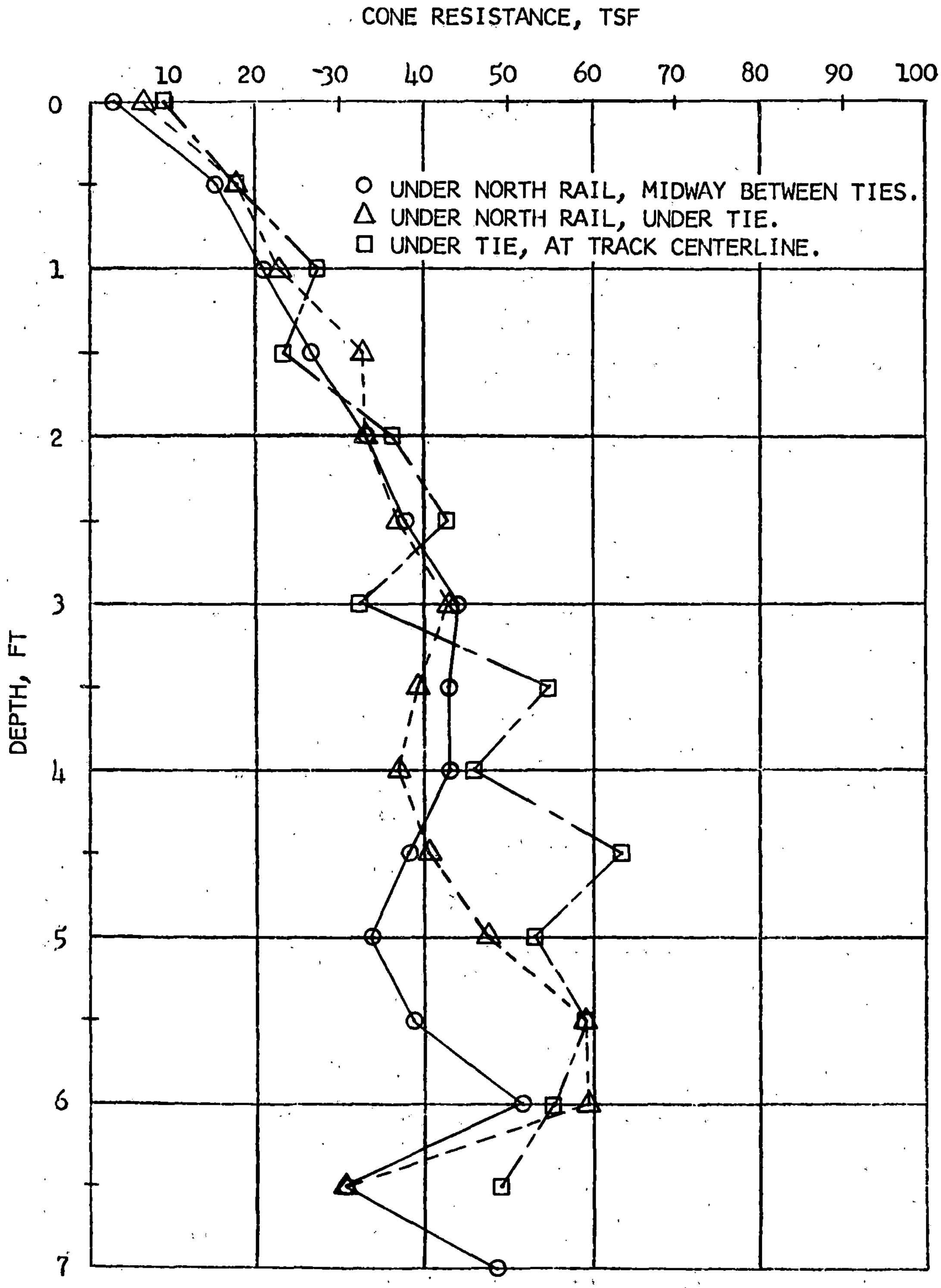


FIGURE C-13. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 3, STA 8540+00

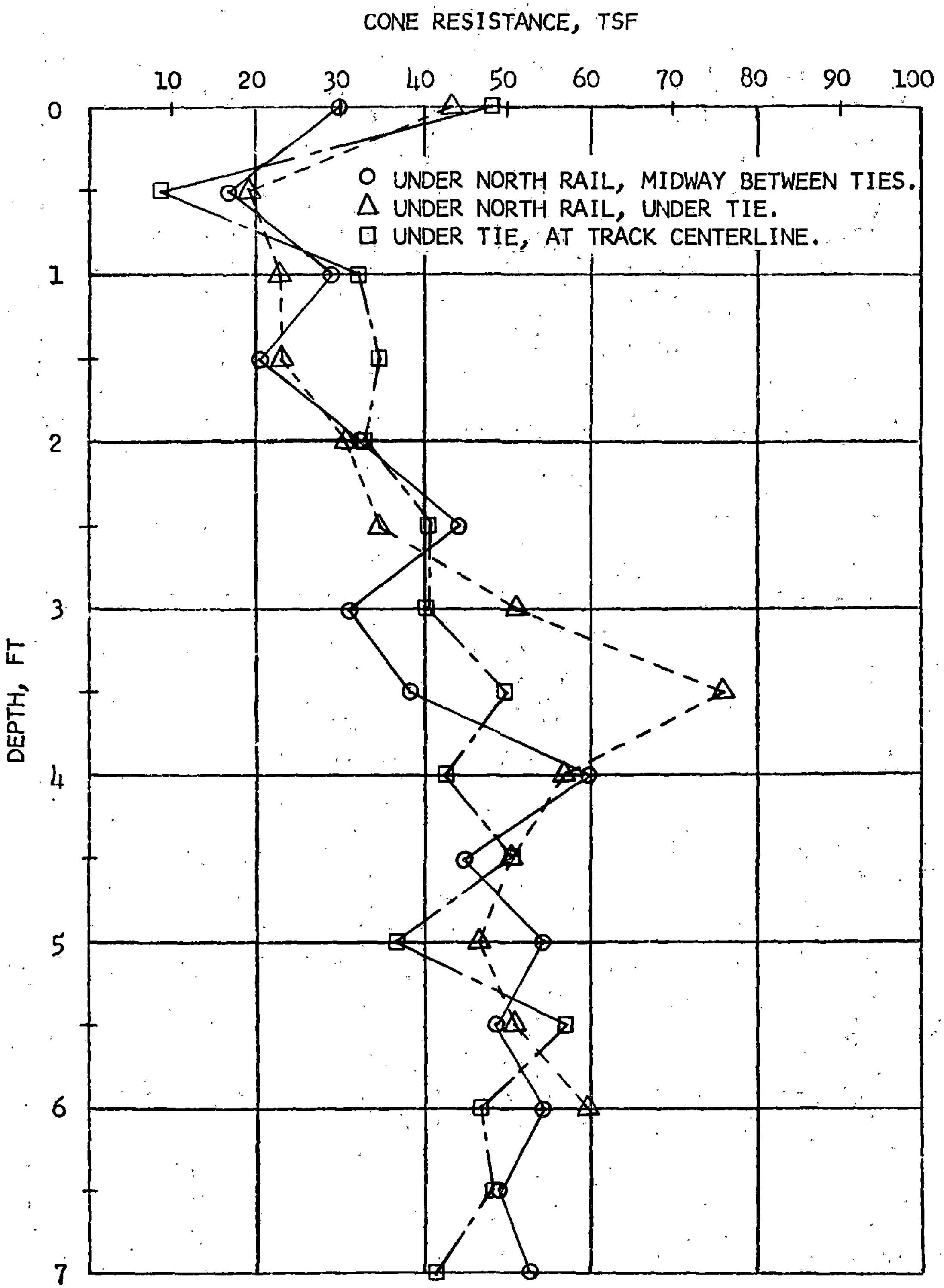


FIGURE C-14. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 3, STA 8543+30.3

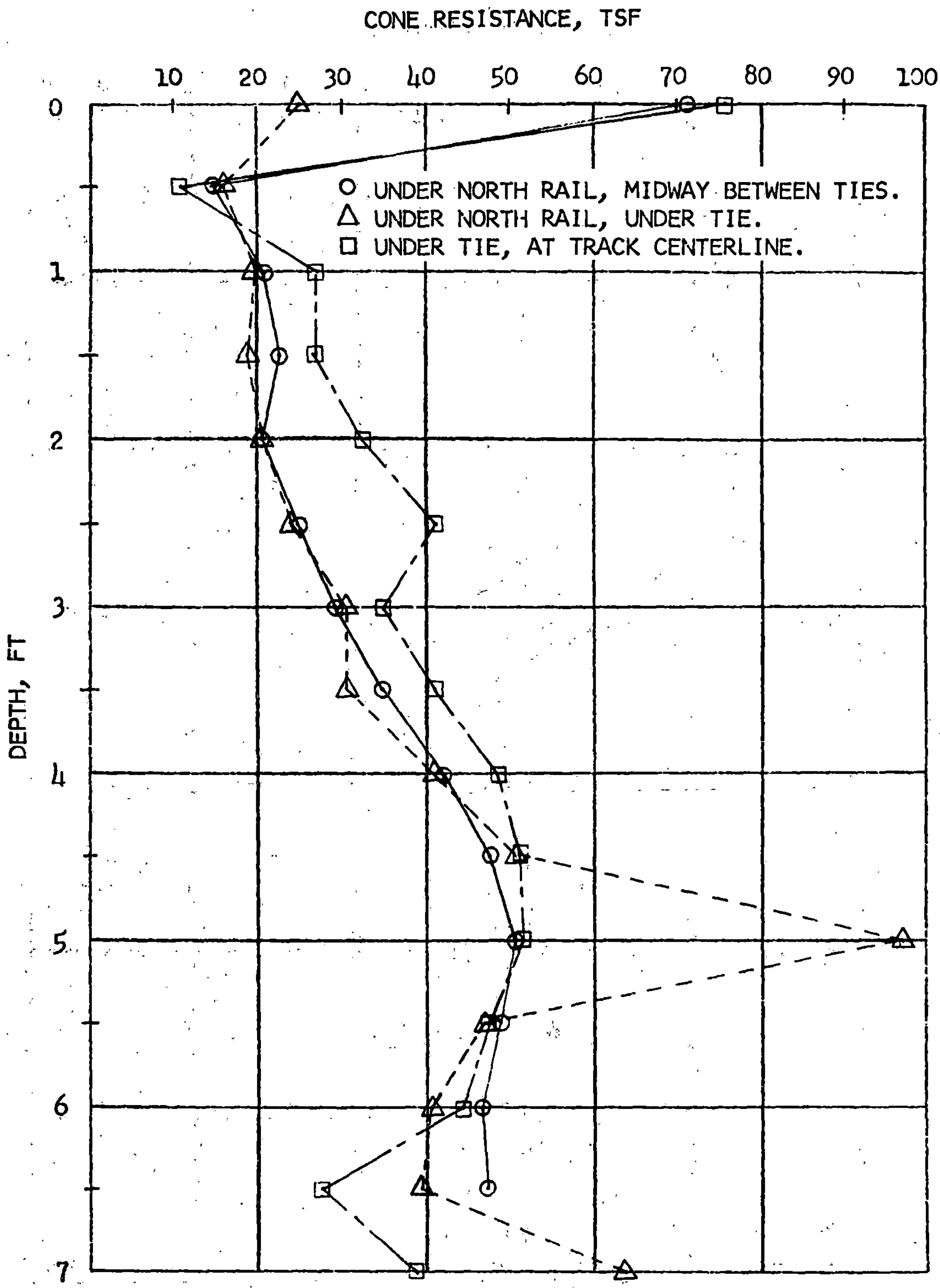


FIGURE C-15. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 3, STA 8544+00

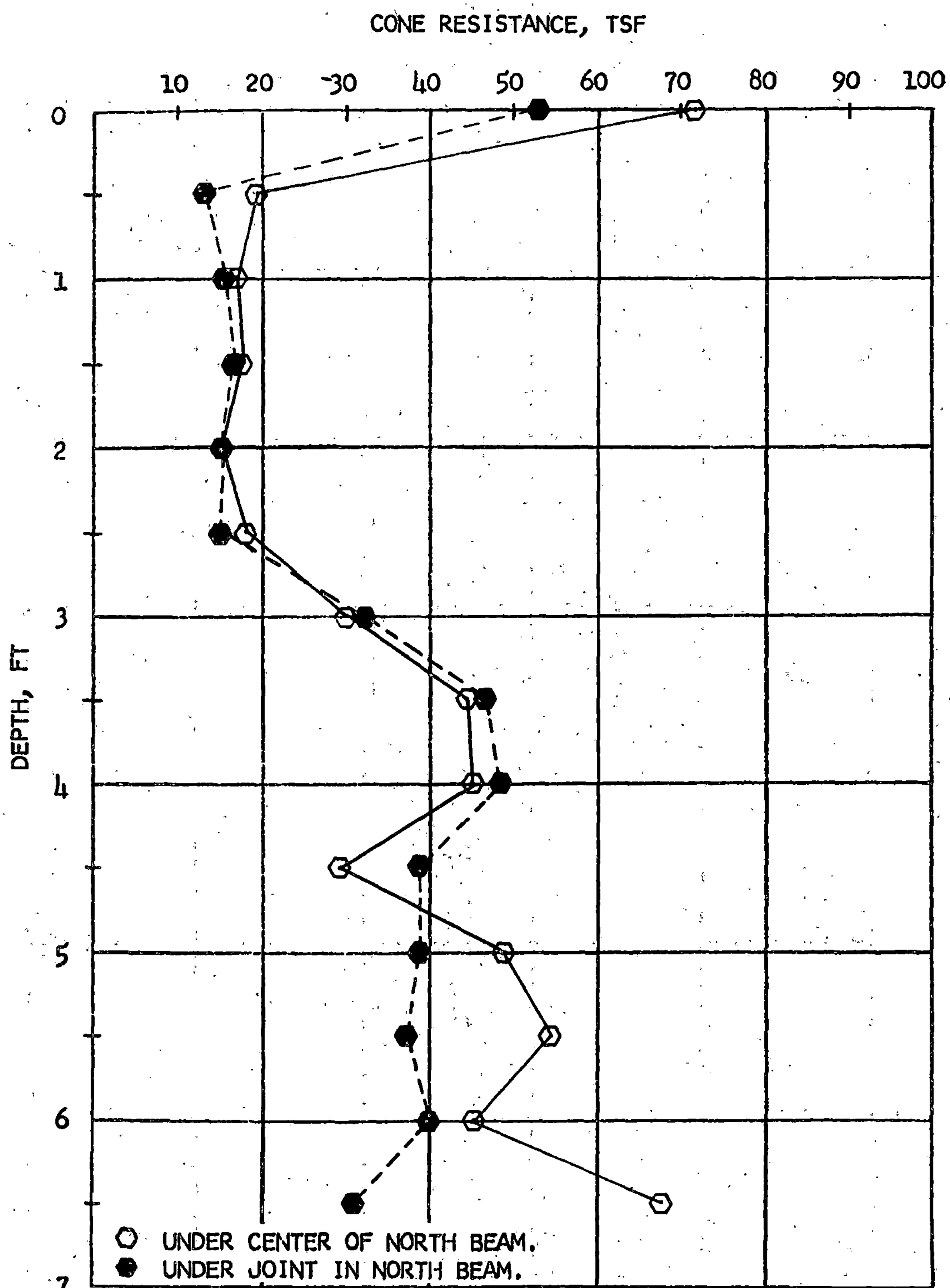


FIGURE C-16. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 4, STA 8546+45 AND 8546+50

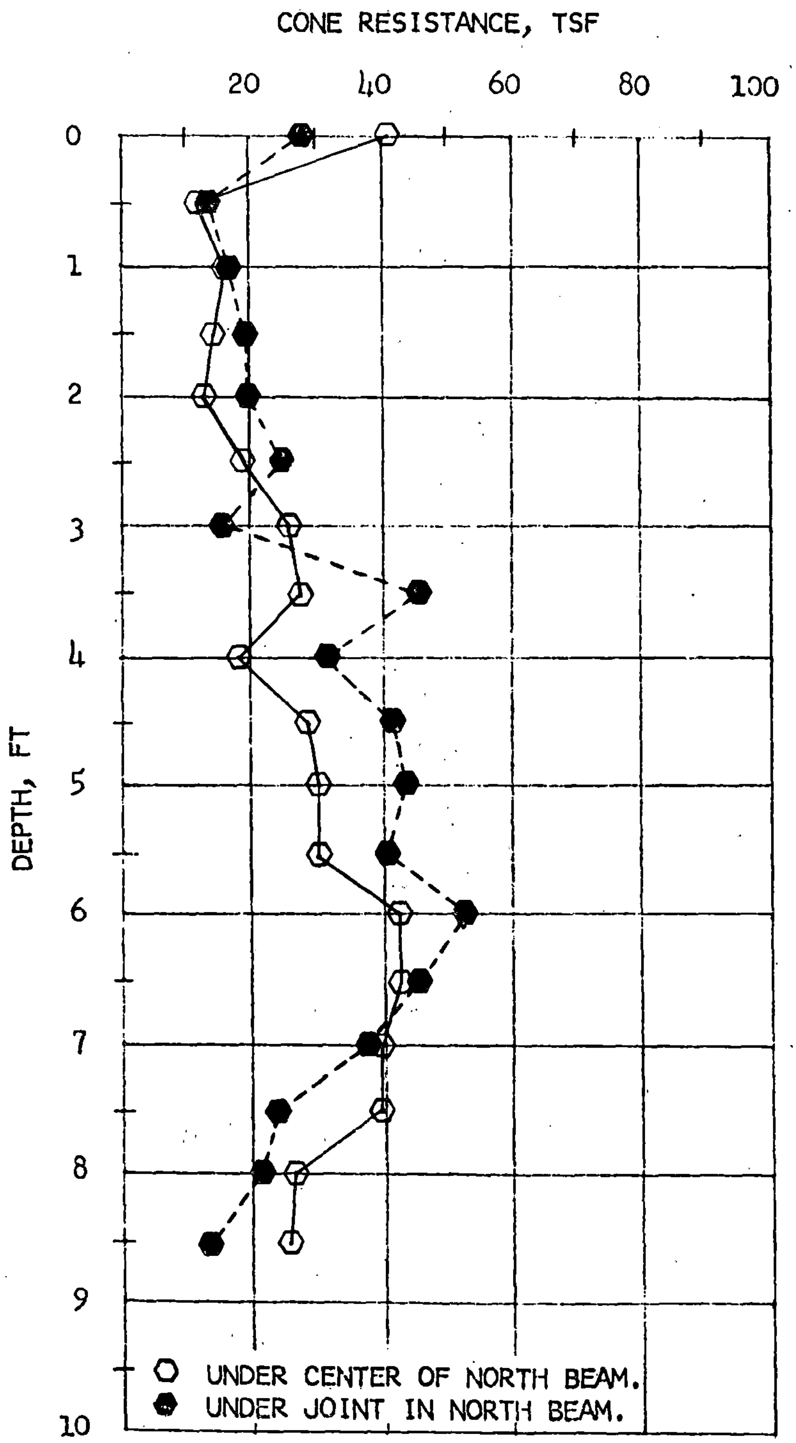


FIGURE C-17. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 4, STA 8547+95 AND 8548+00

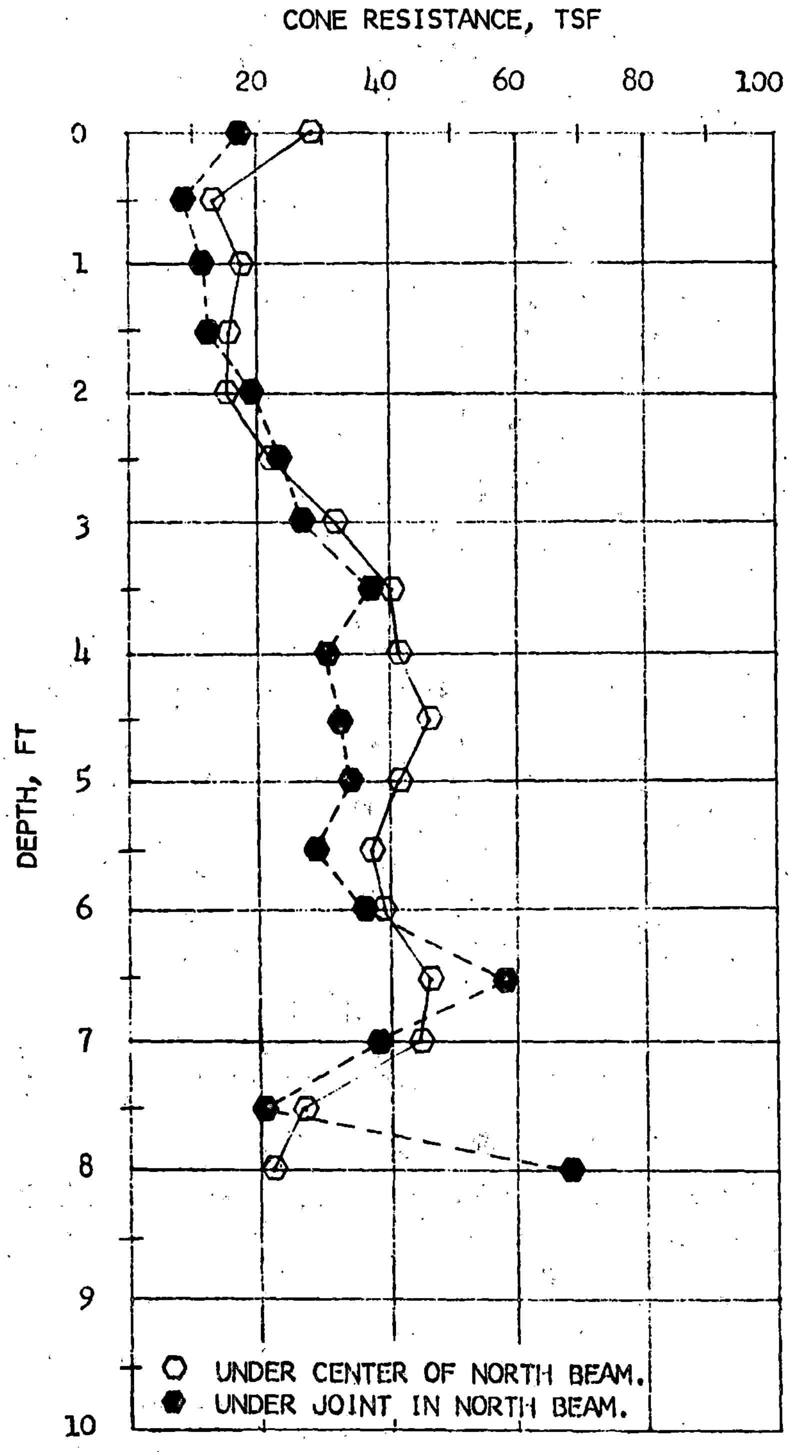


FIGURE C-18. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 4, STA 8549+95 AND 8550+00

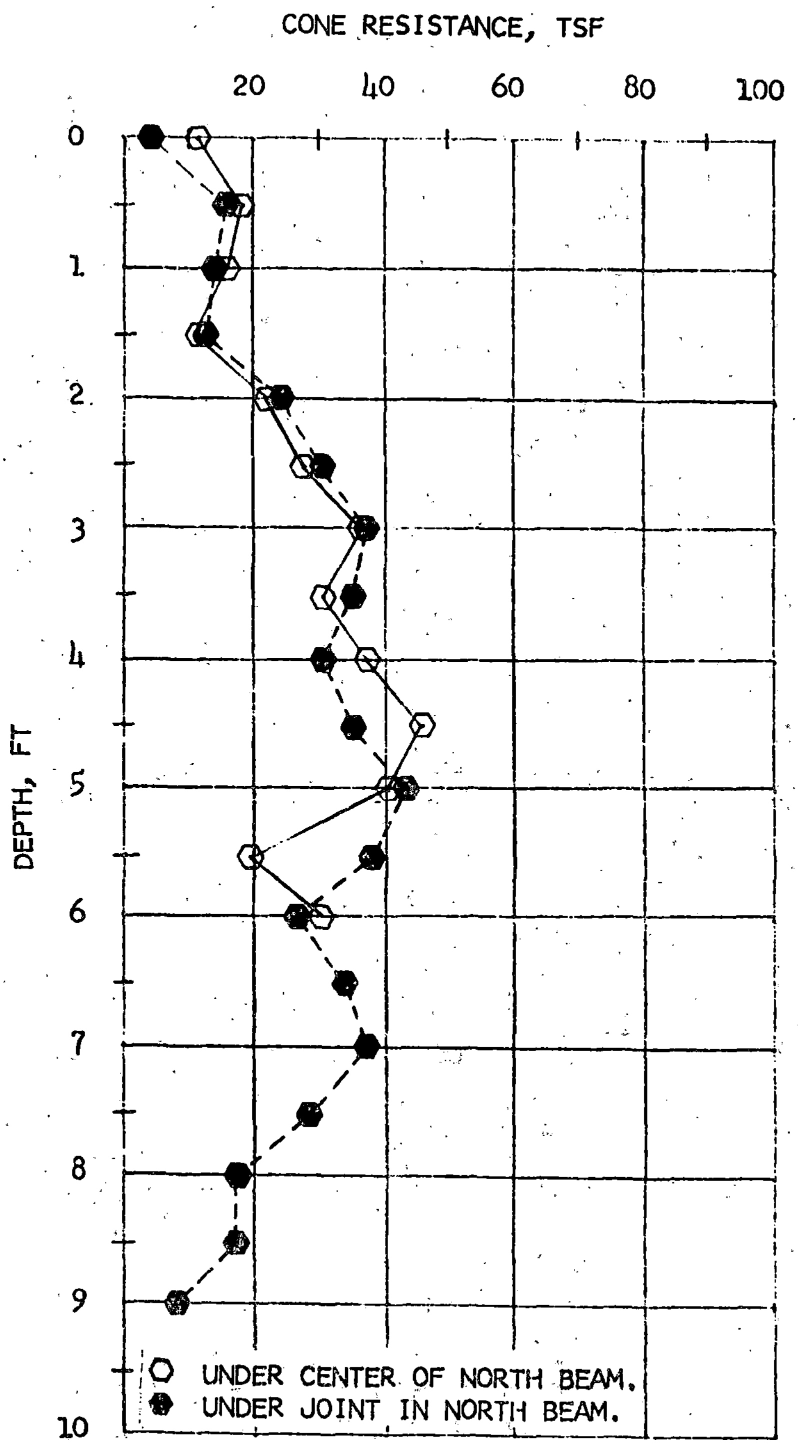


FIGURE C-19. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 4, STA 8551+55 AND 8551+60, NORTH BEAM

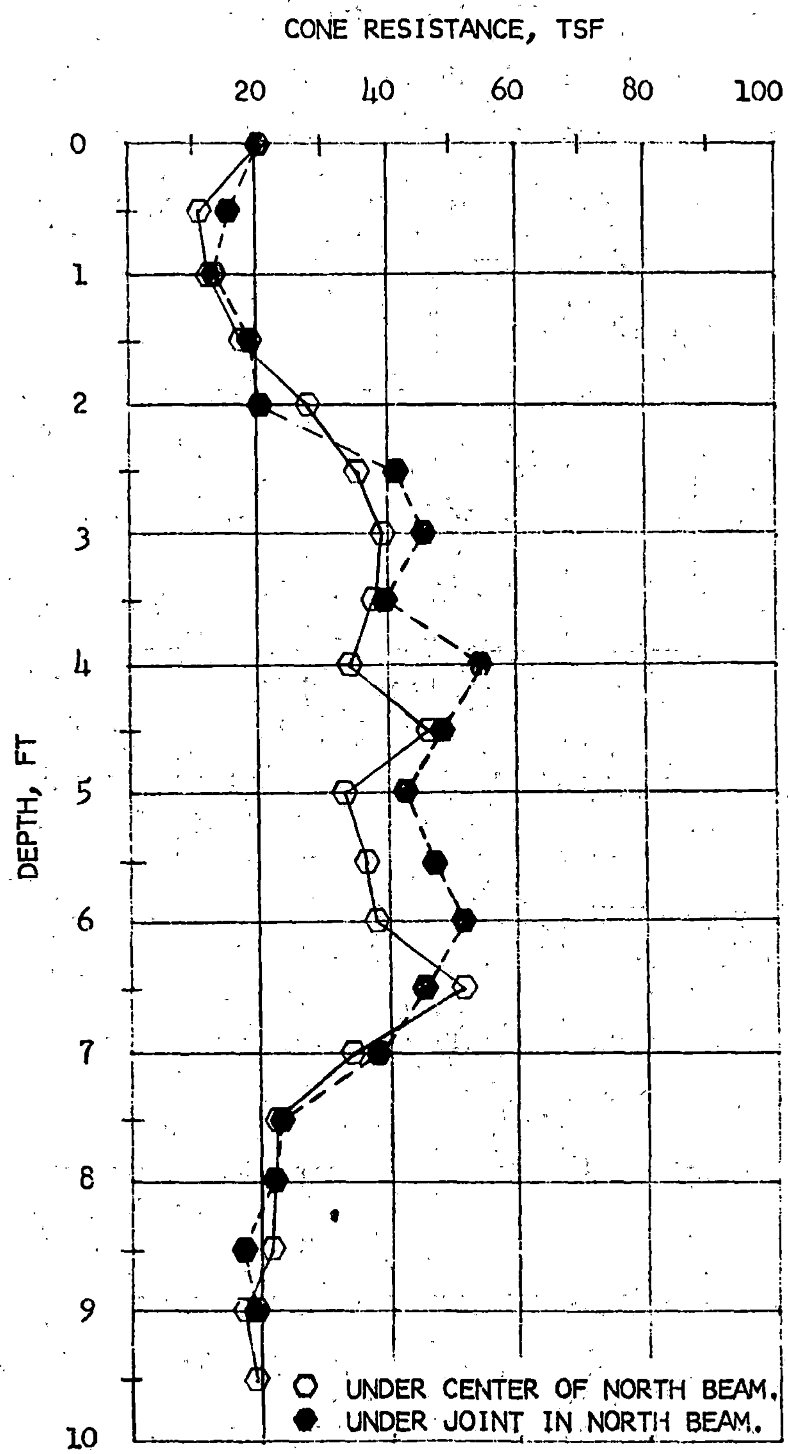


FIGURE C-20. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 4, STA 8551+55 AND 8551+60, SOUTH BEAM

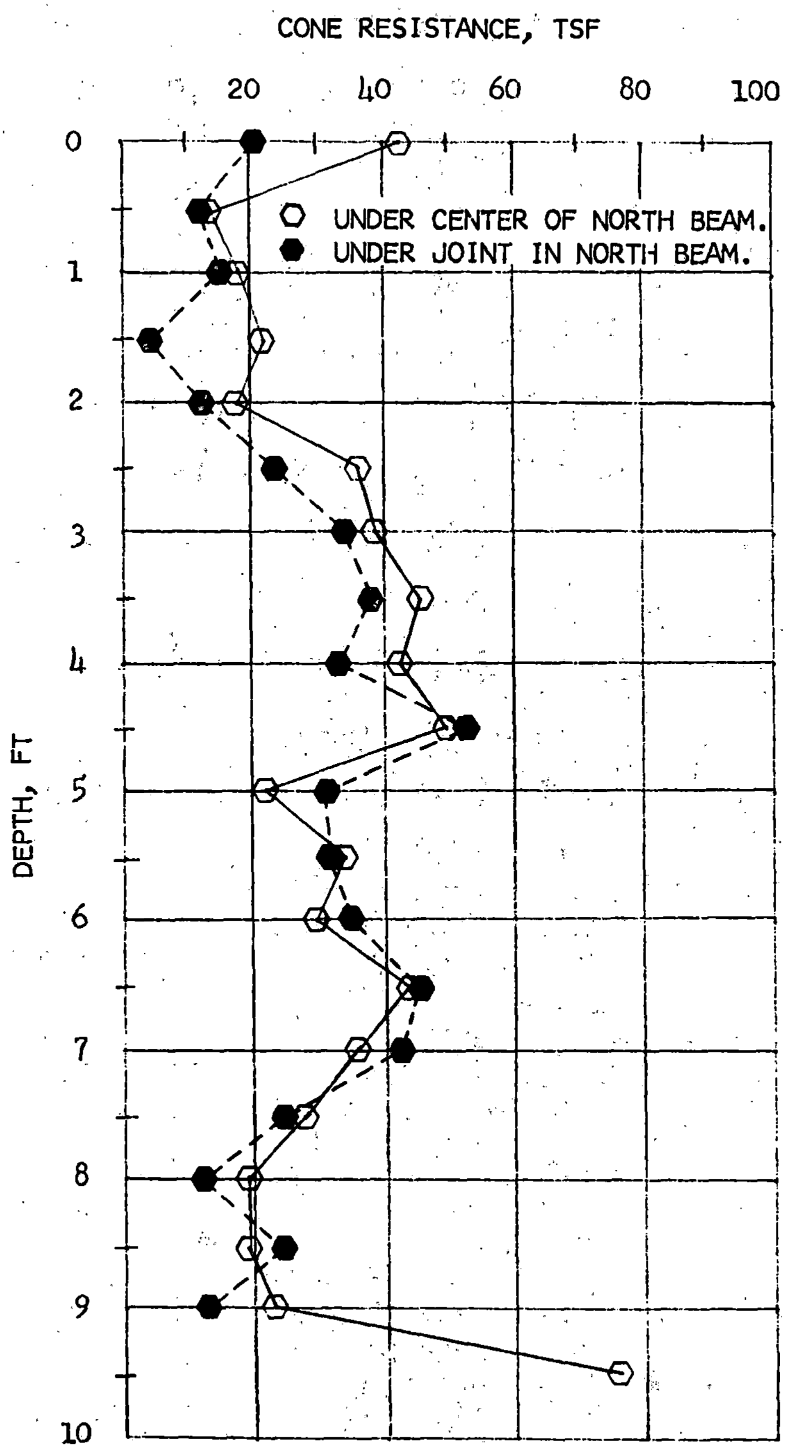


FIGURE C-21. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 4, STA 8553+95 AND 8554+00

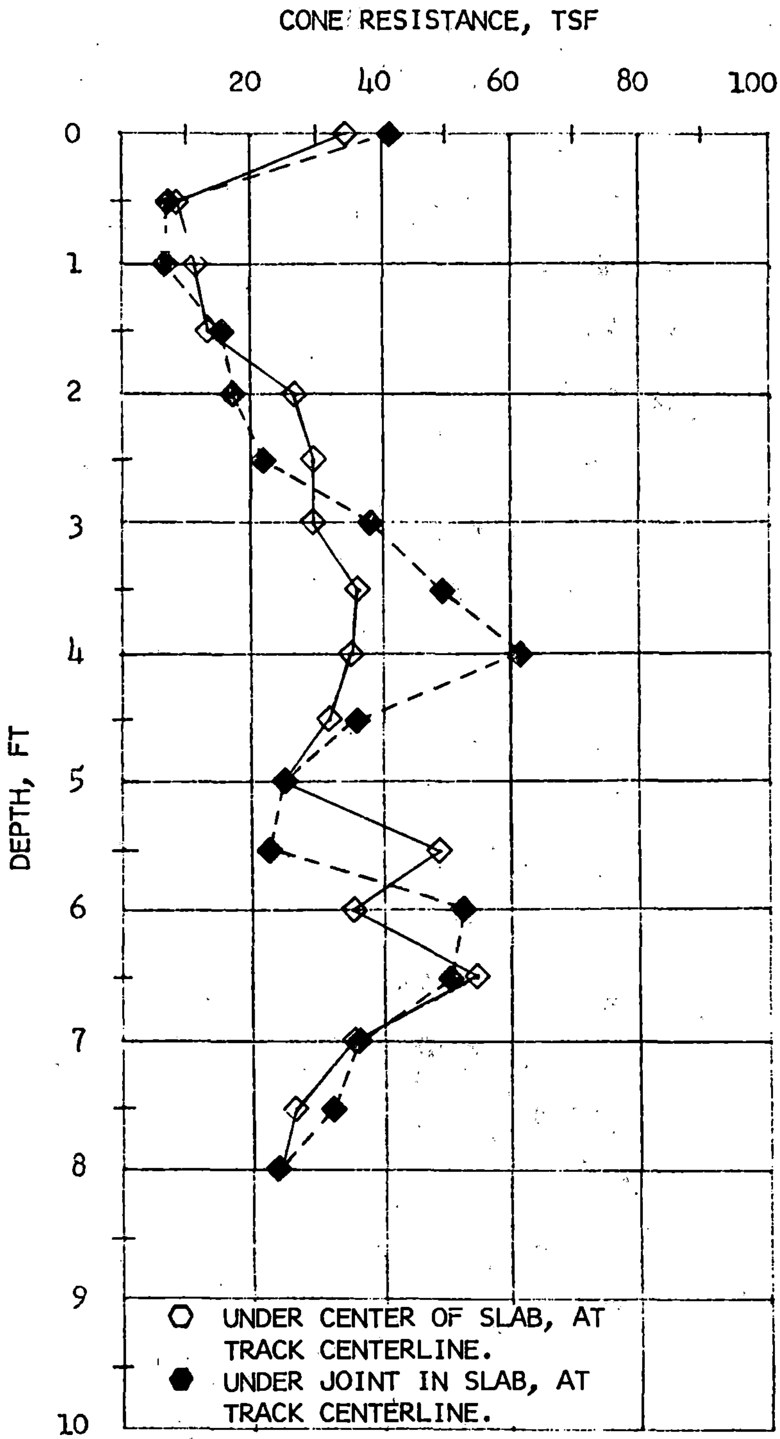


FIGURE C-22. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 5, STA 8555+95 AND 8556+00

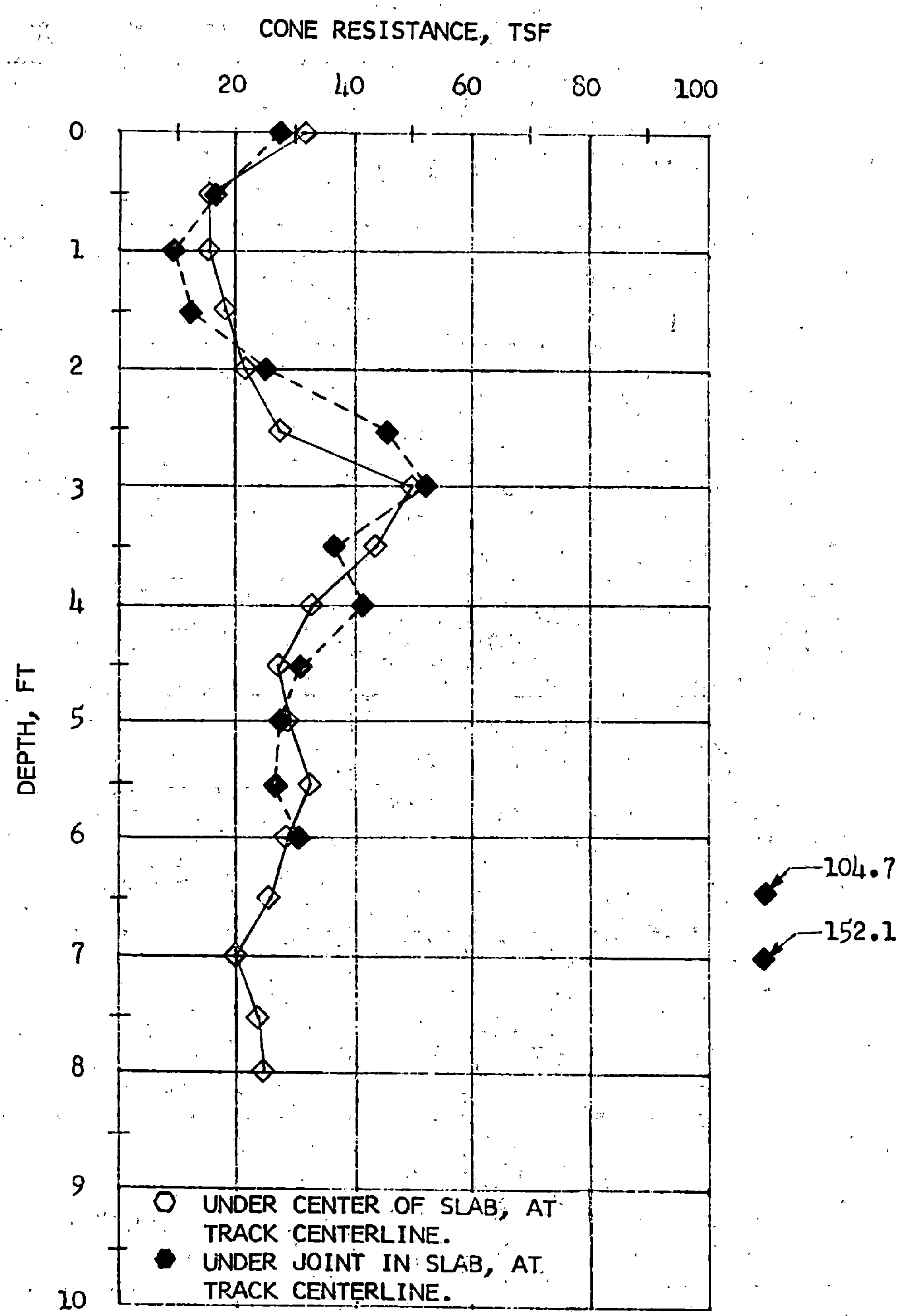


FIGURE C-23. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 5, STA 8557+95 AND 8558+00

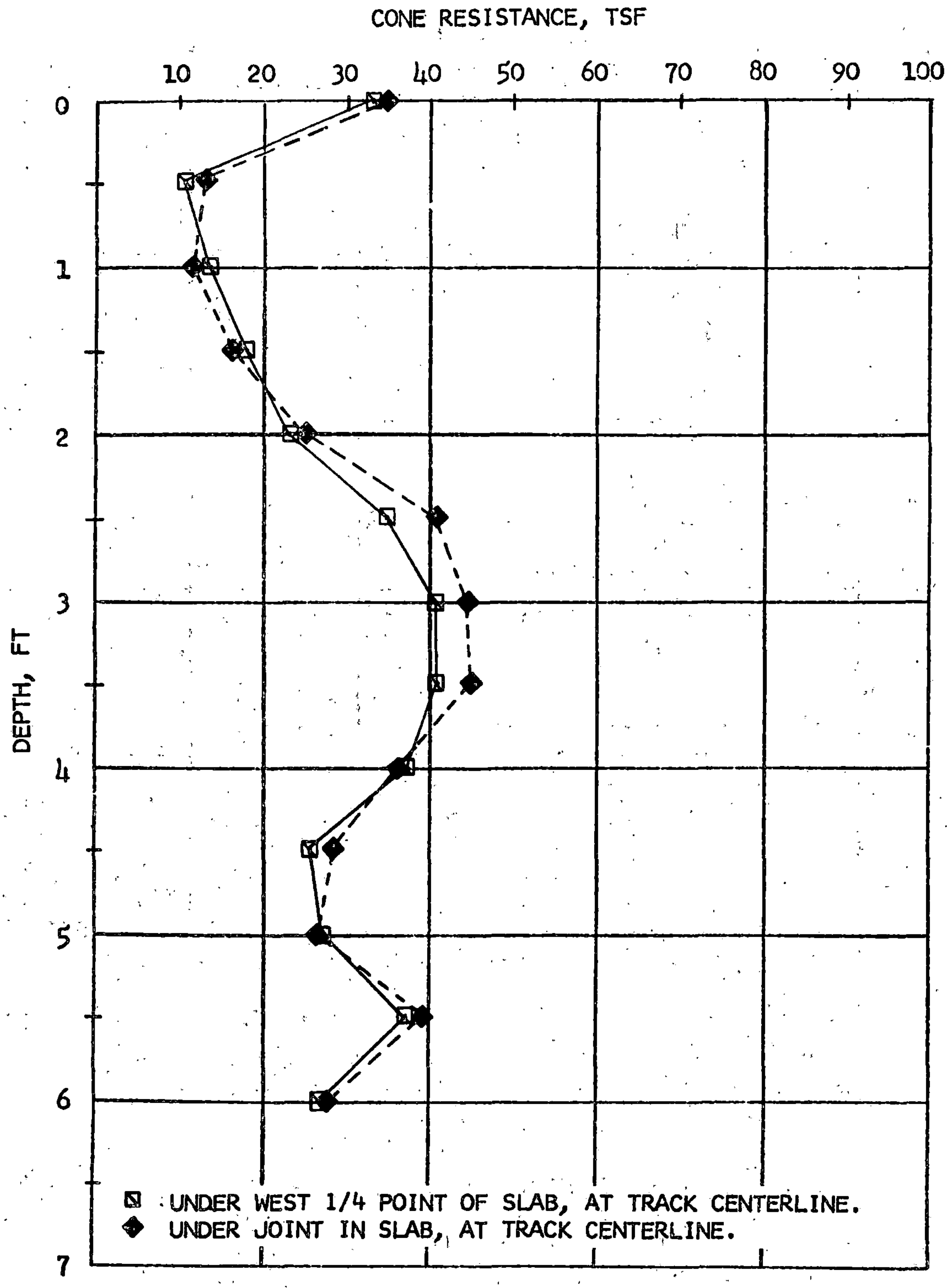


FIGURE C-24. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 5, STA 8558+27.5 AND 8558+30

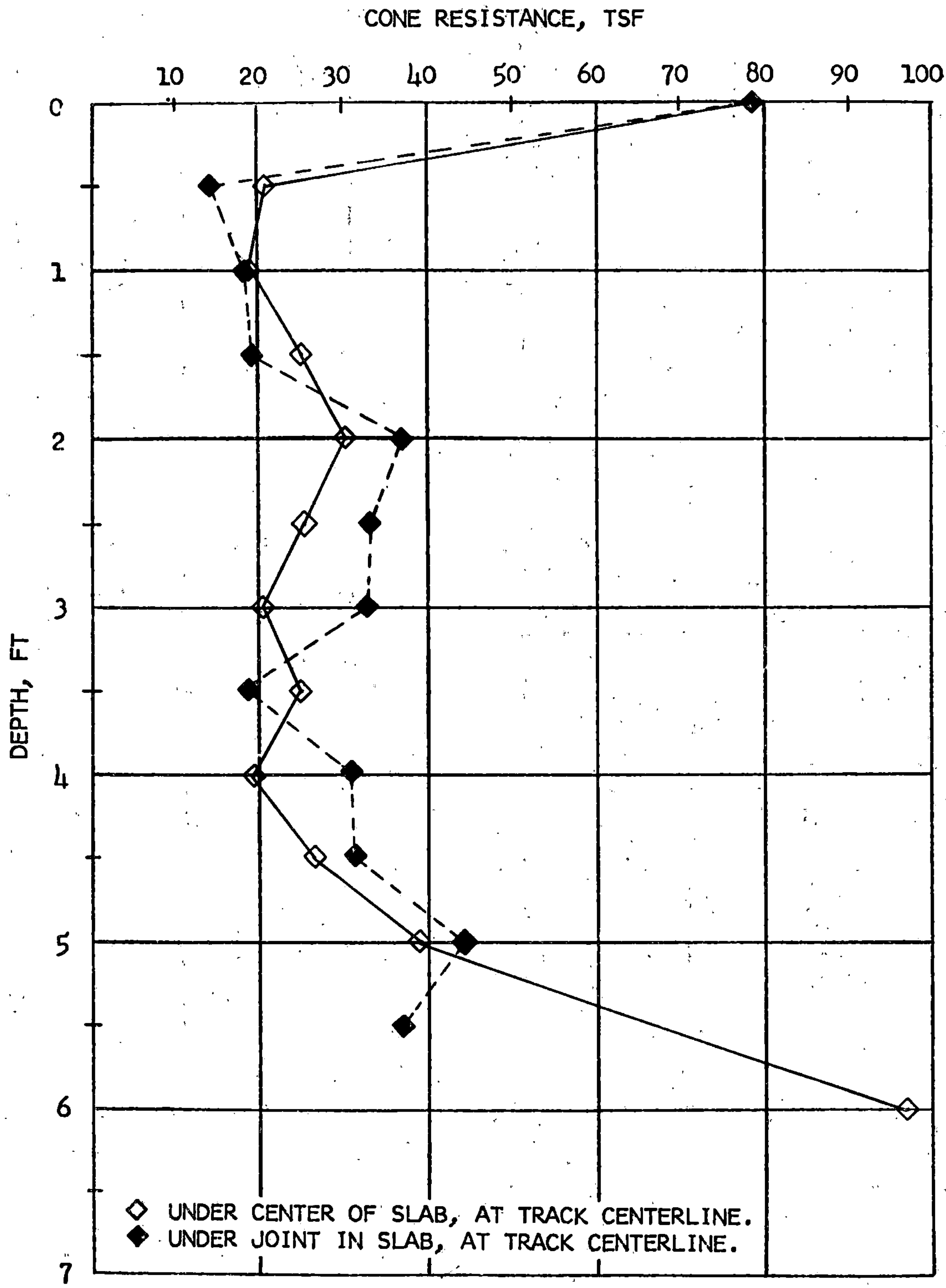


FIGURE C-25. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 5, STA 8559+95 AND 8560+00

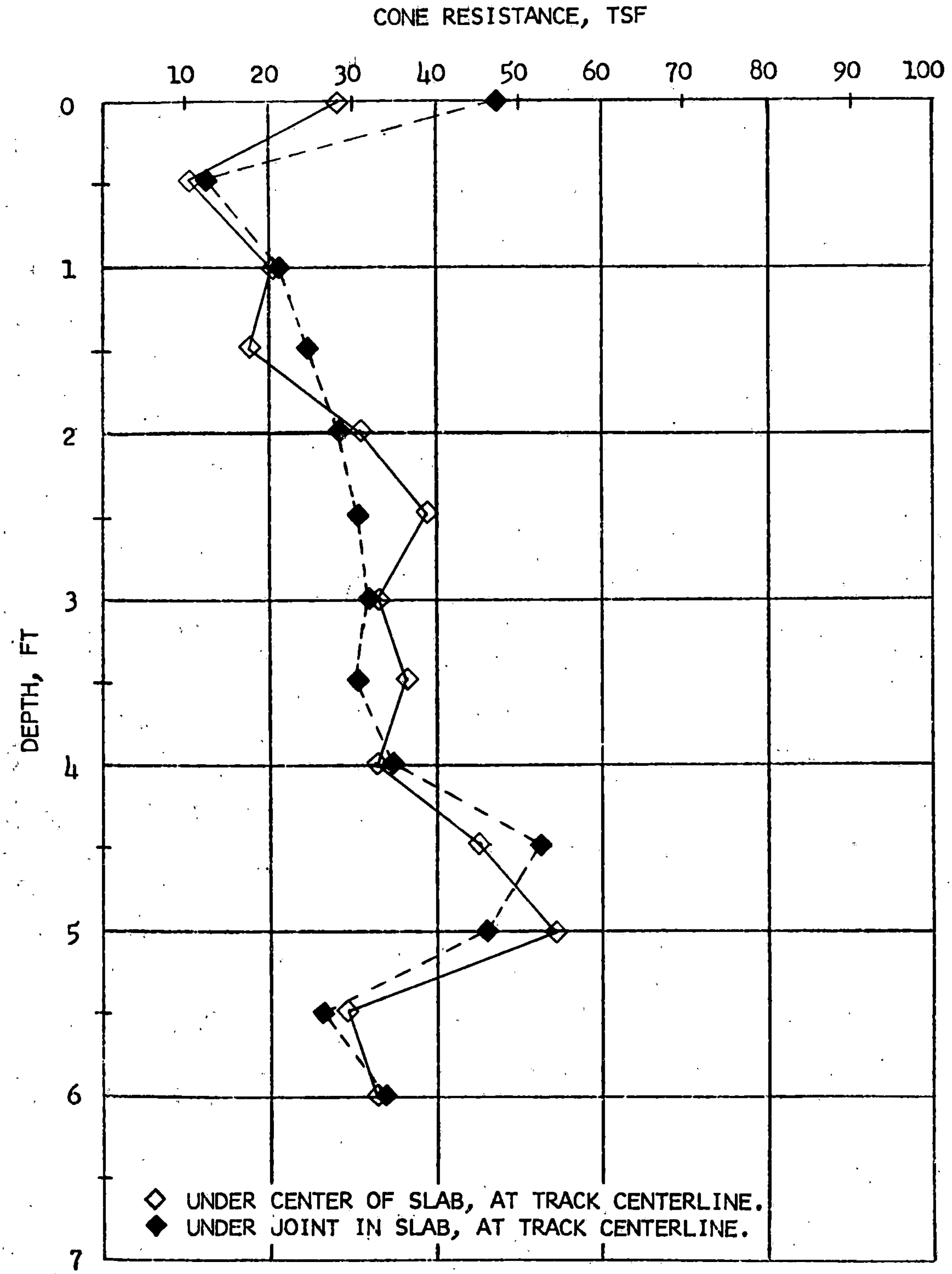


FIGURE C-26. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 5, STA 8561+95 AND 8562+00

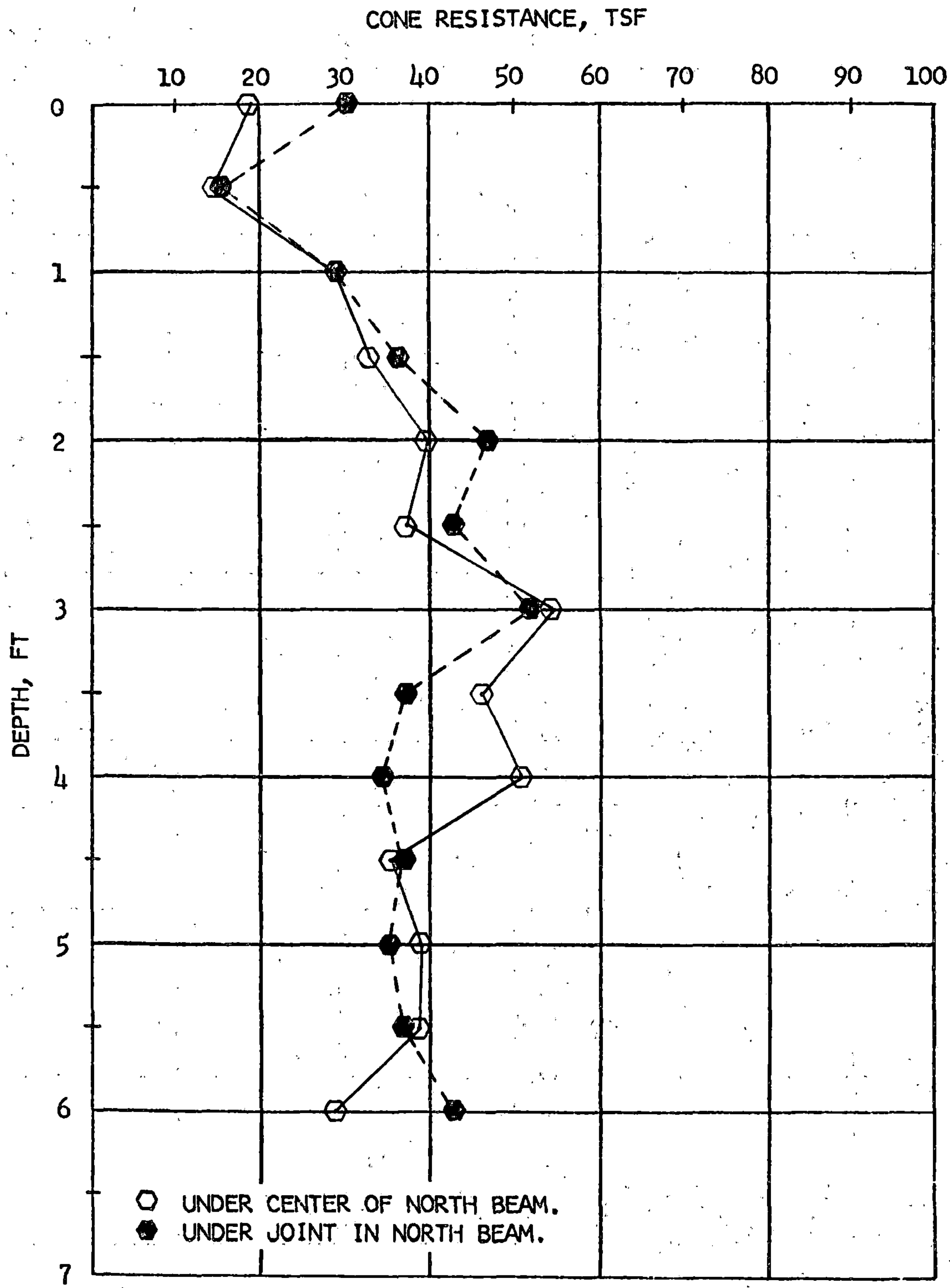


FIGURE C-27. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 7, STA 8570+95 AND 8571+00

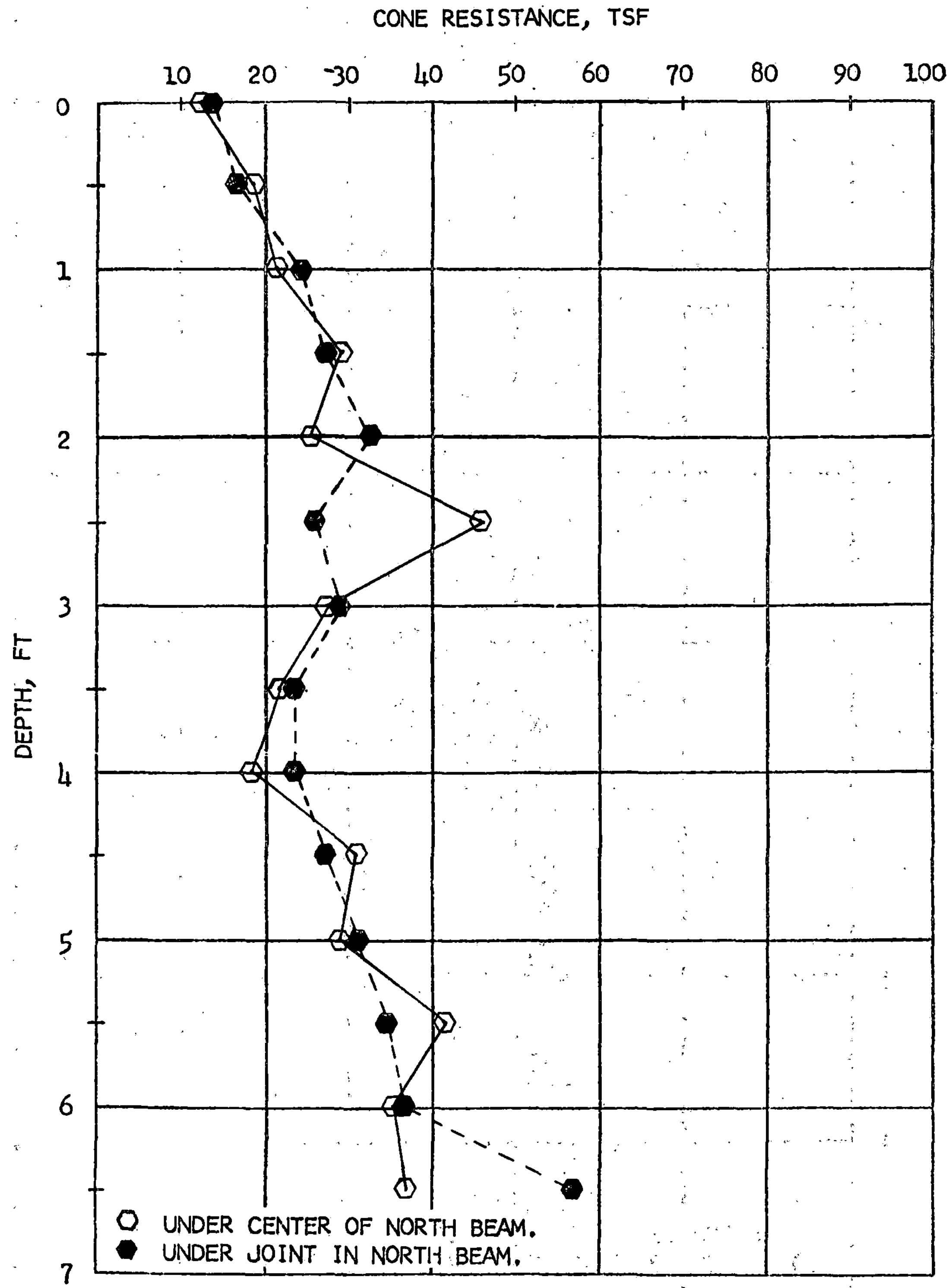


FIGURE C-28. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 7, STA 8573+00 AND 8573+05

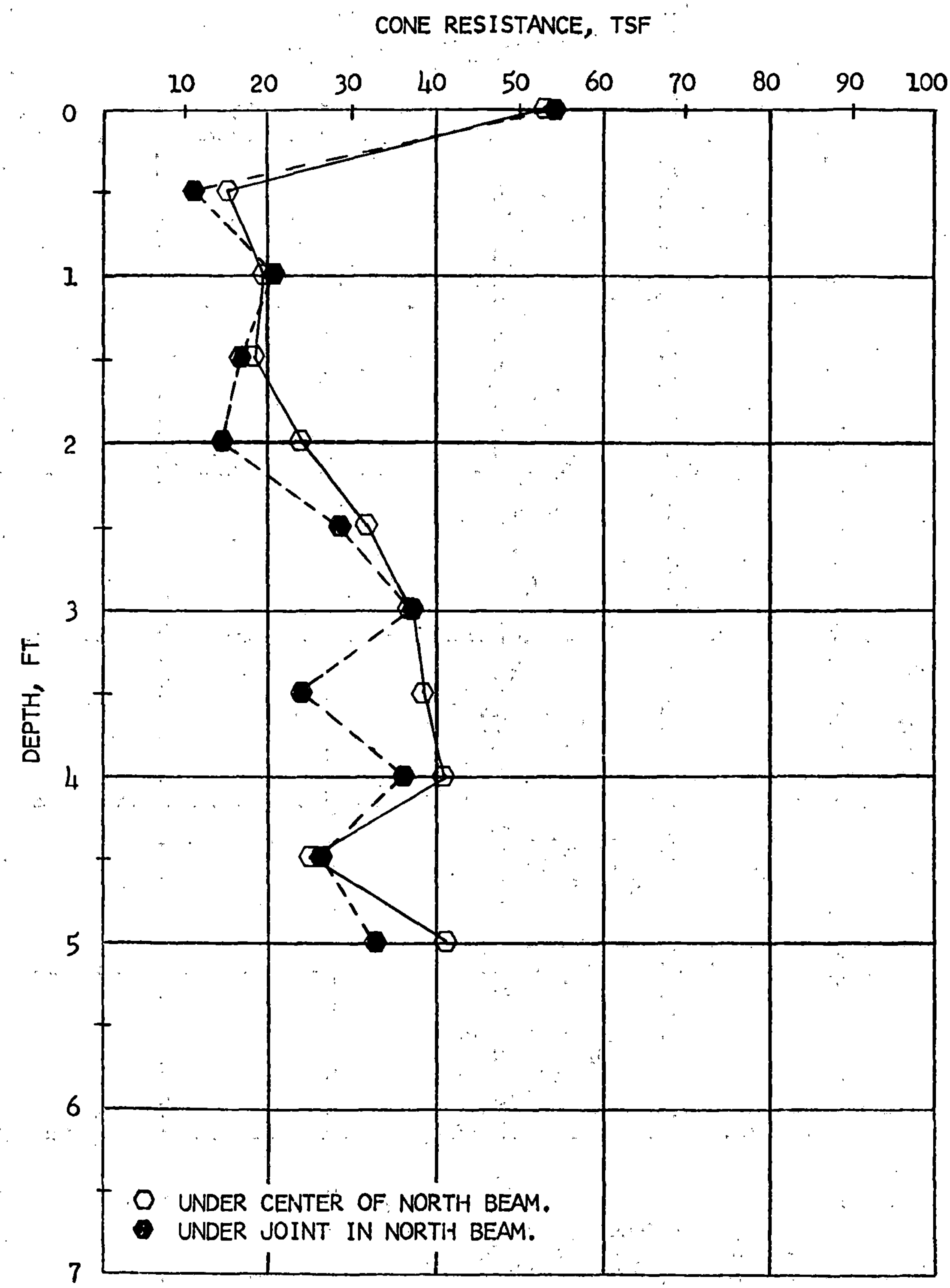


FIGURE C-29. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 7, STA 8574+50 AND 8574+55

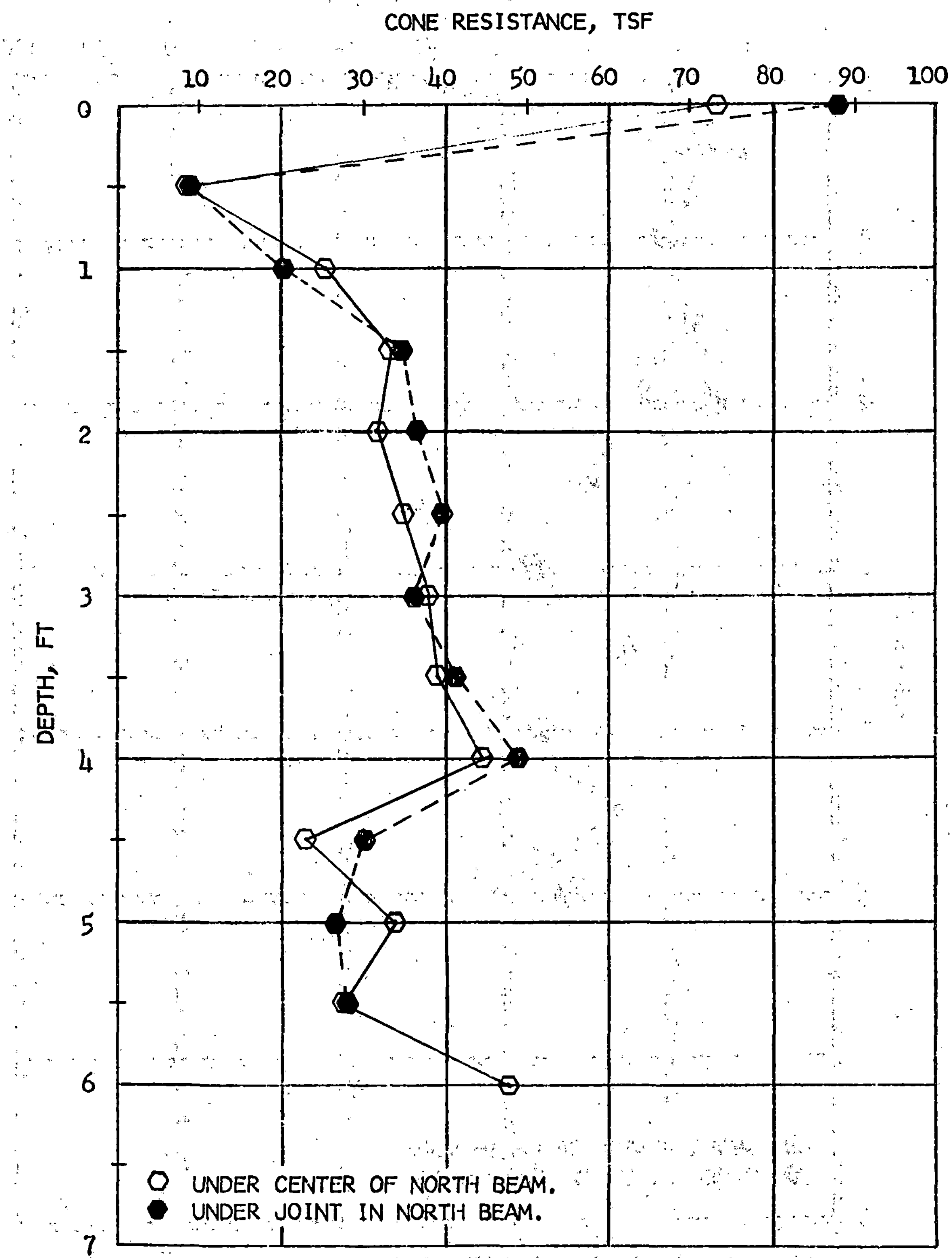


FIGURE C-30. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 7, STA 8576+10 AND 8576+15, NORTH BEAM

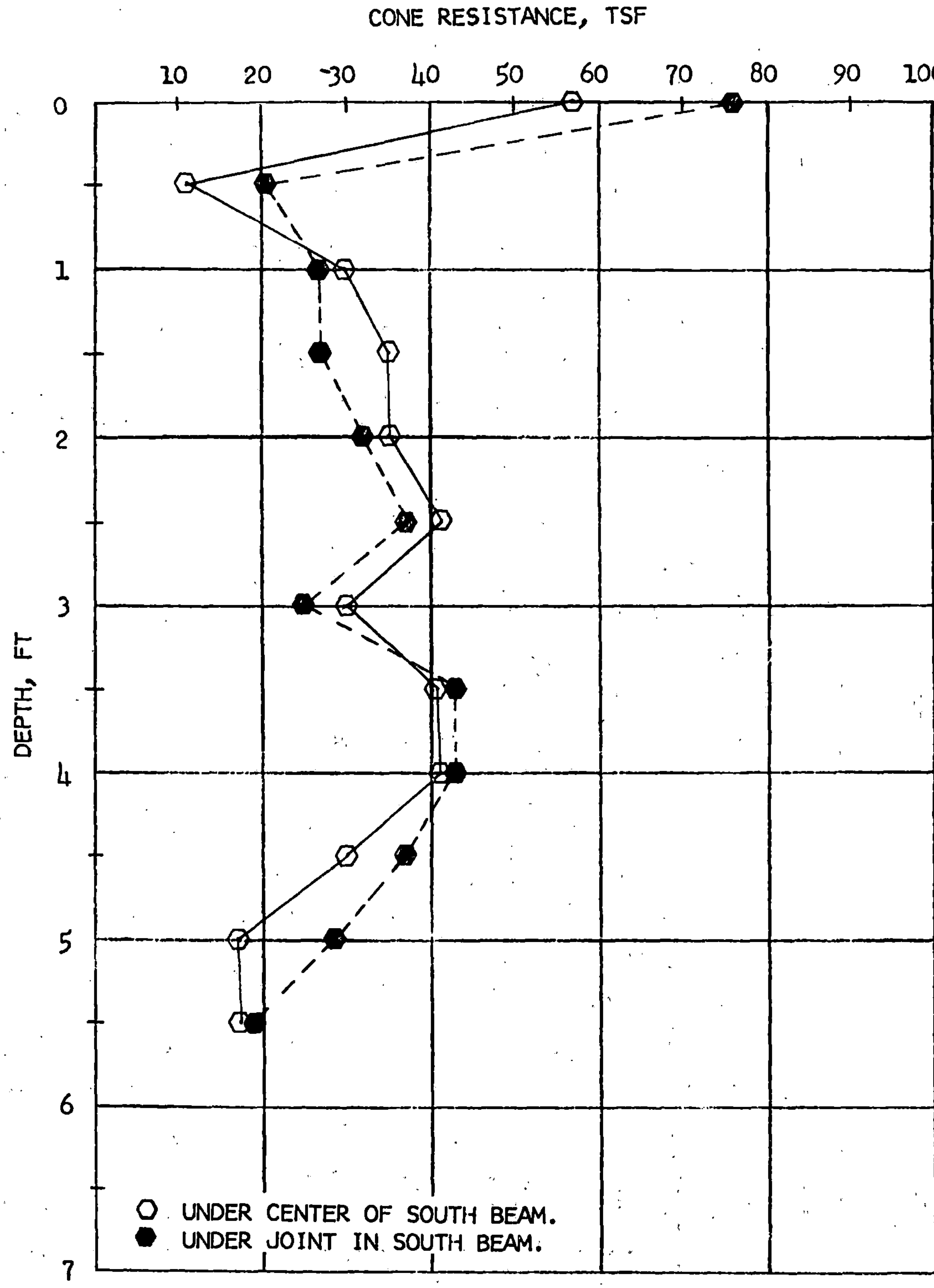


FIGURE C-31. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 7, STA 8576+10 AND 8576+15, SOUTH BEAM

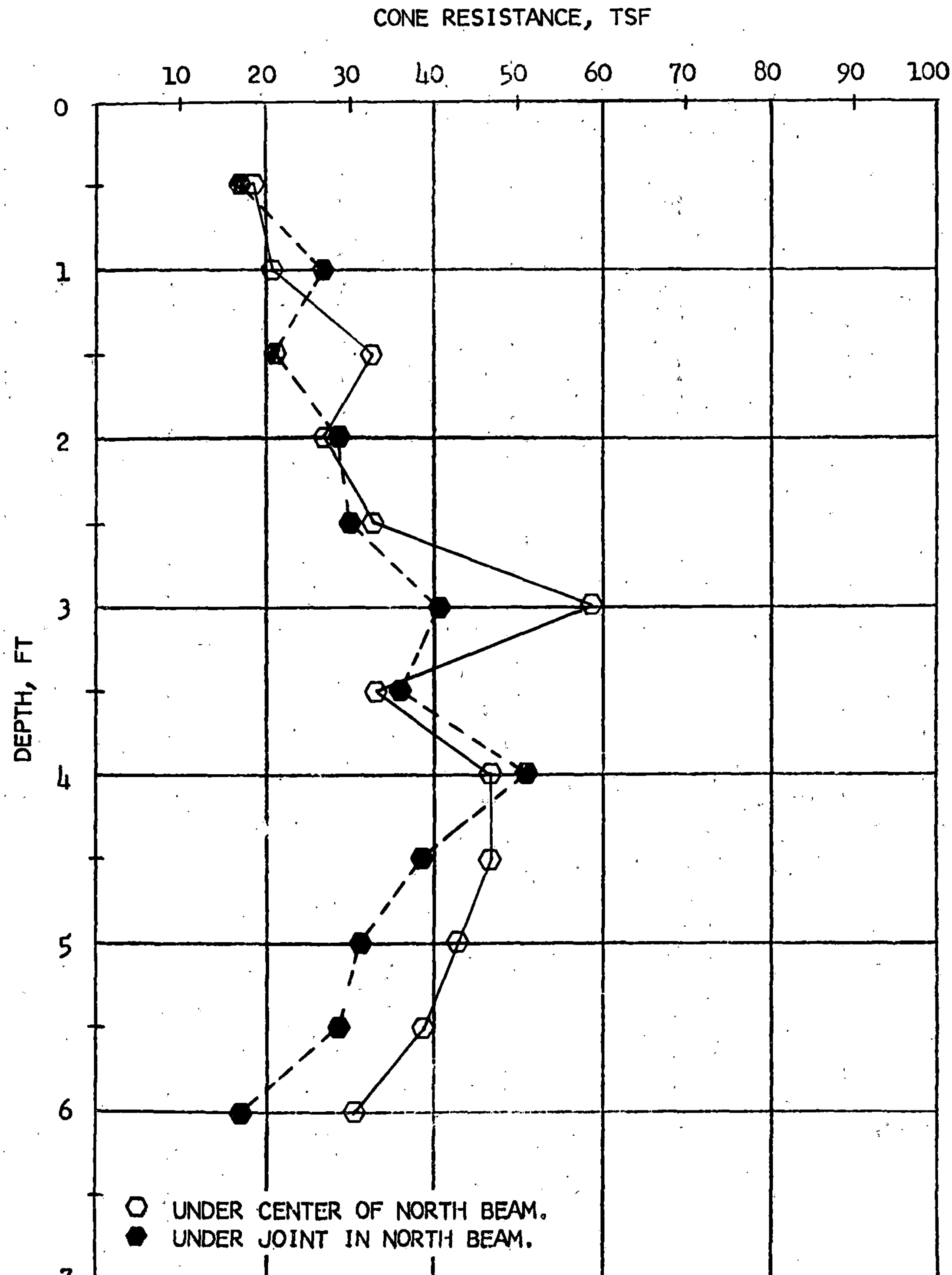


FIGURE C-32. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 7, STA 8578+00 AND 8578+05

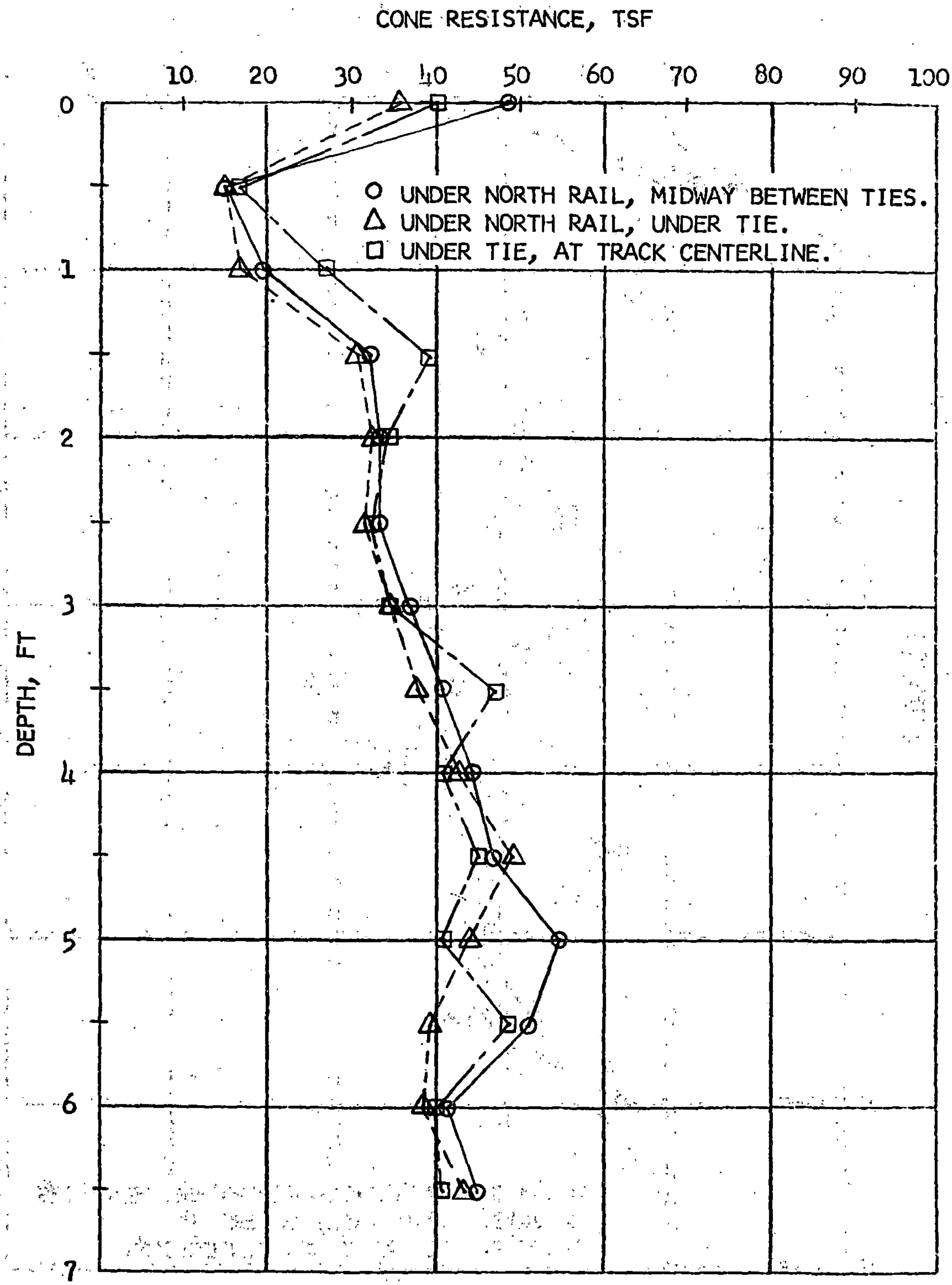


FIGURE C-33. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 8, STA 8581+30

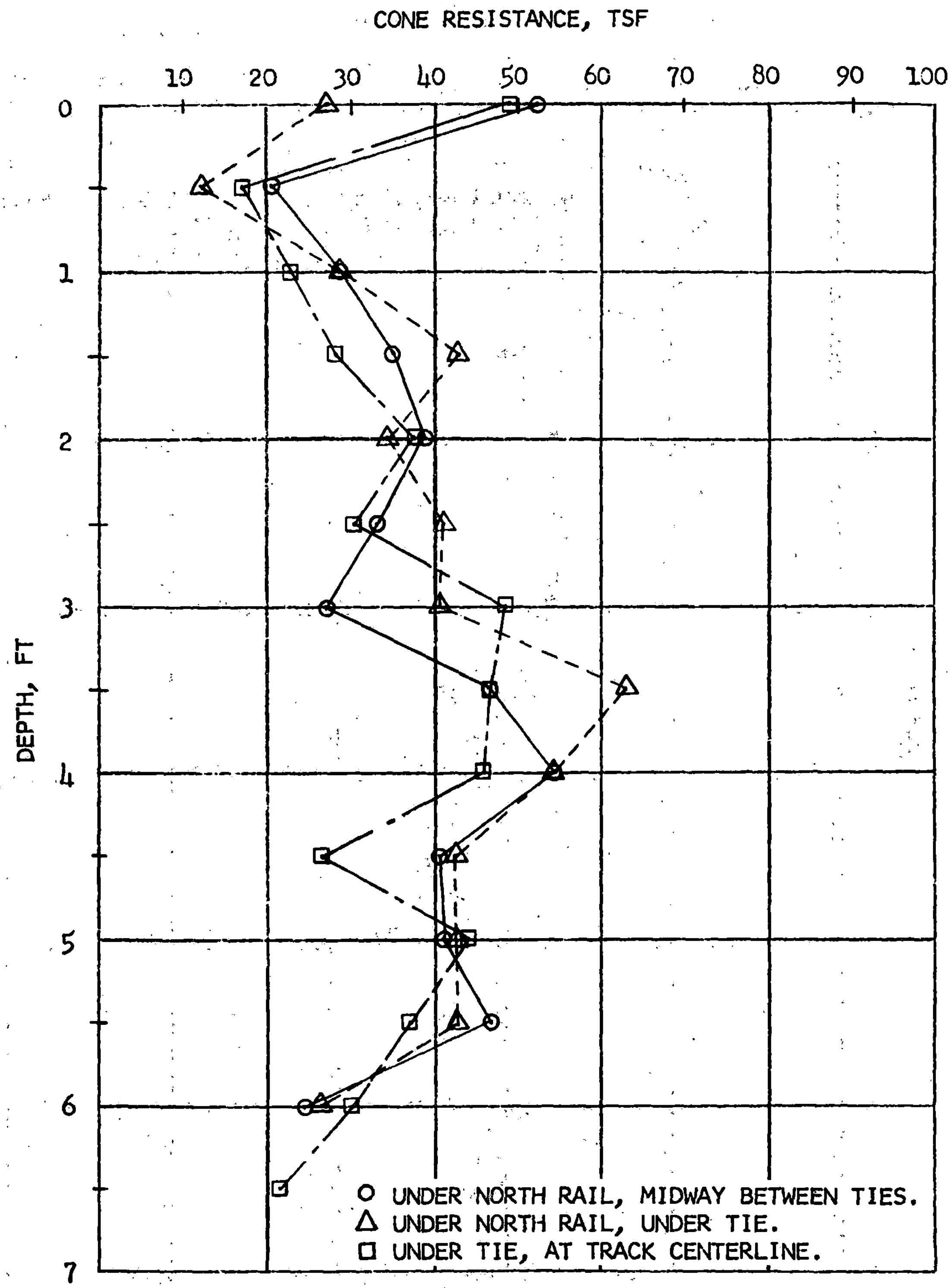


FIGURE C-34. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 8, STA 8583+00

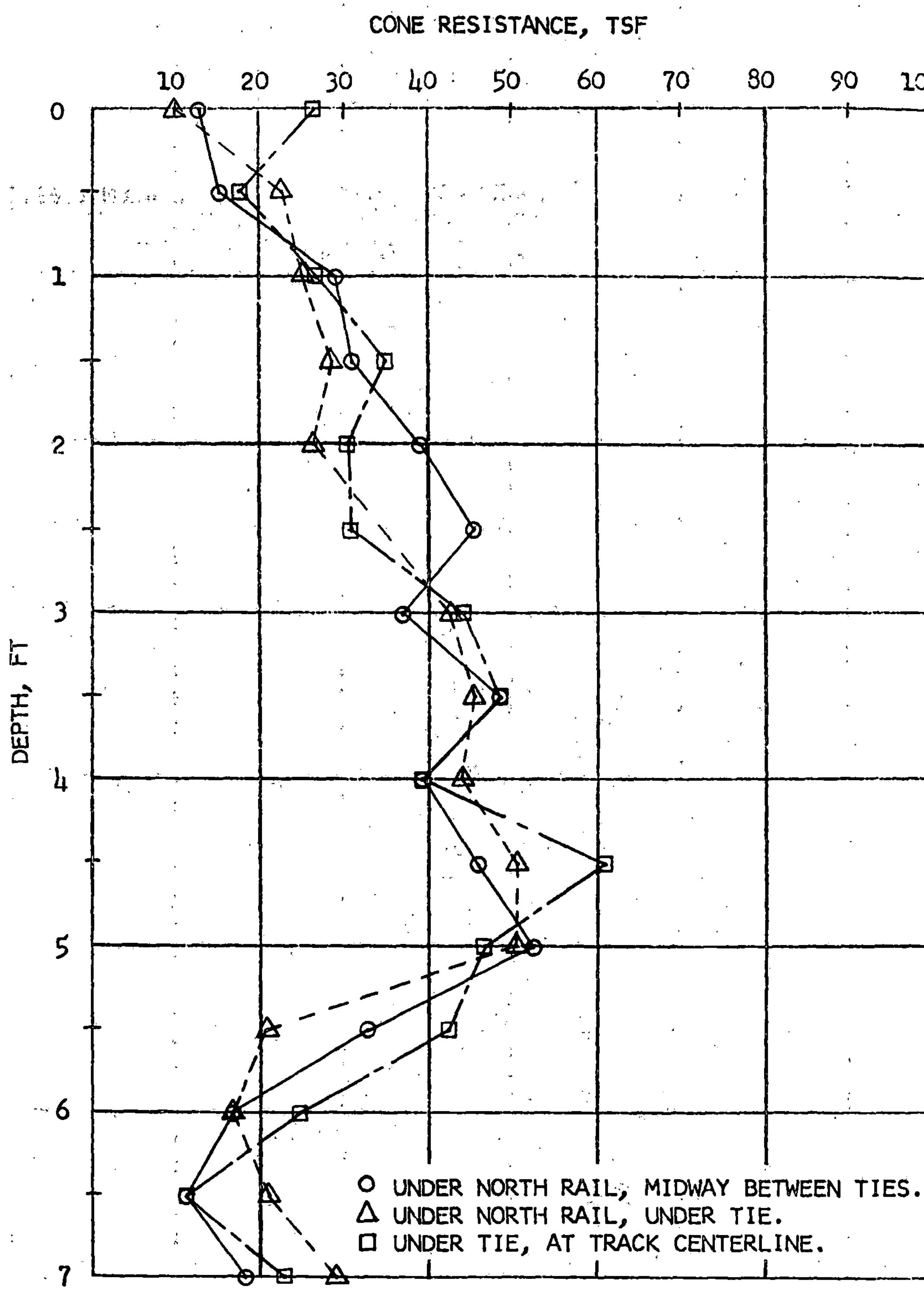


FIGURE C-35. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 8, STA 8585+00

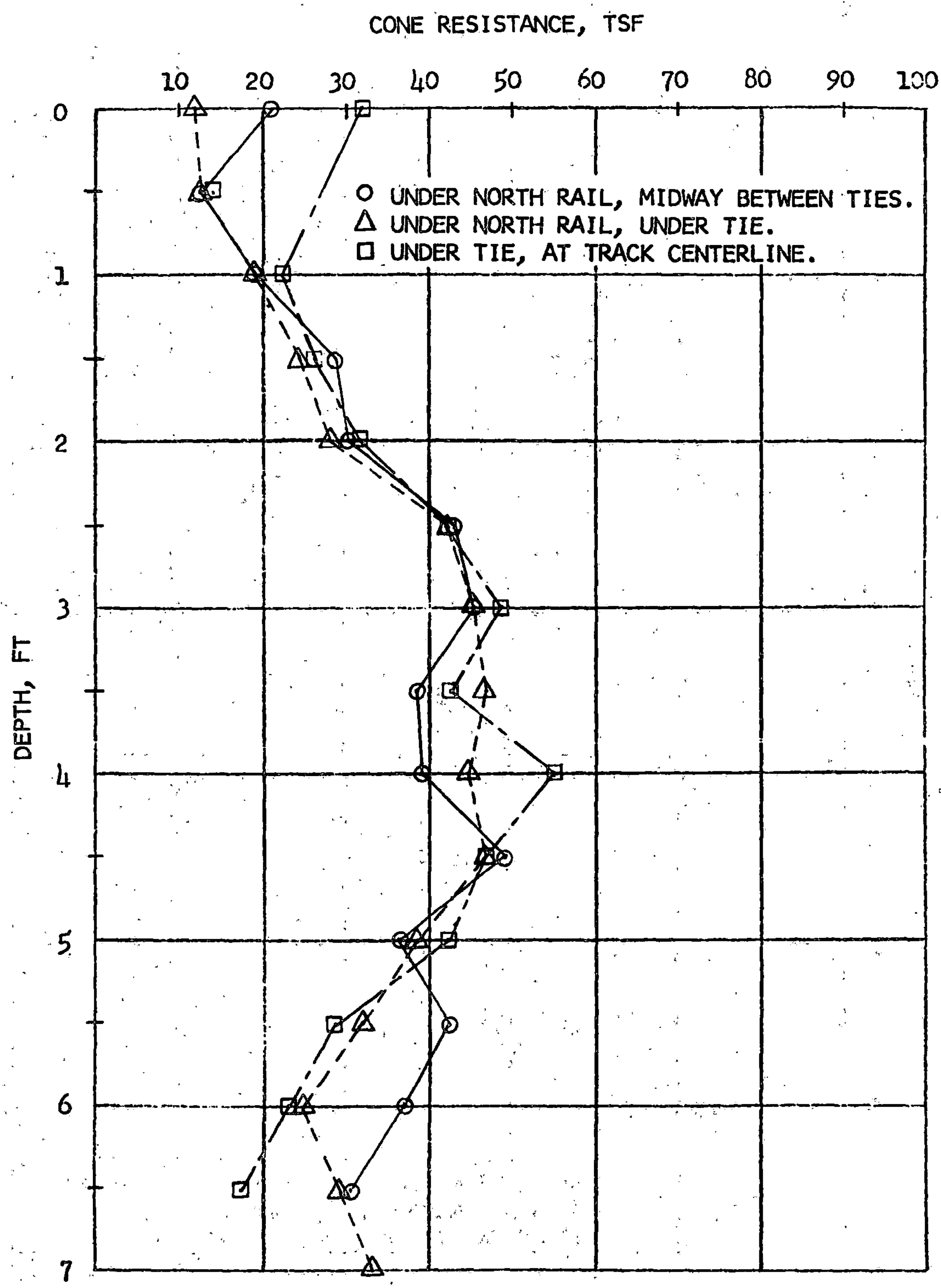


FIGURE C-36. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 8, STA 8586+80

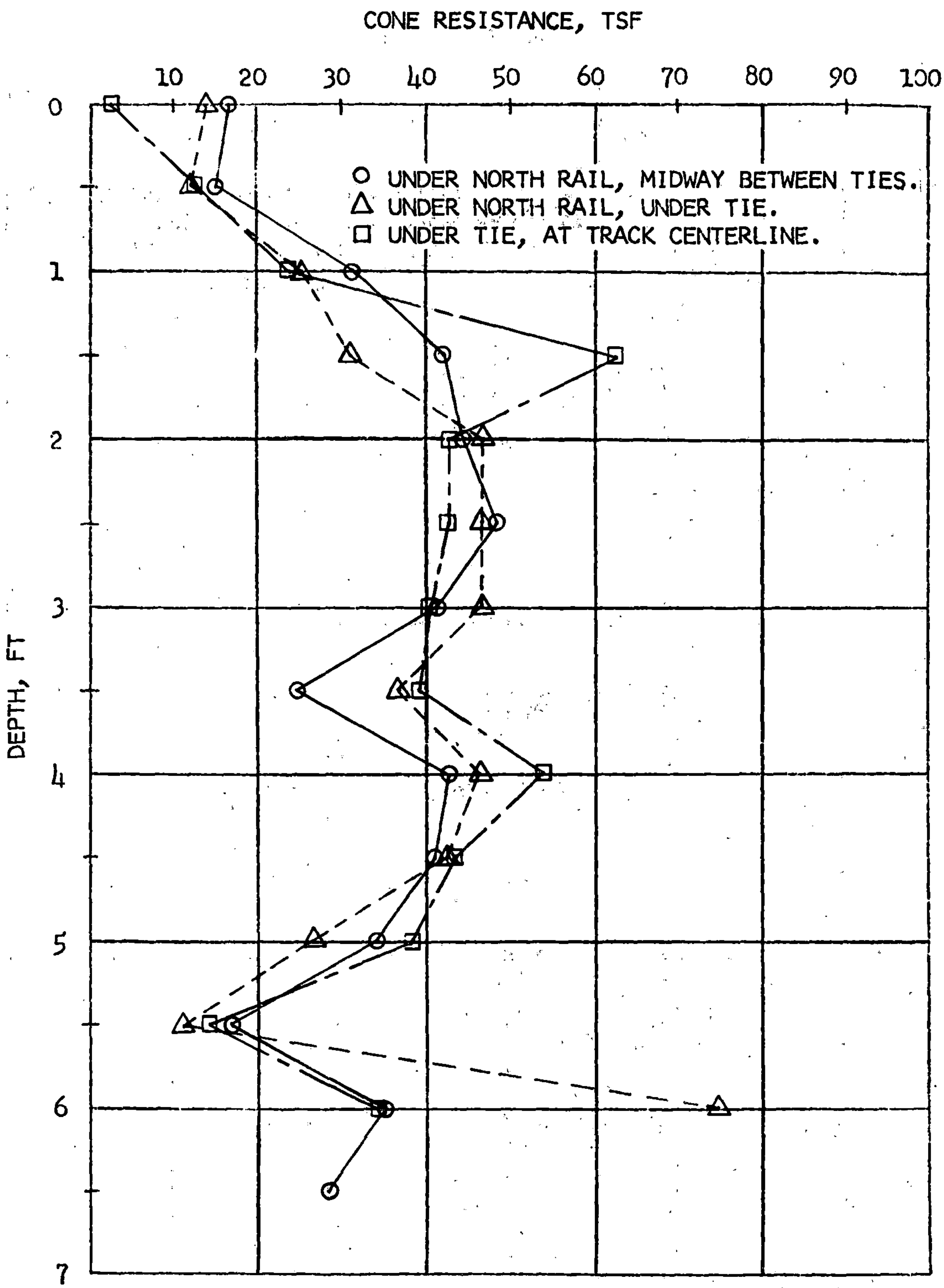


FIGURE C-37. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 8, STA 8588+00.5

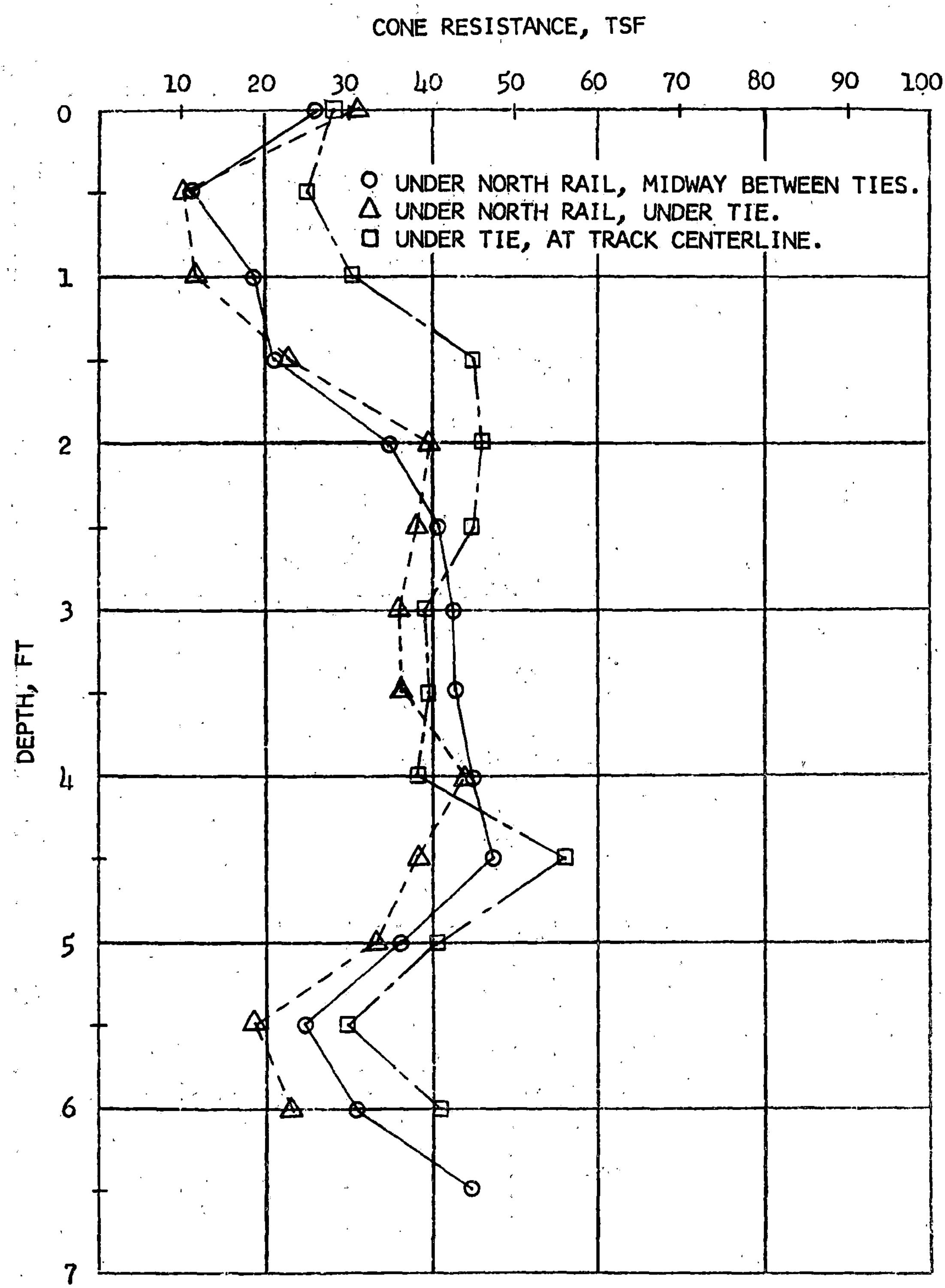


FIGURE C-38. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 9, STA 8591+01

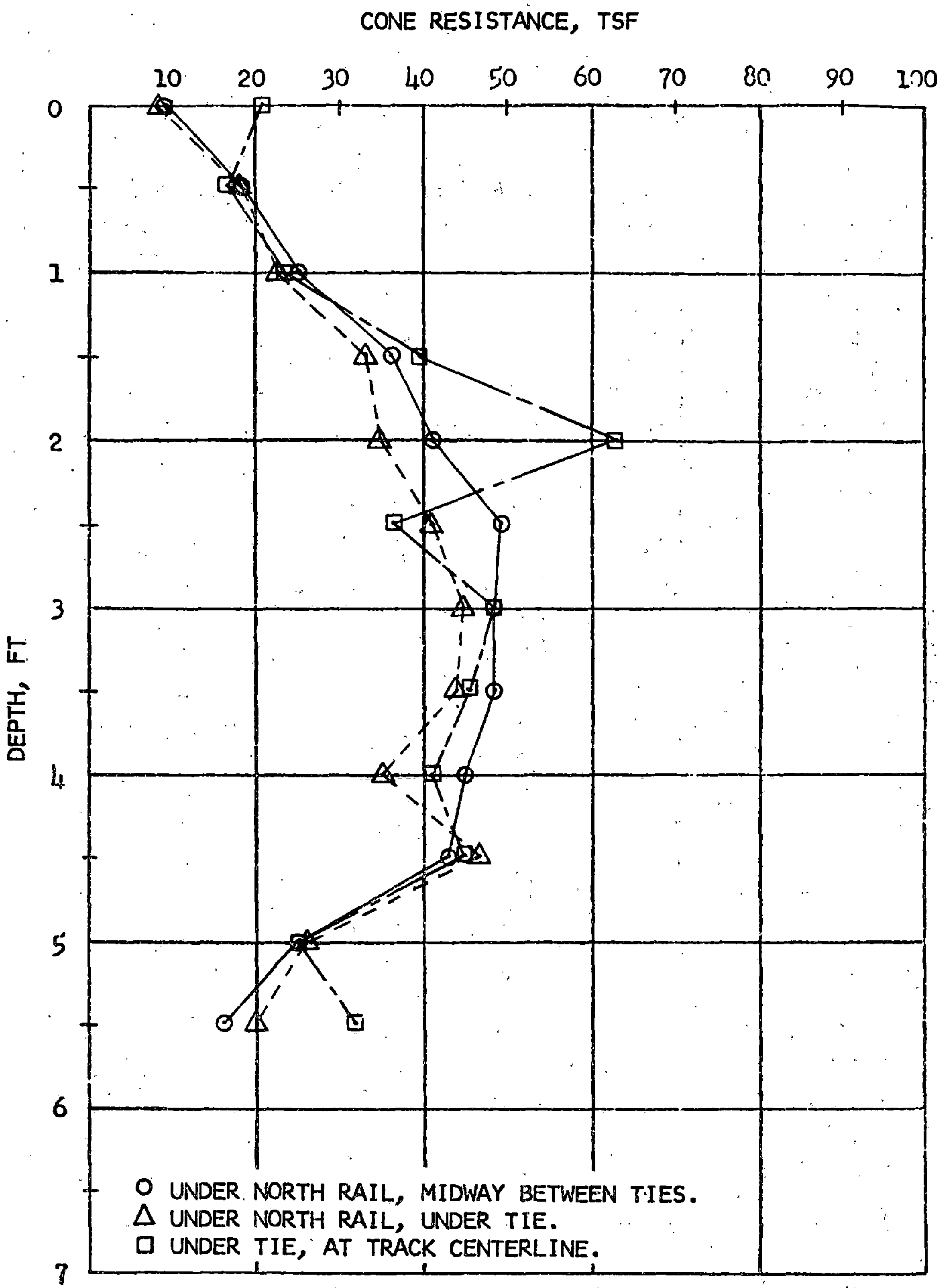


FIGURE C-39. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 9, STA 8593+00

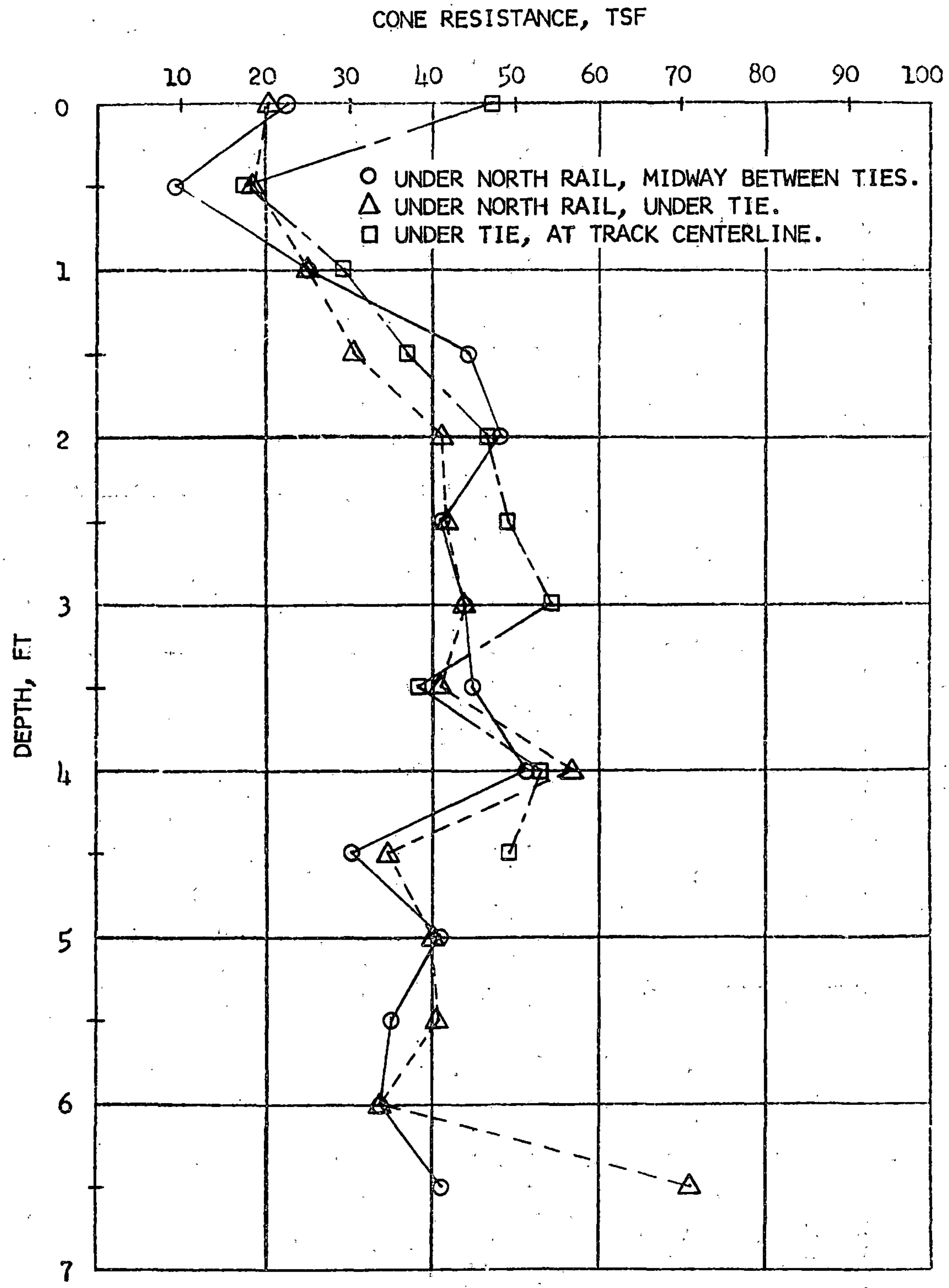


FIGURE C-40. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 9, STA 8594+82.7

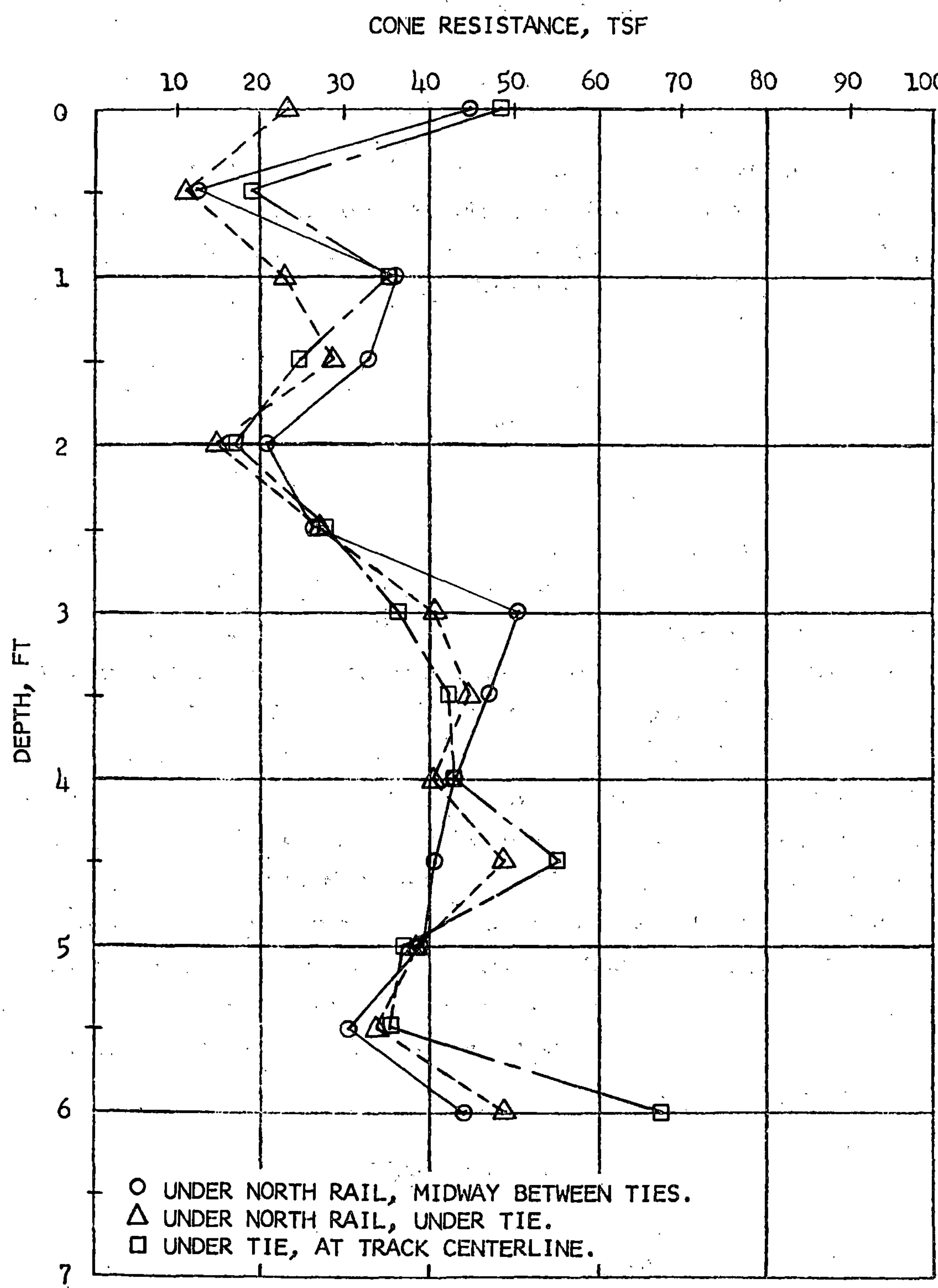


FIGURE C-41. DUTCH CONE PENETROMETER DRIVE POINT RESISTANCE VERSUS DEPTH IN THE SUBGRADE, TRACK SECTION 9, STA 8596+31

APPENDIX D: TRENCHING, SAMPLING, AND SOIL TESTING

General

During the period 19 April - 21 May 1976, a field party from the Pavement Investigations Division, Soils and Pavements Laboratory (now designated Geotechnical Laboratory) performed in situ soil tests and collected samples for the posttraffic investigation of the Kansas Test Track.

Test Plan

The investigation consisted of visual observations of ballast, drainage, settlement, cracking, and overall conditions of each test item. These conditions were also documented using color photographs. Test trenches, approximately 4 ft wide and 8 ft long were excavated in each track section with the exception of Track Section 6. In-place testing in each trench consisted of at least one 30-in.-diam plate bearing test on the ballast just beneath the structure (tie, slab, or beam). Water contents, densities, and California Bearing Ratio (CBR) tests were also conducted on the subgrade to a depth of 3 ft measured from the top of the subgrade. Disturbed samples were taken in each test pit for laboratory classification tests and compaction tests. Two undisturbed samples were taken in each trench. One was taken between the surface and 12 in., and the other was between 12- and 24-in. depth. Laboratory triaxial and unconfined compression tests were conducted on the undisturbed samples.

Field Testing

Location and depth control

A thorough study was made of the maintenance records kept by the Santa Fe Railroad during the traffic tests. Sites were selected in areas of high maintenance to determine causes of failure. The location of the approximate center of each trench with the tie, beam, or slab numbers is given in Table D-1.

Prior to the field testing at the KTT, all rails and fasteners had been removed. Therefore, elevations were taken on the top of each structure in the center of the north and south rails. This is not consistant with the elevations taken during traffic testing since they referenced the base of the rail. Cross sections and profiles along each rail were taken on the top of the subgrade after the ballast had been removed. These cross sections and profiles are shown in Figures D-1 to D-9. All depths of soil tests were referenced to the top of the subgrade during this testing and in this report.

Plate bearing tests

Thirty-inch-diameter plate bearing tests were conducted in each track section with the exception of Track Section 6. These tests were conducted in accordance with ASTM D1196-64. Tests were conducted on the ballast beneath the tie, beam, or slab structure. The track structure was removed and ballast cleared to the level of the bottom of the structure and wide enough for the plate (Figure D-10). Sand was used to obtain a level seat for the plate. A typical load-deflection plot is shown in Figure D-11. Plate bearing test results are given in Table D-2.

Pit excavation

After completion of plate bearing tests, samples of ballast were taken. The locations of these samples for each type track section is shown on Figures D-12 through D-14. The upper portion of ballast was then removed with a back hoe. The final cover was excavated by hand so that the subgrade surface would not be disturbed. Cross sections of the subgrade surface and profiles along the rails were taken at each pit location on the ballast-subgrade interface. These measurements are shown in Figures D-1 through D-9. Note the undulations beneath the ties on Tie Sections 1, 2A, 2B, 3B, and 8. This was not evident on Track Section 9. Also, a profile was taken on the shoulder of most track sections. Note the effects of loading by comparing the shoulder profile with the rail profile. Figures D-15 and D-16 illustrate the undulations on Track Sections 1 and 2A. Figure D-17 illustrates the deformation in the tie area on Track Section 2B.

California Bearing Ratio tests

California Bearing Ratio (CBR) tests were conducted in accordance with MIL-STD-621A, Method 101. CBR is a measure of the soil resistance to penetration of a 3-sq-in. piston expressed as a percent of a standard. The standard is 1000 psi at 0.1-in. penetration of 1,500 psi at 0.2-in. penetration. CBR tests were used to determine the relative soil strengths throughout the KTT. Tests were taken under ties, between ties, and under the north and south rails on the sections. In beam and slab sections they were conducted under joints, under the north and south rails, and between the rails. Locations are shown in Figures D-14, D-18, and D-19. A typical test setup is shown in Figure D-20. CBR data for each test pit is shown in Tables D-3 through D-12.

Moisture and density tests

At each CBR test location, moisture content and dry density tests were conducted. Original plans included use of a nuclear moisture density testing apparatus. This method was abandoned because of the influence of the walls of the test trench on the readings. Density tests were conducted using drive cylinders of known volume. Moisture content was determined by sampling and oven drying overnight. Results of moisture and density tests are also shown in Table D-3 through D-12.

Laboratory Testing

Ballast

Laboratory tests on ballast consisted of sieve analysis on all samples collected in Track Sections 1, 4, and 9. If there were enough fines (passing the 200 sieve) in these samples, Atterberg limits were conducted. After this testing was accomplished and the data analyzed, sieve analyses were conducted on selected samples from all other track sections. A total of 56 sieve analyses were conducted on ballast samples from the KTT. Atterberg limits tests were performed on fines obtained from these samples. Two samples were tested from the adjacent main line of the AT&SF Railroad. Results of these tests are shown in Table D-13.

Subgrade

Two undisturbed and two disturbed samples were taken from each test pit. Locations of these samples are shown in Figures D-12 through D-14. Laboratory tests on the disturbed samples consisted of Atterberg limits and sieve analyses. These tests were conducted for classification purposes. The results are given in Table D-14. Compaction tests were also conducted on the disturbed samples from Track Sections 1, 4, and 9. Samples were molded using the modified American Association of State Highway Officials (AASHO) effort. CBR's were conducted on the samples as molded. They were then remolded and soaked for 96 hours. CBR's were conducted on the soaked specimens. Results of these tests are shown in Figures D-21 to D-23. Note the almost total loss of strength under the soaked conditions.

Laboratory tests on undisturbed samples consisted of unconsolidated, undrained (Q) triaxial tests on samples from Track Sections 1, 4, and 9. Q test results are an average of at least three tests at confining pressures of 0.3, 0.5, and 0.8 tsf. Results of these tests are shown in Figures D-24 and D-25. Unconfined compression tests were conducted on all undisturbed samples. A minimum of two tests were run on each of the two samples taken from each pit. Results of these tests are presented in Figures D-26 through D-30.

TABLE D-1. LOCATIONS OF EACH TEST TRENCH

Track Section	Test Pit No.	Station of the Approximate Center Line	Tie, Beam or Slab No.
1	1	8524+75	208,209,210
2	2A	8531+60	115,116,117
2	2B	8535+16	276,277,278
3	3A	8540+17	160,161,162
3	3B	8542+49	275,276,277
4	4	8551+50	53,54
5	5	8558+20	120,121
7	7	8576+41	62,63
8	8	8587+10	261,262,263
9	9	8595+37	10,11,12

TABLE D-2. PLATE BEARING TEST RESULTS

Track Section	Location	k* psi
1	Sta 8524+75 (south rail)	380
2A	Sta 8531+62 (south rail)	303
2B	Sta 8535+16 (north rail)	317
3A	Sta 8542+49 (south rail)	229
3B	Sta 8540+20 (north rail)	294
4	Sta 8551+50 (north rail)	217
5	Sta 8558+20 (center)	88
5	Sta 8558+10 (center)	232
5	Sta 8562+05 (center)	317
7	Sta 8576+41 (south rail)	338
8	Sta 8587+08 (north rail)	261
9	Sta 8595+33 (north rail)	203

* k = slope of average pressures versus deflection curve during loading.

TABLE D-3. KANSAS TEST TRACK
TEST PIT 1

Material	Depth or Elev	Location		CBR Data CBR	WC	DW	Remarks
Lime Stab Lean Cl	Surface	Under Tie 210		3.3	29.9	89.3*	N - lime stab layer not present
				33.0	30.9	85.4*	M - lime stab layer approx 2" thick
				30.0	39.1	82.5*	S - lime stab layer approx 2" thick
			AVG	22.1	33.3	85.7	
Hvy Cl	6"			7.7	29.8	92.2	N
				6.8	27.1	93.4	M
				5.0	29.0	93.4	S
			AVG	6.5	28.6	93.0	
	12"			7.3	27.1	92.1	N
				7.9	27.6	91.5	M
				6.7	28.1	89.1	S
			AVG	7.3	27.6	90.9	
	24"			10.0	26.5	93.0	N
				6.8	26.1	93.6	M
				12.0	26.0	92.1	S
			AVG	9.6	26.2	92.9	
Hvy Cl	36"	Under Tie 210		10.0	26.5	91.7	N
				13.0	25.6	90.9	M
				12.0	28.0	88.9	S
			AVG	11.7	26.7	90.5	
Lime Stab Lean Cl	Surface	Between Ties 209-210		7.0	29.0	90.9*	N - lime stab layer not present
				39.0	28.5	86.2*	M - lime stab layer approx 3" thick
				48.0	36.1	84.3*	S - lime stab layer approx 3" thick
			AVG	31.3	31.2	87.1	
Hvy Cl	6"	Between Ties 209-210		6.6			
				4.5			
				4.0			
			AVG	5.0			

(Continued)

TABLE D-3 (Continued)

Material	Depth or Elev	Location		CBR Data: CBR	CBR Data: WC	CBR Data: DW	Remarks
Hvy Cl	12"	Between Ties 209-210		6.5	27.6	91.2	N
				6.8	28.6	89.0	M
				5.2	27.9	89.4	S
			AVG	6.2	28.0	89.9	
	24"			8.1	25.4	93.8	N
				6.8	30.5	83.0	M
				9.0	23.1	94.2	S
			AVG	8.0	26.3	90.3	
Hvy Cl	36"	Between Ties 209-210		11.0	27.6	90.8	N
				11.0	24.9	92.6	M
				11.0	28.4	87.7	S
			AVG	11.0	27.0	90.4	
Lime Stab Lean Cl	Surface	Under Tie 209		1.8	34.5	88.1*	N - lime stab layer not present
				31.0	34.5	85.9*	M - lime stab layer approx 2" thick
				12.0	42.5	81.1*	S - lime stab layer approx 1" thick
			AVG	14.9	37.2	85.0	
Hvy Cl	6"			3.9	28.3	89.0	N
				4.2	27.4	94.6	M
				5.0	29.7	89.2	S
			AVG	4.4	28.5	90.9	
	12"			7.0	26.7	92.7	N
				7.5	26.1	93.1	M
				8.8	26.3	93.3	S
			AVG	7.8	26.4	93.0	
Hvy Cl	24"	Under Tie 209		11.0	27.2	88.1	N
				6.3	26.2	91.4	M
				11.0	25.8	89.3	S
			AVG	9.4	26.4	89.6	

(Continued)

(Sheet 2 of 3)

TABLE D-3 (Concluded)

Material	Depth or Elev	Location		CBR Data CBR	WC	DW	Remarks
Hvy Cl	36"	Under Tie 209		10.0	28.4	89.1	N
				12.0	26.6	90.4	M
				10.0	27.1	89.1	S
			AVG	10.7	27.4	89.5	
Lime Stab Lean Cl	Surface	Between Ties 208-209		11.0	33.4	86.0*	N - lime stab layer approx 1" thick
				48.0	42.7	80.6*	M - lime stab layer approx 3" thick
				43.0	30.9	89.9*	S - lime stab layer approx 3" thick
			AVG	34.0	35.7	85.5	
Hvy Cl	6"			7.0	31.3	87.0	N
				6.1	28.0	90.2	M
				4.5	28.9	89.2	S
			AVG	5.9	29.4	88.8	
	12"			7.2	27.2	90.9	N
				7.1	27.7	90.8	M
				6.0	28.5	90.7	S
			AVG	6.8	27.8	90.8	
	24"			15.0	27.6	89.0	N
				6.8	25.4	94.3	M
				11.0	23.8	94.3	S
			AVG	10.9	25.6	92.5	
Hvy Cl	36"	Between Ties 208-209		11.0	25.8	91.4	N
				11.0	25.4	93.3	M
				12.0	26.3	90.7	S
			AVG	11.3	25.8	91.8	

* Computed from moisture cans with nuclear density.

(Sheet 3 of 3)

Material	Depth or Elev	Location
Lime Stab Lean Cl	Surface	Between Ties 117-116
Lime Stab Lean Cl	Surface	Under Tie 116
Hvy Cl	6"	
	12"	
	24"	
Hvy Cl	36"	Under Tie 116

TABLE D-4. KANSAS TEST TRACK
SECTION 2A

	CBR Data			Remarks
	CBR	WC	DW	
	3.8	27.6	91.2	N
	9.0	26.4	89.7	M
	6.6	26.0	90.8	S
AVG	6.5	26.7	90.6	
	3.0	29.8	89.7	N
	9.3	27.8	87.2	M
	7.6	24.7	94.0	S
AVG	6.6	27.4	90.3	
	9.1	24.4	94.9	N
	10.0	26.9	92.2	M
	8.2	29.5	89.4	S
AVG	9.1	26.9	92.2	
	9.3	28.6	87.7	N
	14.0	30.6	87.3	M
	9.4	27.2	91.7	S
AVG	10.9	28.8	88.9	
	13.0	23.0	95.0	N
	13.0	22.3	94.4	M
	14.0	21.9	97.3	S
AVG	13.3	22.4	95.6	
	11.0	21.6	94.9	N
	16.0	24.3	92.7	M
	13.0	24.3	93.2	S
AVG	13.3	23.4	93.6	

(Continued)

TABLE D-4 (Concluded)

Material	Depth or Elev	Location		CBR Data: CBR	WC	DW	Remarks
Lime Stab Lean Cl	Surface	Between Ties 116-115		3.1	31.3	89.7	N
				9.3	28.1	85.1*	M - void in cylinder
				6.6	28.4	90.2	S
			AVG	6.3	29.3	88.3	
Hvy Cl	6"			12.0	24.4	94.7	N
				9.3	27.1	89.9	M
				10.0	25.6	92.5	S
			AVG	10.4	25.7	92.4	
	12"			9.1	28.3	89.0	N
				10.0	30.2	87.4	M
				9.0	27.6	90.8	S
			AVG	9.4	28.7	89.1	
	24"			14.0	22.9	96.0	N
				15.0	24.4	94.7	M
				13.0	21.6	94.6	S
			AVG	14.0	23.0	95.1	
Hvy Cl	36"	Between Ties 116-115		12.0	22.4	95.4	N
				12.0	24.2	93.6	M
				13.0	21.1	96.1	S
			AVG	12.3	22.6	95.0	
Lime Stab Lean Cl	Surface	Under Tie 115		3.7	27.5	90.4	N
				9.5	28.4	86.6*	M - void in cylinder
				6.6	25.8	91.3	S
			AVG	6.6	27.2	89.4	

* Computed from moisture cans with nuclear density.

Material	Depth or Elev	Location
Lime Stab Lean Cl	Surface	Between Ties 276-277
Hvy Cl	6"	
	12"	
	24"	
Hvy Cl	36"	Between Ties 276-277
Lime Stab Lean Cl	Surface	Under Tie 277

TABLE D-5. KANSAS TEST TRACK
SECTION 2B

	CBR Data				Remarks
	CBR	WC	DW	WC	
	25.0	34.9	79.8	35.9	N
	9.6	33.2	82.7	32.8	M
	12.0	29.9	83.6	29.6	S
AVG	15.5	32.7	82.0	32.8	
	4.9	26.0	93.0		N
	2.7	27.1	89.4		M
	4.5	29.4	87.2		S
AVG	4.0	27.5	89.9		
	7.4	24.2	94.4		N
	5.1	31.5	83.2		M
	7.0	23.9	90.6		S
AVG	6.5	26.5	89.4		
	12.0	24.2	90.2		N
	12.0	24.8	92.9		M
	7.2	23.6	93.9		S
AVG	10.4	24.2	92.3		
	8.0	27.0	89.4		N
	6.5	29.0	87.8		M
	10.0	26.2	90.6		S
AVG	8.2	27.4	89.3		
	4.4	33.7	83.2	34.1	N
	8.3	33.7	79.8	34.8	B
	9.4	30.6	83.3	30.2	S
AVG	7.4	32.7	82.1	33.0	

(Continued)

TABLE D-5 (Concluded)

Material	Depth or Elev	Location		CBR Data: CBR	CBR Data: WC	CBR Data: DW	CBR Data: WC	Remarks
Hvy Cl	6"	Under Tie 277		4.6	24.9	94.2		N
				3.5	28.8	89.6		M
				4.0	27.2	90.1		S
			AVG	4.0	27.0	91.3		
	12"			6.0	26.5	91.2		N
				8.2	26.3	89.2		M
				9.3	26.4	90.0		S
			AVG	7.8	26.4	90.1		
	24"			9.1	22.3	95.5		N
				9.3	24.3	92.7		M
				10.0	24.6	92.9		S
			AVG	9.5	23.7	93.7		
Hvy Cl	36"	Under Tie 277		8.0	23.7	91.8		N
				8.3	26.0	89.4		M
				8.7	23.8	91.8		S
			AVG	8.3	24.5	91.0		
Lime Stab Lean Cl	Surface	Between Ties 277-278		6.9	33.3	79.3	33.7	N
				9.1	28.8	83.9	29.9	M
				9.1	32.8	82.0	29.7	S
			AVG	8.4	31.5	81.7	31.1	
Lime Stab Lean Cl	Surface	Under Tie 278		5.7	33.0	83.5	33.5	N
				8.1	32.9	80.1	34.0	M
				9.1	31.4	82.8	31.4	S
			AVG	7.6	32.4	82.1	33.0	

TABLE D-6. KANSAS TEST TRACK
SECTION 3A

Material	Depth or Elev	Location		CBR Data: CBR	CBR Data: WC	CBR Data: DW		Remarks
Lime Stab Lean Cl	Surface	Under Tie 161		3.8	24.6	84.6	N	Pit had layers of limestone dust throughout and rocks
				10.0	31.7	85.8	M	
				9.0	29.0	87.1	S	
			AVG	7.6	28.4	85.8		
Hvy Cl	6"			7.0	22.1	95.8	N	
				7.0	21.5	95.5	M	
				7.8	25.3	93.7	S	
			AVG	7.3	23.0	95.0		
	12"			7.1	29.0	88.1	N	
				12.0	23.9	92.8	M	
				9.0	31.5	84.4	S	
			AVG	9.4	28.1	88.4		
	24"			10.0	22.5	95.5	N	
				11.0	24.8	92.1	M	
				9.0	23.1	94.4	S	
			AVG	10.0	23.5	94.0		
Hvy Cl	36"	Under Tie 161		11.0	25.9	92.6	N	
				10.0	25.8	88.4	M	
				8.0	24.5	94.9	S	
			AVG	9.7	25.4	92.0		
Lime Stab Lean Cl	Surface	Between Ties 161-162		2.5	25.5	86.2	N	
				14.0	24.6	91.1	M	
				7.0	30.0	88.6	S	
			AVG	7.8	26.7	88.6		

(Continued)

Material	Depth or Elev	Location
Hvy Cl	6"	Between Ties 161-162
	12"	
	24"	
Hvy Cl	36"	Between Ties 161-162
Lime Stab	Surface	Between Ties 160-161
Lime Stab	Surface	Under Tie 162

TABLE D-6 (Concluded)

	CBR Data			Remarks
	CBR	WC	DW	
	9.0	23.1	96.5	N
	8.0	27.3	91.6	M
	9.5	22.2	96.4	S
AVG	8.8	24.2	94.8	
	11.0	28.8	89.3	N
	10.0	27.1	88.7	M
	7.5	30.4	85.4	S
AVG	9.5	28.8	87.8	
	11.0	25.1	93.2	N
	11.0	23.9	94.9	M
	9.0	27.4	90.3	S
AVG	10.3	25.5	92.8	
	11.0	26.4	82.8	N
	16.0	25.5	82.5	M
	12.0	25.1	92.9	S
AVG	13.0	25.7	86.1	
	4.0	19.9	91.9	N
	4.8	18.0	92.0	M
	9.0	25.2	93.0	S
AVG	5.9	21.0	92.3	
	4.1	31.5	90.2	N
	17.0	32.8	88.0	M
	3.4	29.1	84.9	S
AVG	8.2	21.1	87.7	

Material	Depth or Elev	Location
Lime Stab Lean Cl	Surface	Between Ties 275-276
		Under Tie 277
Lime Stab Lean Cl	Surface	Under Tie 276
Hvy Cl	6"	
	12"	
Hvy Cl	24"	Under Tie 276

TABLE D-7. KANSAS TEST TRACK
SECTION 3B

	CBR Data			Remarks
	CBR	WC	DW	
	23.0	35.0	79.7	N
	19.0	32.4	79.6	M
	21.0	35.7	78.7	S
AVG	21.0	34.4	79.3	
	28.0	30.1	82.4	N
	20.0	28.1	83.4	M
	20.0	32.9	81.9	S
AVG	22.7	30.4	82.6	
	22.0	30.3	81.8	N
	13.0	28.2	82.4	M
	36.0	33.6	81.3	S
AVG	23.7	30.7	81.8	
	2.3	26.5	90.4	N
	8.0	26.0	92.4	M
	4.0	25.5	91.5	S
AVG	4.8	26.0	91.4	
	3.6	28.1	85.7	N
	3.2	26.9	86.7	M
	3.1	29.7	86.4	S
AVG	3.3	28.2	86.3	
	11.0	23.0	95.0	N
	10.0	22.3	95.7	M
	13.0	23.6	94.8	S
AVG	11.3	23.0	95.2	

(Continued)

Material	Depth or Elev	Location
Hvy Cl	36"	Under Tie 276
Lime Stab Lean Cl	Surface	Between Ties 276-277
Hvy Cl	6"	
	12"	
	24"	
Hvy Cl	36"	Between Ties 276-277

TABLE D-7 (Concluded)

	CBR Data			Remarks
	CBR	WC	DW	
	9.0	24.7	94.3	N
	8.0	22.8	95.0	M
	9.0	22.4	94.9	S
AVG	8.7	23.3	94.7	
	17.0	35.8	77.8	N
	21.0	33.5	82.8	M
	20.0	36.4	77.6	S
AVG	19.3	35.2	79.4	
	5.5	26.4	92.2	N
	7.0	26.0	92.4	M
	5.1	26.0	89.5	S
AVG	5.9	26.1	91.4	
	3.8	26.6	89.1	N
	4.4	27.0	90.2	M
	4.2	24.2	94.0	S
AVG	4.1	25.9	91.1	
	13.0	23.0	95.6	N
	12.0	21.6	94.9	M
	12.0	25.6	91.7	S
AVG	12.3	25.9	94.1	
	9.0	23.8	95.0	N
	11.0	23.7	95.6	M
	9.0	22.6	93.5	S
AVG	9.7	23.4	94.7	

Material	Depth or Elev	Location
Lime Stab Lean Cl	Surface	Joint Beams 53-54
Hvy Cl	6"	
	12"	
	24"	
Hvy Cl	36"	Joint Beams 53-54
Lime Stab Lean Cl	Surface	Middle Beam 54

TABLE D-8. KANSAS TEST TRACK
SECTION 4

	CBR DAta			Remarks
	CBR	WC	DW	
	12.0	29.3	82.4	N
	7.6	29.5	85.9	M
	8.0	27.6	88.7	S
AVG	9.2	28.8	85.7	
	3.8	26.5	88.2	N
	4.1	24.0	91.0	M
	4.2	29.4	87.6	S
AVG	4.0	26.6	88.9	
	4.6	24.8	90.4	N
	8.0	27.1	88.9	M
	2.6	25.1	93.4	S
AVG	5.1	25.7	90.9	
	4.4	37.4	80.5	N
	4.9	32.0	86.2	M
	1.8	30.8	85.9	S
AVG	3.7	33.4	84.2	
	9.7	25.3	93.1	N
	8.8	26.1	92.3	M
	9.0	26.2	91.6	S
AVG	9.2	25.9	92.3	
	27.0	28.6	86.8	N
	8.5	30.0	86.2	M
	7.4	32.7	82.1	S
AVG	14.3	30.4	85.0	

(Continued)

Material	Depth or Elev	Location
Hvy Cl	6"	Middle Beam 54
	12"	
	24"	
Hvy Cl	36"	Middle Beam 54

TABLE D-8 (Concluded)

	CBR Data			Remarks
	CBR	WC	DW	
	3.6	26.5	90.4	N
	3.4	26.2	92.2	M
	3.8	25.8	93.2	S
AVG	3.6	26.2	91.9	
	4.6	25.0	91.0	N
	3.8	26.2	91.0	M
	6.0	29.2	86.4	S
AVG	4.8	26.8	89.5	
	6.0	30.2	87.3	N
	7.8	26.7	90.1	M
	7.4	27.5	90.5	S
AVG	7.1	28.1	89.3	
	6.1	30.2	89.4	N
	5.8	25.9	92.3	M
	6.6	22.9	94.9	S
AVG	6.2	26.3	92.2	

Material	Depth or Elev	Location
Lime Stab Lean Cl	Surface	Center Slab 121
Hvy Cl	6"	
	12"	
	24"	
Hvy Cl	36"	Center Slab 121
Lime Stab Lean Cl	Surface	Joint Slabs 121-120
Hvy Cl	6"	
Hvy Cl	12"	Joint Slabs 121-120

TABLE D-9. KANSAS TEST TRACK
SECTION 5

	CBR Data			Remarks
	CBR	WC	DW	
	18.0	31.6	82.4	M
	9.4	30.4	84.5	S
AVG	13.7	31.0	83.5	
	4.3	29.8	86.7	M
	2.0	29.8	85.1	S
AVG	3.2	29.8	85.9	
	2.3	29.5	86.3	M
	3.2	29.6	86.7	S
AVG	2.8	29.6	86.5	
	5.3	27.6	84.5	M
	5.2	27.0	88.7	S
AVG	5.3	27.3	86.6	
	14.0	25.5	92.0	M
	13.0	25.3	91.3	S
AVG	13.5	25.4	91.7	
	17.0	30.3	83.7	N
	10.0	31.8	82.4	S
AVG	13.5	31.1	83.1	
	3.5	29.5	87.3	N
	3.0	30.2	84.6	S
AVG	3.3	29.9	86.0	
	2.8	29.3	87.2	N
	2.6	35.1	83.0	S
AVG	2.7	32.2	85.1	

(Continued)

TABLE D-9 (Concluded)

Material	Depth or Elev	Location		CBR Data		
				CBR	WC	DW
Hvy Cl	24"	Joint Slabs 121-120		6.6	27.8	85.1
				5.1	26.1	89.0
			AVG	5.9	27.0	87.1
Hvy Cl	36"	Joint Slabs 121-120		17.0	25.6	91.7
				18.0	26.0	90.2
			AVG	17.5	25.8	91.0

Remarks
N S
N S

Material	Depth or Elev	Location
Cement Stab Lean Cl	Surface	Joint Beams 63-62
Hvy Cl	6"	
	12"	
	24"	
Hvy Cl	36"	Joint Beams 63-62
Cement Stab Lean Cl	Surface	Center Beam 63

TABLE D-10. KANSAS TEST TRACK
SECTION 7

	CBR Data			Remarks
	CBR	WC	DW	
	30.0	92.8	83.1	N
	50.0	30.6	85.6	M
	44.0	28.1	87.0	S
AVG	41.3	29.5	85.2	
	1.3	37.0	82.8	N
	3.1	31.0	88.4	M
	1.8	38.3	84.0	S
AVG	2.1	35.4	85.1	
	6.6	26.2	92.9	N
	7.4	26.5	93.1	M
	8.0	24.8	95.4	S
AVG	7.3	25.8	93.8	
	6.0	27.3	90.8	N
	5.6	27.2	88.5	M
	6.0	30.6	86.8	S
AVG	5.9	28.4	88.7	
	7.0	26.1	89.8	N
	11.0	26.0	91.4	M
	10.0	25.8	93.6	S
AVG	9.6	26.0	91.6	
	33.0	29.4	85.3	N
	62.0	30.5	84.8	M
	33.0	32.4	81.9	S
AVG	42.7	30.8	84.0	

(Continued)

TABLE D-10 (Concluded)

Material	Depth or Elev	Location		CBR Data			Remarks
				CBR	WC	DW	
Hvy Cl	6"	Center Beam		1.3	37.3	84.0	N
		63		2.8	32.5	87.1	M
				1.5	46.8	78.6	S
			AVG	1.9	38.9	83.2	
	12"			6.7	26.5	93.9	N
				10.0	26.5	92.8	M
				9.0	25.4	94.0	S
			AVG	8.6	26.5	93.6	
	24"			8.0	15.0	91.2	N
				10.0	30.3	88.0	M
				5.4	24.5	90.8	S
			AVG	7.8	26.6	90.0	
Hvy Cl	36"	Center Beam		10.0	25.0	93.8	N
		63		12.0	25.4	92.8	M
				7.2	25.6	92.0	S
			AVG	9.7	25.3	92.9	

TABLE D-11. KANSAS TEST TRACK
SECTION 8

Material	Depth or Elev	Location		CBR Data: CBR	WC	DW		Remarks
Lime Stab Lean Cl	Surface	Under Tie 261		10.0	31.5	86.4	N	Free water in ballast; stab layer approx. 4-1/2" thick; soil under this appears to be saturated; this could account for the high WC in the density
				17.0	37.0	75.6	M	
				13.0	32.4	83.5	S	
			AVG	13.3	33.6	81.8		
		Between Ties 262-263		3.3	32.3	79.8	N	
					33.8	79.7	M	
				18.0	33.2	82.3	S	
			AVG	12.1	33.1	80.5		
Lime Stab Lean Cl	Surface	Between Ties 261-262		12.0	35.3	78.6	N	
				26.0	34.2	79.3	M	
				10.0	35.9	79.3	S	
			Avg	16.0	35.1	79.1		
Hvy Cl	6"			2.8	31.0	87.3	N	Rock and voids in samples past surface depth
				3.4	28.2	89.9	M	
				4.2	28.3	90.4	S	
			Avg	3.5	29.1	89.2		
	12"			6.0	26.0	94.4	N	
				7.0	26.0	92.1	M	
				8.0	25.3	94.7	S	
			AVG	7.0	25.8	93.7		
Hvy Cl	24"	Between Ties 261-262		14.0	26.1	92.0	N	
				15.0	24.4	95.2	M	
				13.0	20.1	97.9	S	
			AVG	14.0	23.5	95.0		

(Continued)

TABLE D-11 (Concluded)

Material	Depth or Elev	Location		CBR Data		
				CBR	WC	DW
Hvy Cl	36"	Between Ties 261-262		12.0	25.0	93.0
				12.0	24.7	94.0
				12.0	24.4	93.4
			AVG	12.0	24.7	93.5
Lime Stab Lean Cl	Surface	Under Tie 262		16.0	34.4	79.6
				18.0	35.8	75.3
				17.0	32.8	82.3
			AVG	17.0	34.3	79.1
Hvy Cl	6"			3.1	26.3	93.0
				3.6	28.3	89.2
				3.5	28.3	90.9
			AVG	3.4	27.6	90.9
	12"			6.0	27.6	90.3
				8.0	25.9	93.9
				10.0	25.2	94.6
			AVG	8.0	26.2	92.9
	24"			14.0	25.6	93.6
				12.0	23.1	94.9
				13.0	24.9	93.4
			AVG	13.0	24.5	94.0
Hvy Cl	36"	Under Tie 262		13.0	23.1	93.9
				12.0	25.9	88.8
				14.0	25.7	91.2
			AVG	13.0	24.9	91.3

Remarks
N M S
N M S
N M S
N M S
N M S
N M S

TABLE D-12. KANSAS TEST TRACK
SECTION 9

Material	Depth or Elev	Location		CBR Data CBR	WC	DW	WC	Remarks
Lime Stab Lean Cl	Surface	Under Tie 11		10.0		76.2	38.0	N
				17.0		79.9	38.0	M
				23.0		75.0	38.0	S
			AVG	16.7		77.2	38.0	
		Between Ties 11-12		16.0		76.3	36.0	N
				14.0		75.3	39.0	M
				18.0		76.9	37.0	S
			AVG	16.0		76.1	37.3	
Lime Stab Lean Cl	Surface	Under Tie 10		19.0	35.0	78.3	37.0	N
				15.0	38.0	77.5	35.0	M
				23.0	35.9	78.1	36.0	S
			AVG	19.0	36.0	78.0	36.0	
Hvy Cl	6"			2.7		87.0	31.0	N
				2.2		84.2	33.0	M
				2.4		87.7	30.0	S
			AVG	2.4		86.3	31.3	
	12"			4.0		83.3	34.0	N
				2.8		87.7	30.0	M
				8.0		94.8	23.0	S
			AVG	4.9		88.6	29.0	
Hvy Cl	24"	Under Tie 10		12.0		94.9	22.0	N
				6.0		97.2	22.0	M
				19.0		96.8	23.0	S
			AVG	12.3		96.3	22.3	

(Continued)

TABLE D-12 (Concluded)

Material	Depth or Elev	Location		CBR Data: CBR	CBR Data: WC	CBR Data: DW	CBR Data: WC		Remarks
Hyv Cl	36"	Under Tie 10		9.0		87.0	23.0	N	Rocks and voids in samples
				11.0		94.6	23.0	M	
				16.0		98.2	24.0	S	
			AVG	12.0		93.3	23.3		
Lime Stab Lean Cl	Surface	Between Ties 10-11	1	16.0	36.0	74.7	40.0	N	
				26.0	37.0	77.5	37.0	M	
				14.0	39.0	73.4	37.0	S	
			AVG	18.7	37.3	75.2	38.0		
	6"			2.6		88.2	29.0	N	
				2.9		83.9	33.0	M	
				2.9		87.7	30.0	S	
			AVG	2.8		86.6	30.7		
	12"			3.7		81.0	35.0	N	
				3.4		90.8	26.0	M	
				5.4		95.2	24.0	S	
			AVG	4.2		89.0	28.3		
	24"			13.0		97.0	21.0	N	
				7.0		94.4	21.0	M	
				16.0		94.4	22.0	S	
			AVG	12.0		95.3	21.3		
Lime Stab Lean Cl	36"	Between Ties 10-11		10.0		93.7	23.0	N	
				12.0		95.0	23.0	M	
				12.0		94.4	24.0	S	
			AVG	11.3		94.4	23.0		

TABLE D-13. LABORATORY TEST RESULTS ON BALLAST SAMPLES

Identification	Percent Finer by Weight: U. S. Standard Sieve Opening in In. 2	1-1/2	1	3/4	1/2	3/8	U. S. Standard Sieve Numbers 4	8	200	Atterberg Limits on Fines: Liquid Limit	Plastic Limit	Plasticity Index
B-1-N-T*	100	100	85	63	40	26	11	6	2	NP	--	--
B-1-M-T		99	87	66	41	29	14	10	4	NP	--	--
B-1-S-T		100	90	70	50	39	24	20	6	NP	--	--
B-1-N-B			95	81	55	41	21	17	9	37	24	13
B-1-M-B			96	82	63	49	29	24	11	41	24	17
B-1-S-B			97	82	60	47	31	24	11	35	25	10
B-1-N-SH			94	73	35	18	3	1	1	--	--	--
B-1-S-SH			89	57	17	8	4	3	1	--	--	--
B-2A-S-T			90	67	38	26	16	12	4	--	--	--
B-2A-N-B			94	77	52	41	26	26	23	--	--	--
B-2A-S-B			97	81	56	41	24	18	10	--	--	--
B-2A-S-SH		98	80	57	34	27	22	17	7	--	--	--
B-2B-N-T		100	88	65	36	26	14	10	4	--	--	--
B-2B-N-B			93	74	51	38	25	20	12	--	--	--
B-2B-S-B			90	71	45	34	22	19	12	--	--	--
B-2B-N-SH			86	54	22	9	2	1	1	--	--	--
B-3A-S-T			85	55	28	17	8	6	3	--	--	--
B-3A-N-B			97	81	59	48	33	28	14	--	--	--
B-3A-S-B			96	76	52	39	26	21	12	--	--	--
B-3A-S-SH			92	77	50	31	15	12	6	--	--	--
B-3B-N-T			76	50	26	16	11	10	5	--	--	--
B-3B-N-B			97	86	67	54	34	29	18	--	--	--
B-3B-S-B			94	73	49	37	27	24	12	--	--	--
B-3B-N-SH			88	57	13	3	2	2	1	--	--	--
B-4-MM-T			92	74	47	32	13	9	4	29	21	8
B-4-MJ-T			96	81	57	42	24	19	6	28	21	7
B-4-NM-B			95	83	57	42	24	20	11	35	24	11
B-4-NJ-B		99	94	83	64	51	31	24	8	29	21	8
B-4-SM-B		100	96	85	67	54	31	24	8	29	22	7
B-4-SJ-B			96	84	66	53	34	26	8	26	19	7
B-4-N-SH			96	89	70	54	27	17	6	--	--	--
B-4-S-SH			90	75	44	24	6	3	1	--	--	--
B-5-SJ-B			95	70	45	34	22	18	10	--	--	--
B-5-NJ-B			96	84	65	54	35	27	12	--	--	--
B-5-MM-B			99	90	74	61	37	27	11	--	--	--
B-5-S-SH			96	83	60	41	15	11	2	--	--	--
B-7-MM-T			93	74	48	35	22	18	12	--	--	--
B-7-NJ-B			94	74	52	38	25	21	12	--	--	--
B-7-SJ-B			94	75	52	39	27	23	14	--	--	--
B-7-N-SH			93	71	46	33	16	9	3	--	--	--
B-8-S-T			94	69	32	16	4	2	1	--	--	--
B-8-N-B			94	76	43	25	12	9	5	--	--	--
B-8-S-B			93	67	38	26	14	12	9	--	--	--
B-8-S-SH			82	54	28	16	4	3	1	--	--	--
B-9-N-T			96	78	46	31	18	16	12	42	26	16
B-9-M-T			91	75	48	34	13	9	4	35	21	14
B-9-S-T			91	62	23	8	2	2	1	--	--	--
B-9-N-B			91	65	29	18	12	11	9	44	26	18
B-9-M-B			94	79	52	37	24	21	13	43	26	17
B-9-S-B			96	85	61	47	31	26	16	37	24	13
B-9-N-SH			93	72	38	17	7	6	2	--	--	--
B-9-S-SH			89	60	21	7	2	1	1	--	--	--
Additional Tests												
B-2B-AS	100	100	96	87	73	64	47	39	17	--	--	--
B-8-UT			90	61	24	12	5	4	1	--	--	--
B-8-AS			94	85	63	50	32	26	13	--	--	--
B-9-UT			92	68	36	26	17	16	11	42	26	16
B-ML-5900			95	64	27	14	7	6	3	--	--	--
B-ML-8526			97	89	28	16	5	4	2	--	--	--

*Legend and example of sample identification numbers is given below.

Example:

B-1-N-T

B = balast

__ = test pit No.
ML = main line

N = north rail
S = south rail
M = between rails
MM = between rails and between joints
MJ = between rails at a joint
NM = north rail between joints, etc.
AS = ballast above subgrade 2- to 3-in.
5900 = stationing on main line

T = top sample usually 0- to 8-in. depth
B = bottom sample 8- to 18-in. depth
SH = shoulder sample

TABLE D-14. LABORATORY CLASSIFICATION TESTS ON SUBGRADE SAMPLES

Pit No.	Depth From Top of Subgrade	USGS Classification	LL	PL	PI	Percent Finer Than No. 200 Sieve	Color
1	0-12	CH	57	28	34	93	Brown
1	24-36	CH	62	23	39	91	
2A	0-12	CH	62	24	38	95	
2A	24-36	CH	61	24	37	96	
2B	0-12	CH	59	23	36	95	
2B	24-36	CH	63	23	40	95	
3A	0-12	CH	59	23	36	94	
3A	24-36	CH	60	22	38	94	
3B	0-12	CH	53	23	30	93	
3B	24-36	CL	46	20	26	69	
4	0-12	CH	61	24	37	94	
4	24-36	CH	66	24	42	95	
5	0-12	CH	63	20	43	89	
5	24-36	CH	59	25	34	92	
7	0-12	CH	58	24	34	91	
7	24-36	CH	60	19	41	91	
8	0-12	CH	56	23	33	93	
8	24-36	CH	58	19	39	90	
9	0-12	CH	62	24	38	97	
9	24-36	CH	55	21	34	95	Reddish-Brown

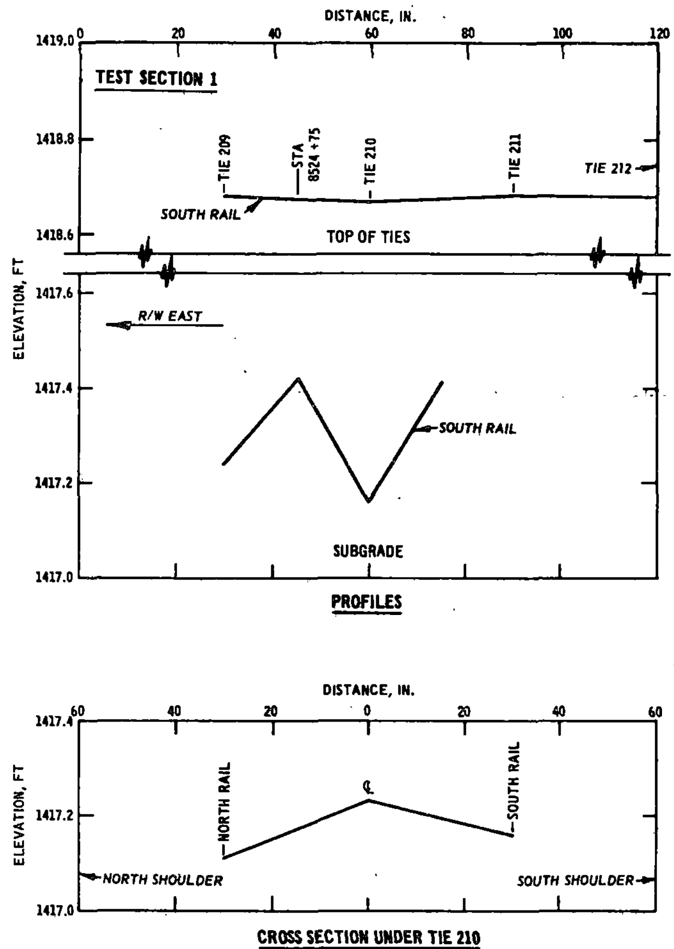


FIGURE D-1. PROFILES AND CROSS SECTION OF TEST SECTION 1

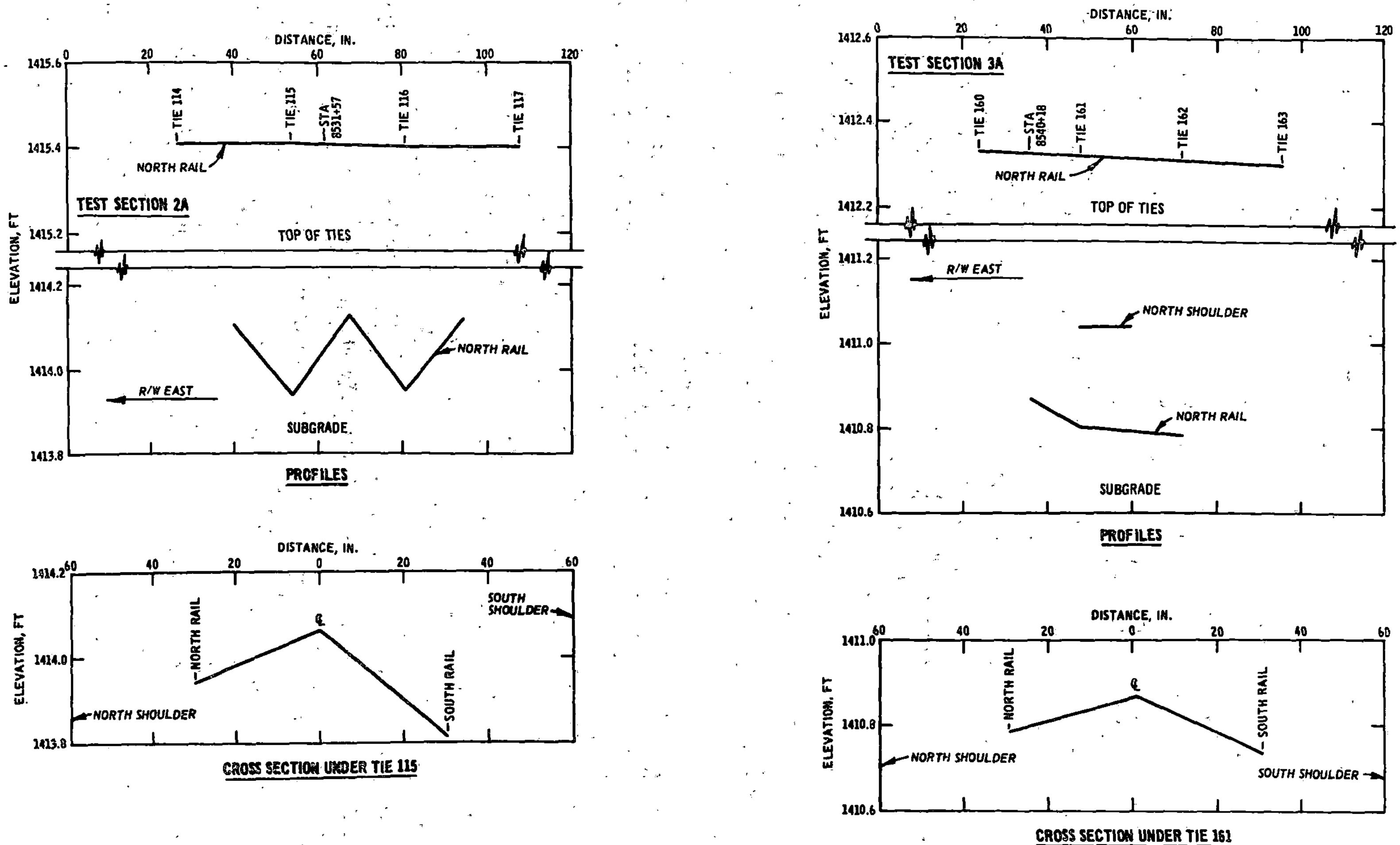
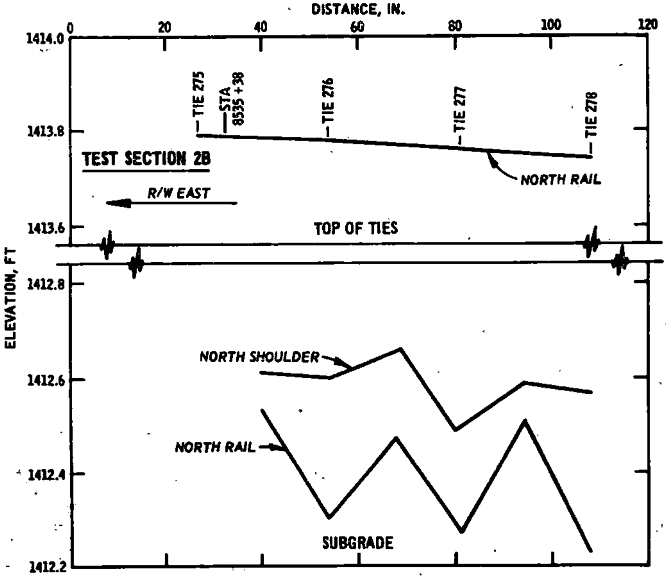
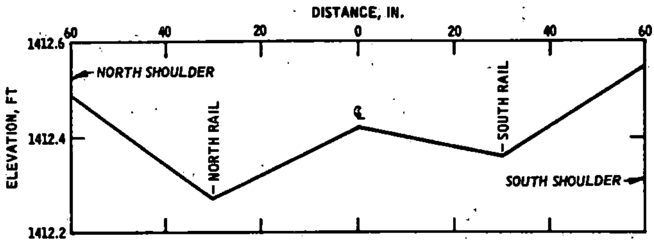


FIGURE D-2. PROFILES AND CROSS SECTION OF TEST SECTIONS 2A AND 3A

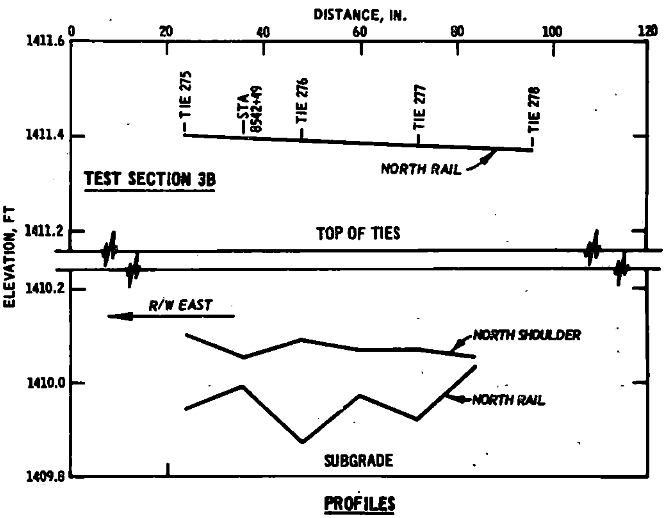


PROFILES



CROSS SECTION UNDER TIE 277

FIGURE D-3. PROFILES AND CROSS SECTION OF TEST SECTION 2B



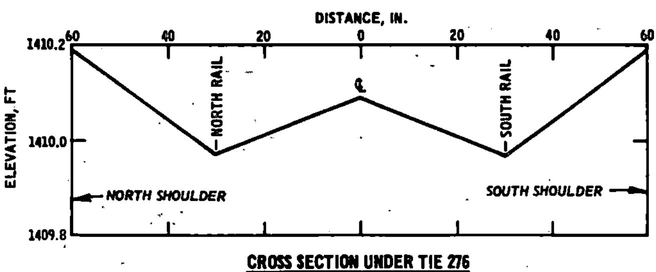


FIGURE D-4. PROFILES AND CROSS SECTION OF TEST SECTION 3B

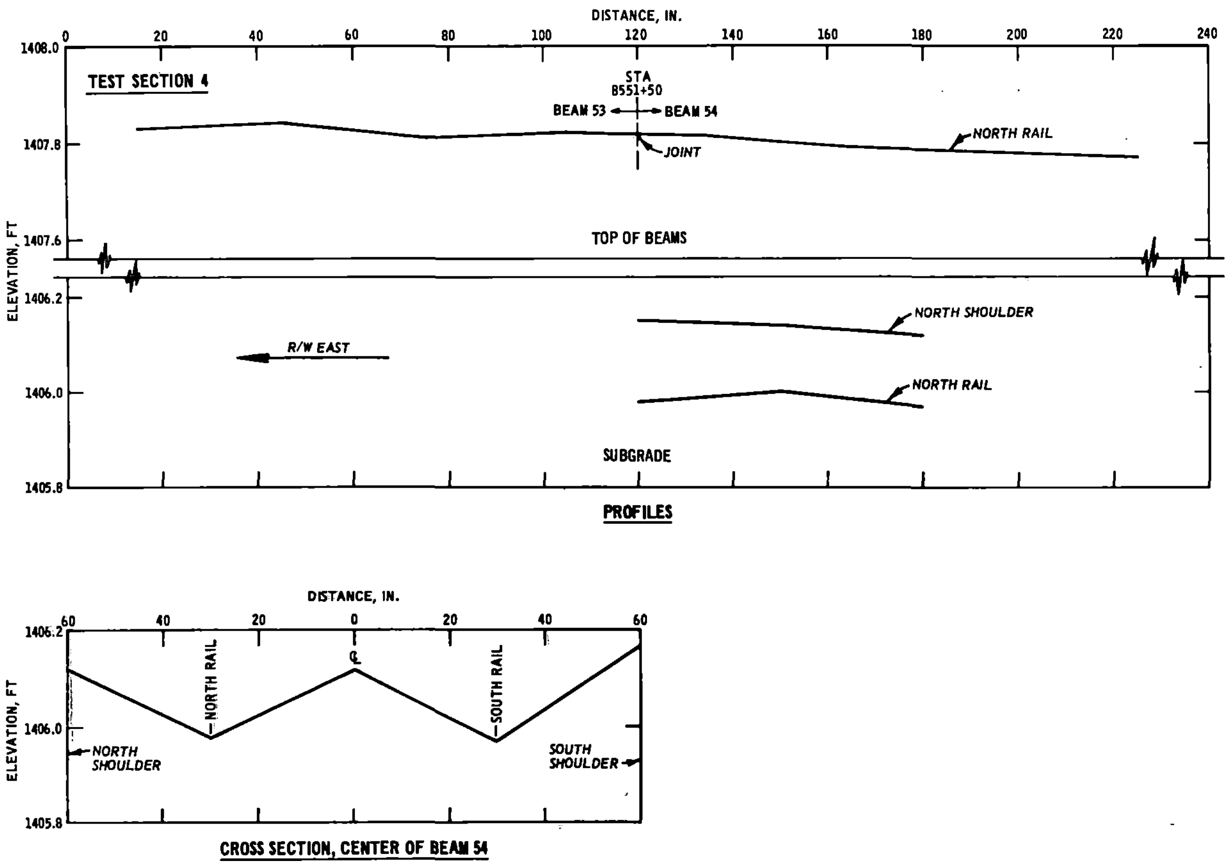


FIGURE D-5. PROFILES AND CROSS SECTION OF TEST SECTION 4

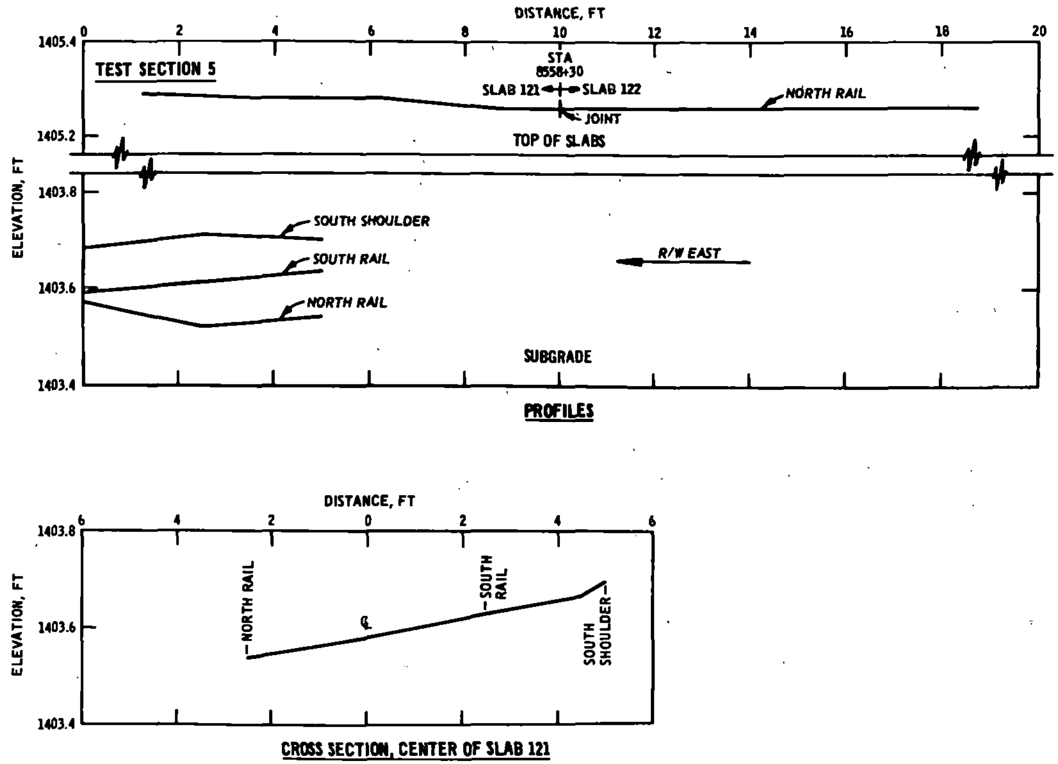


FIGURE D-6. PROFILES AND CROSS SECTION OF TEST SECTION 5

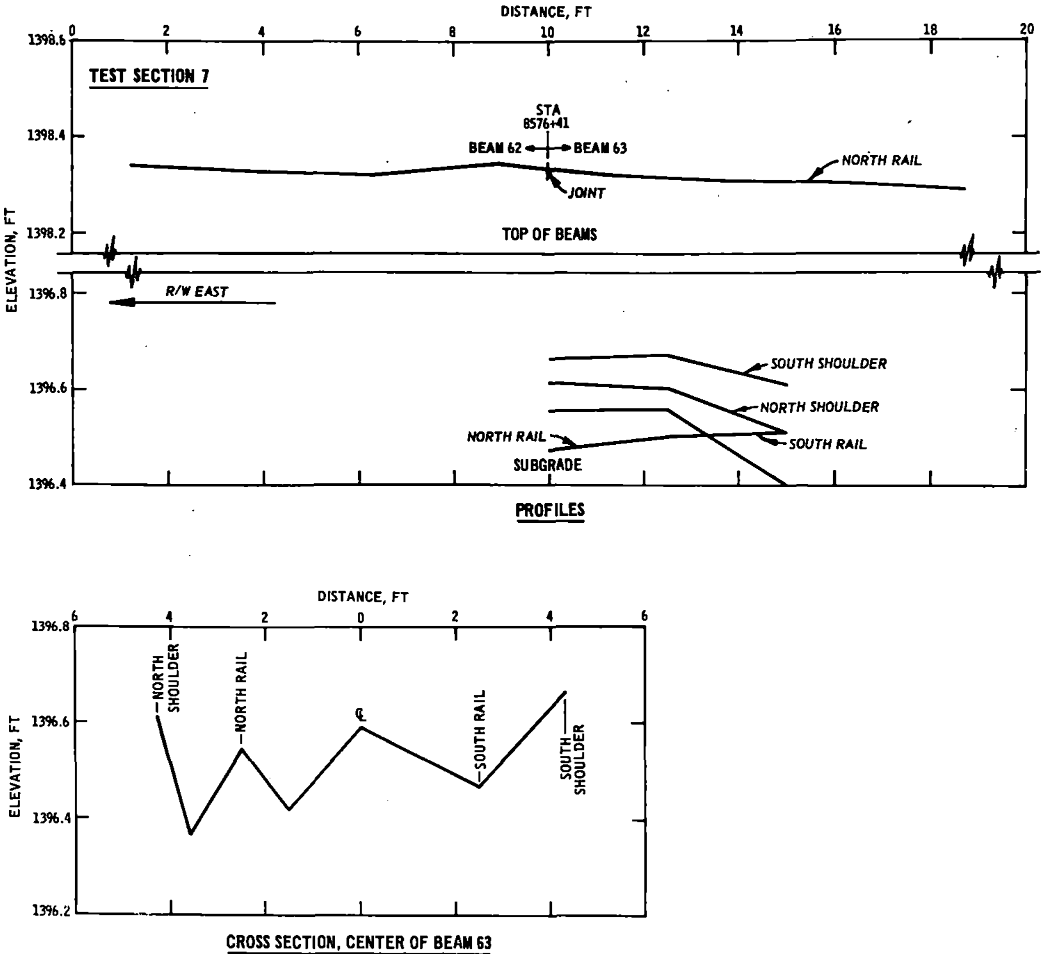
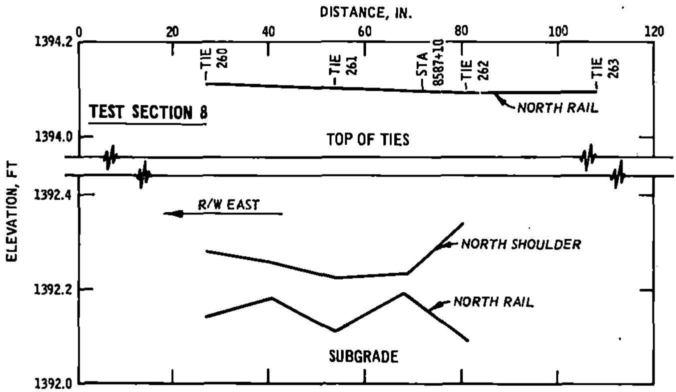
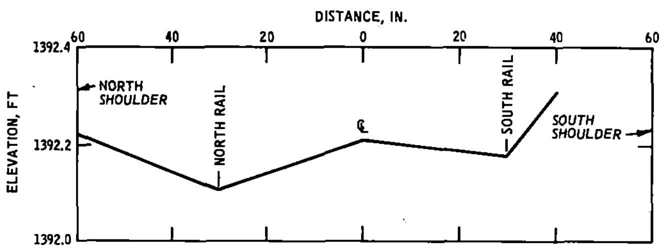


FIGURE D-7. PROFILES AND CROSS SECTION OF TEST SECTION 7

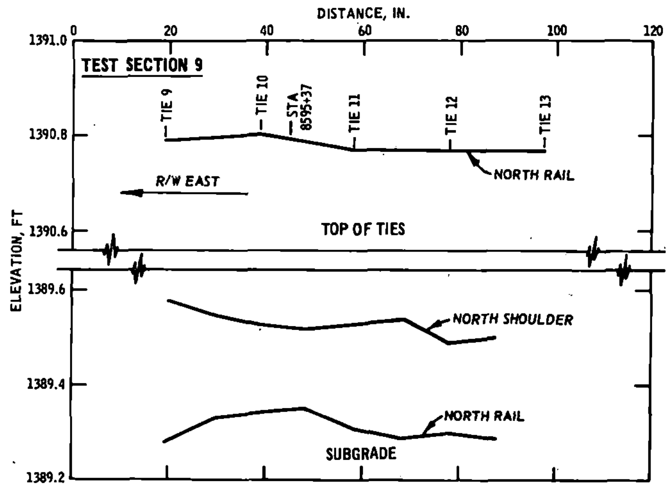


PROFILES

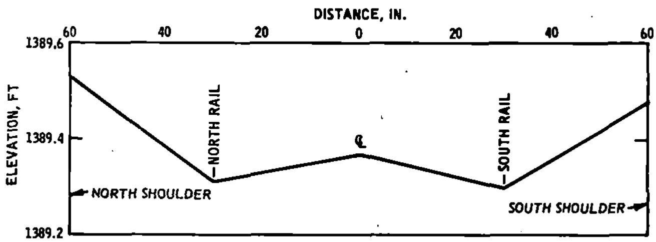


CROSS SECTION UNDER TIE 261

FIGURE D-8. PROFILES AND CROSS SECTION OF TEST SECTION 8



PROFILES



CROSS SECTION UNDER TIE 11

FIGURE D-9. PROFILES AND CROSS SECTION OF TEST SECTION 9

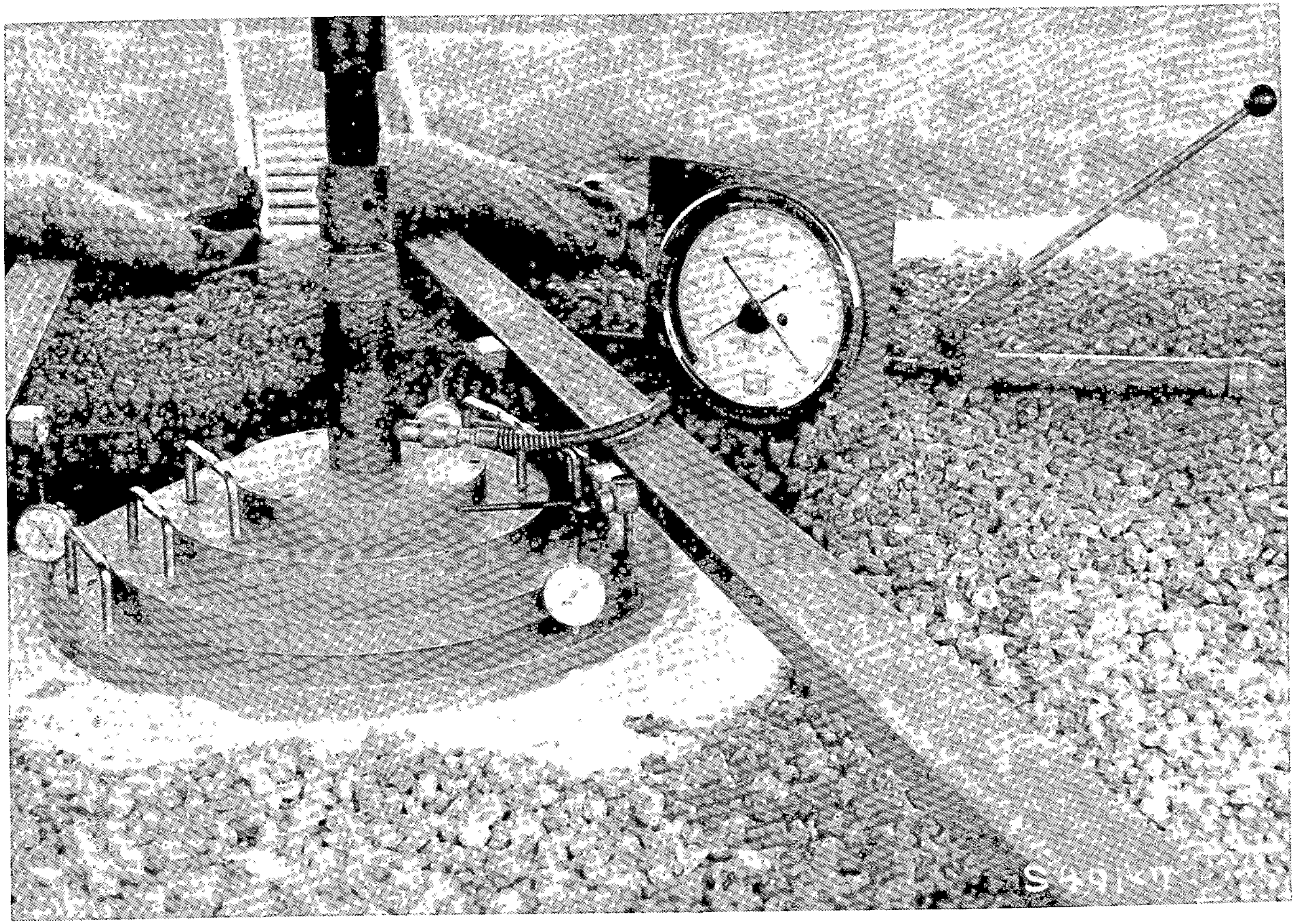


FIGURE D-10. TYPICAL PLATE BEARING TEST SETUP

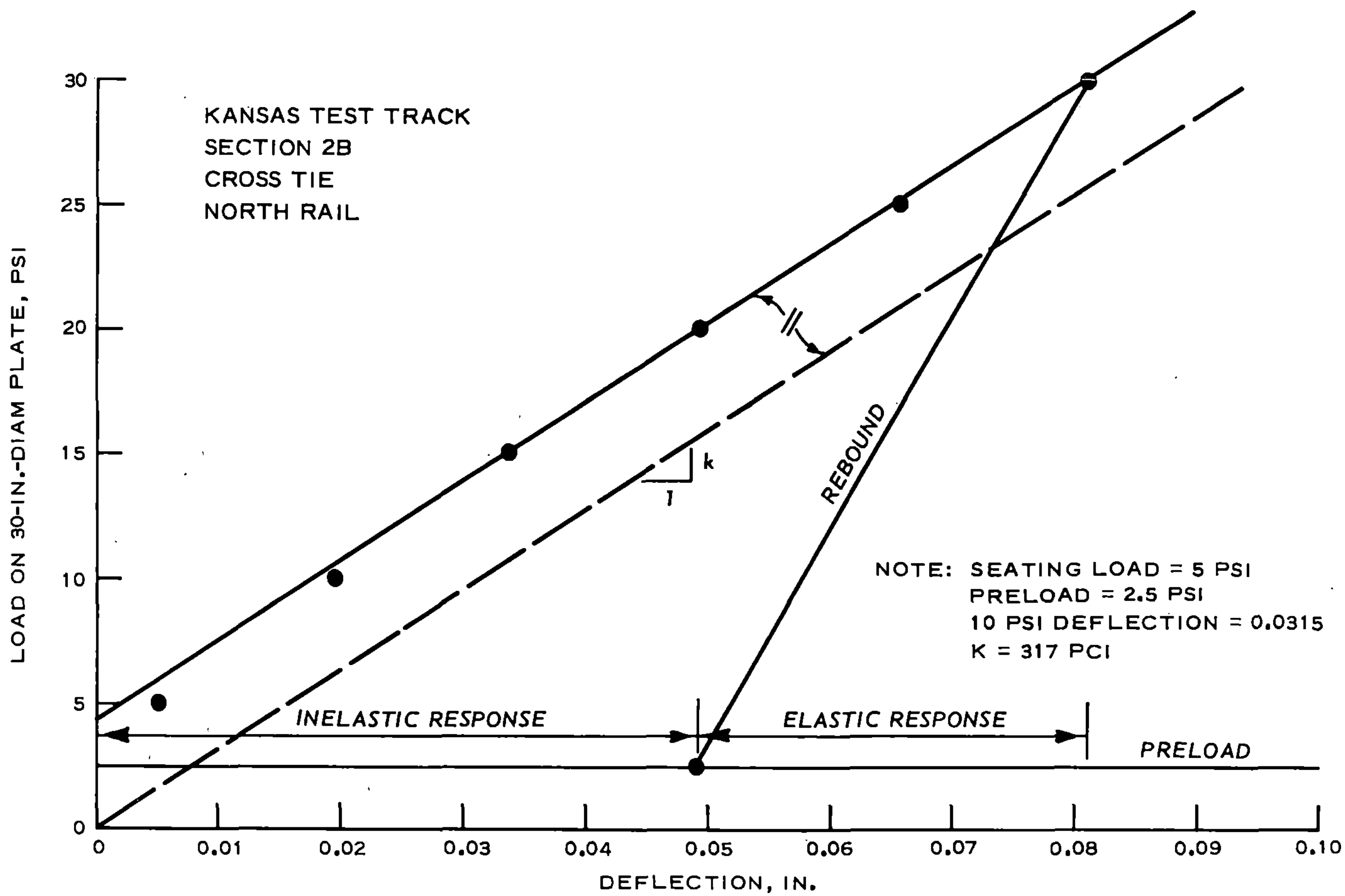
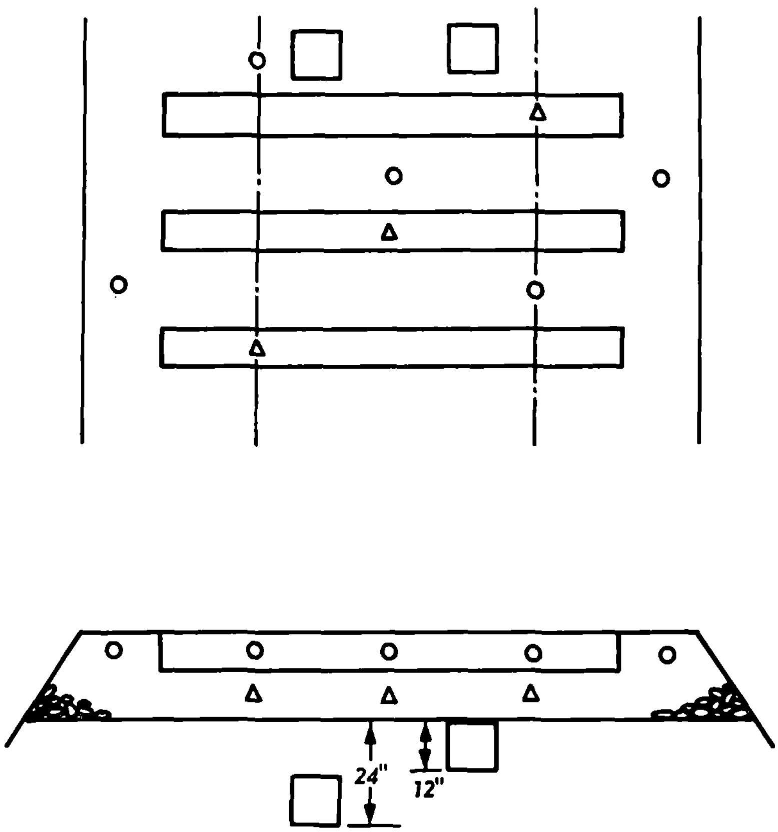


FIGURE D-11. TYPICAL PLATE BEARING LOAD-DEFLECTION PLOT



LEGEND

O LOCATION OF TOP (0 TO 8 IN.) BALLAST SAMPLES

Δ LOCATION OF BOTTOM (8 TO 18 IN.) BALLAST SAMPLES

□ LOCATION OF UNDISTURBED SOIL SAMPLES

NOTE: TWO SACK SAMPLES OF SOIL WERE TAKEN FROM EACH TRENCH.

FIGURE D-12. TYPICAL LOCATIONS OF BALLAST AND UNDISTURBED SOIL SAMPLES ON TIE SECTIONS

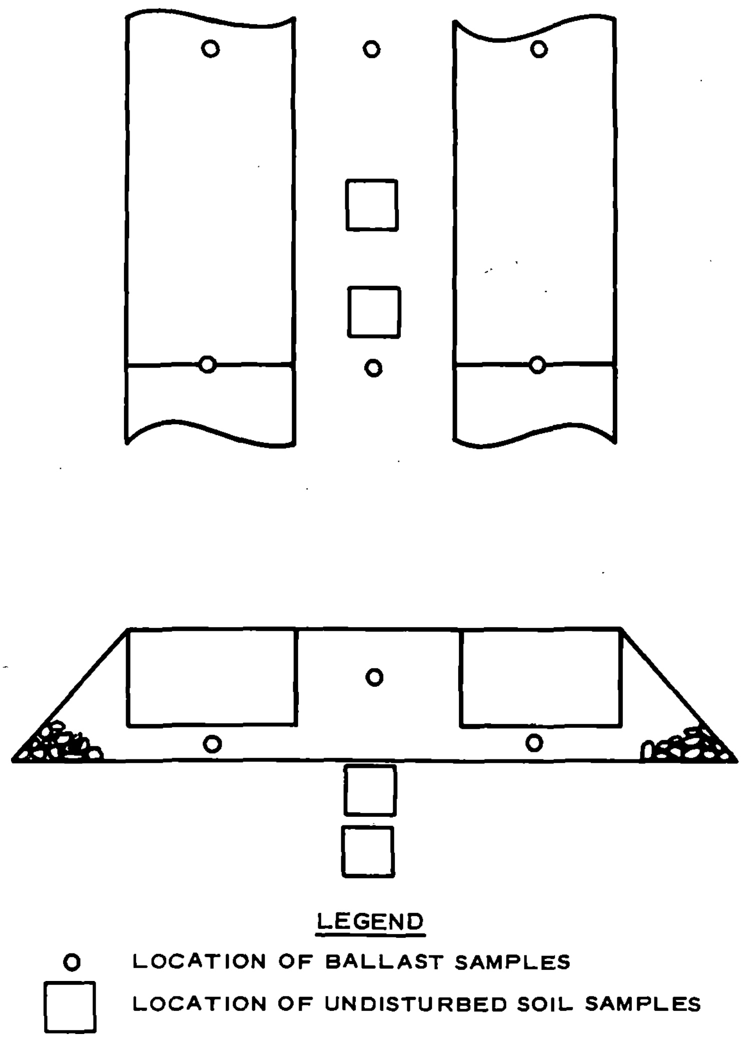
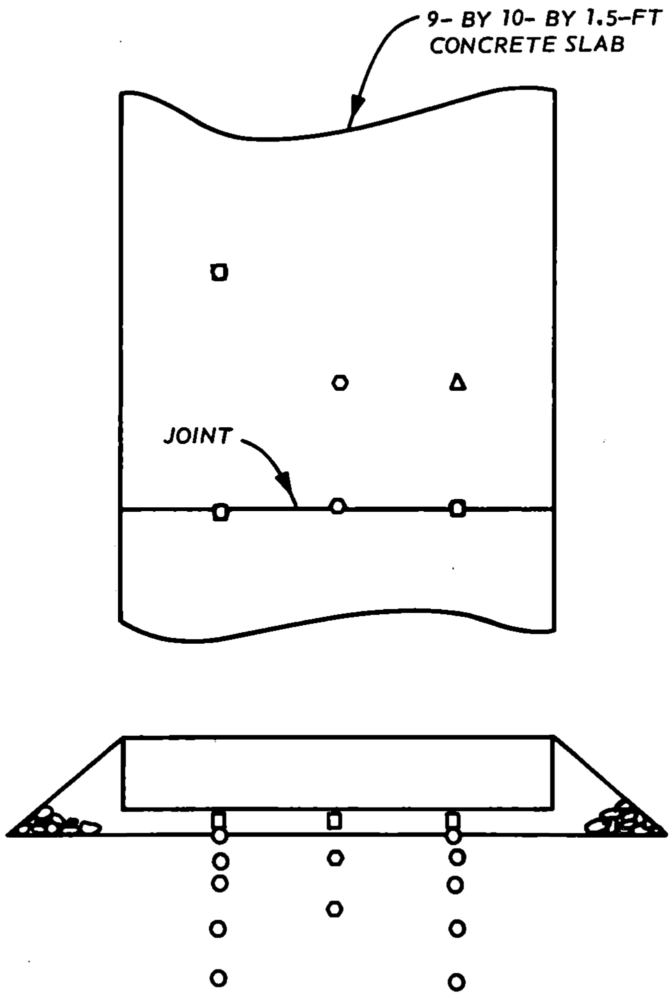


FIGURE D-13. TYPICAL LOCATIONS OF BALLAST AND UNDISTURBED SOIL SAMPLES ON BEAM SECTIONS



LEGEND

△ LOCATION OF PLATE BEARING TEST
○ LOCATION OF CBR, MOISTURE, AND DENSITY TESTS ON SUBGRADE
□ LOCATION OF BALLAST SAMPLES
○ LOCATION OF UNDISTURBED SOIL SAMPLES

FIGURE D-14. LOCATIONS OF FIELD TESTS AND SAMPLES ON TRACK SECTION 5

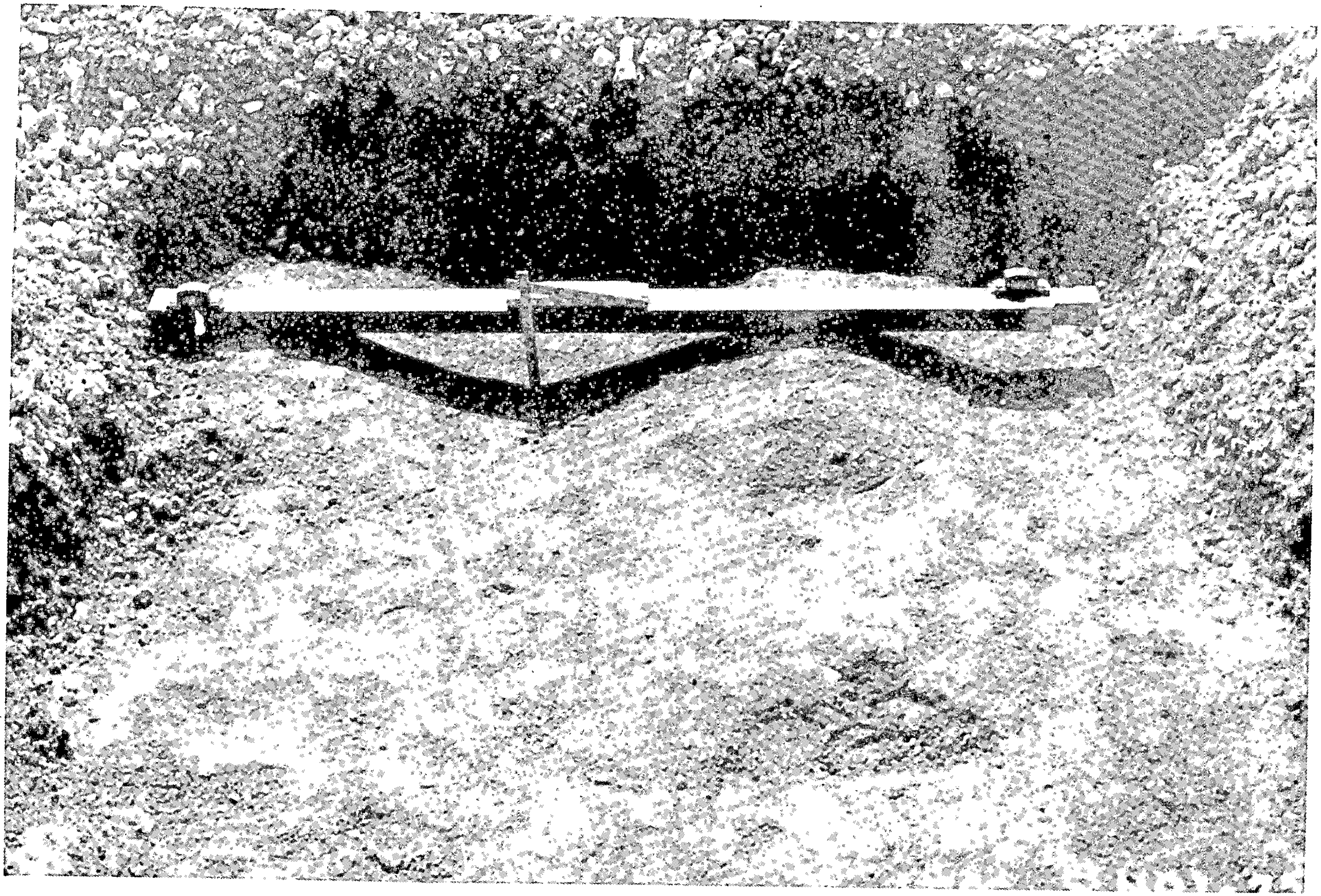


FIGURE D-15. SUBGRADE SURFACE OF TEST PIT 1

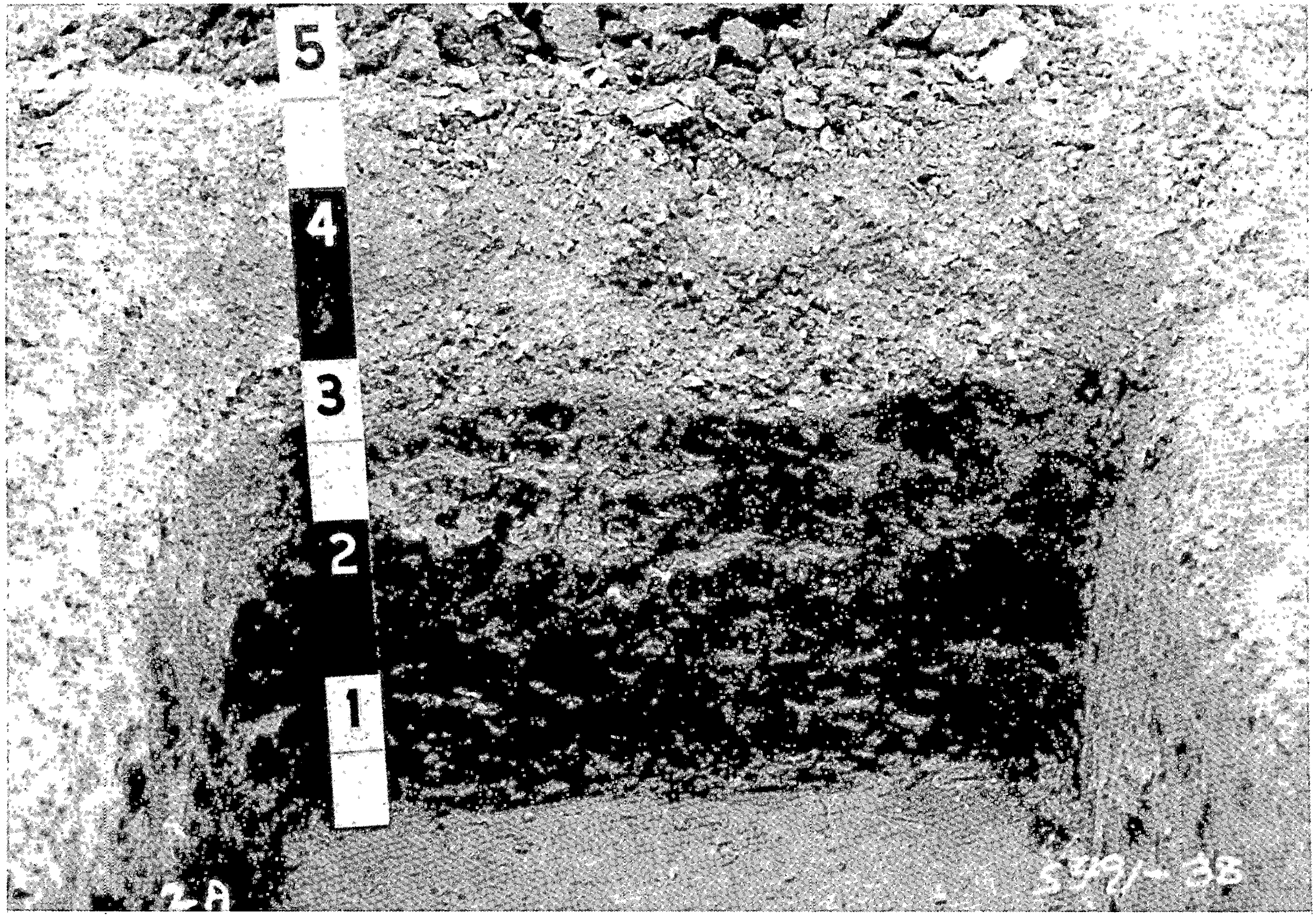


FIGURE D-16. SOUTH WALL OF TEST PIT 2A (NOTE BALLAST SUBGRADE INTERFACE)

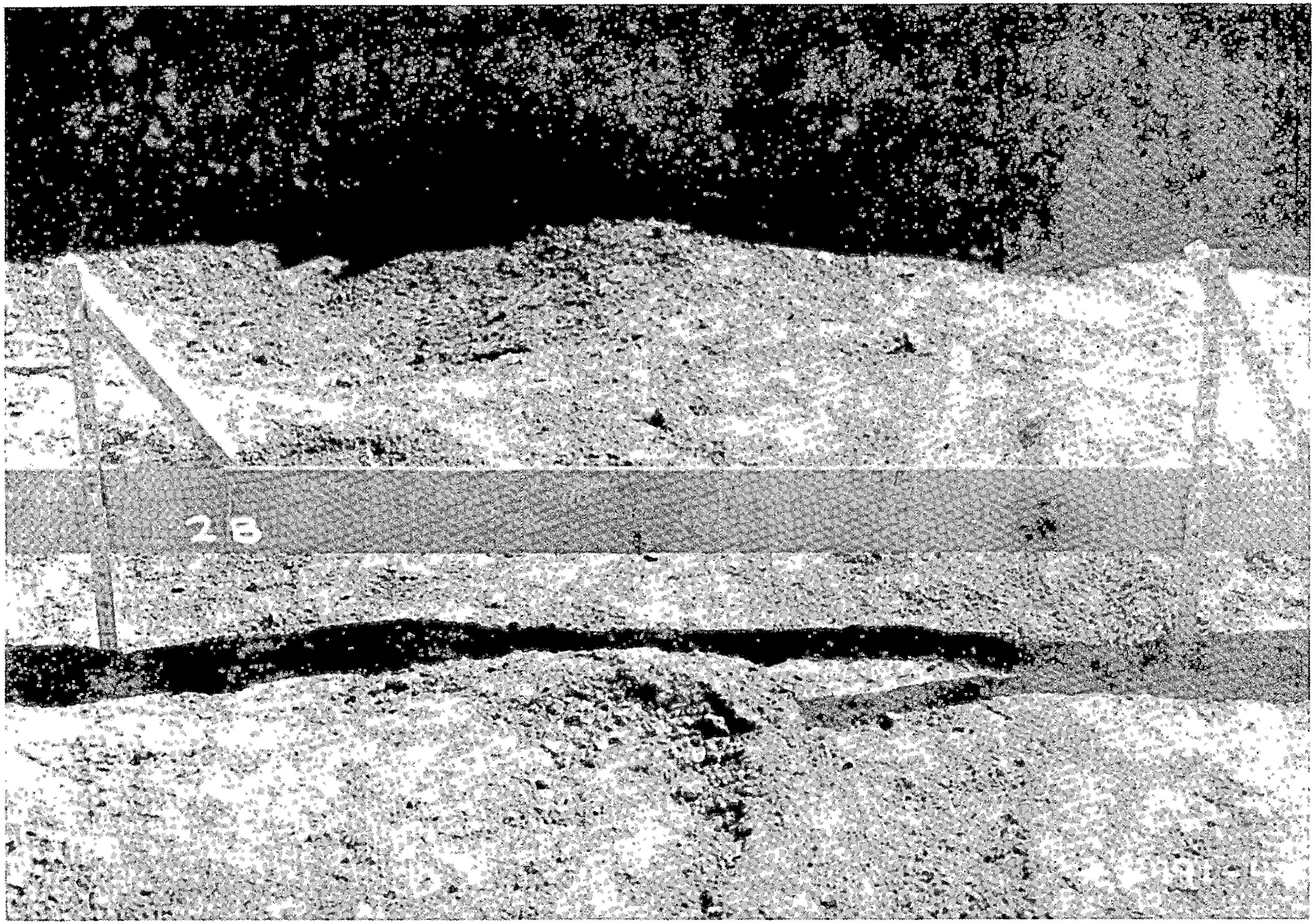
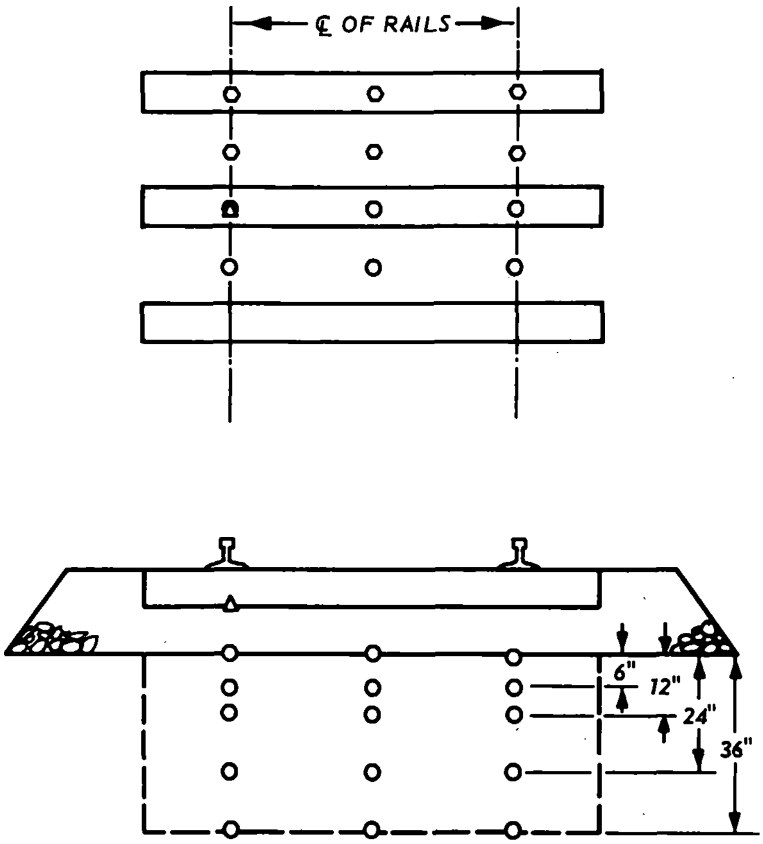


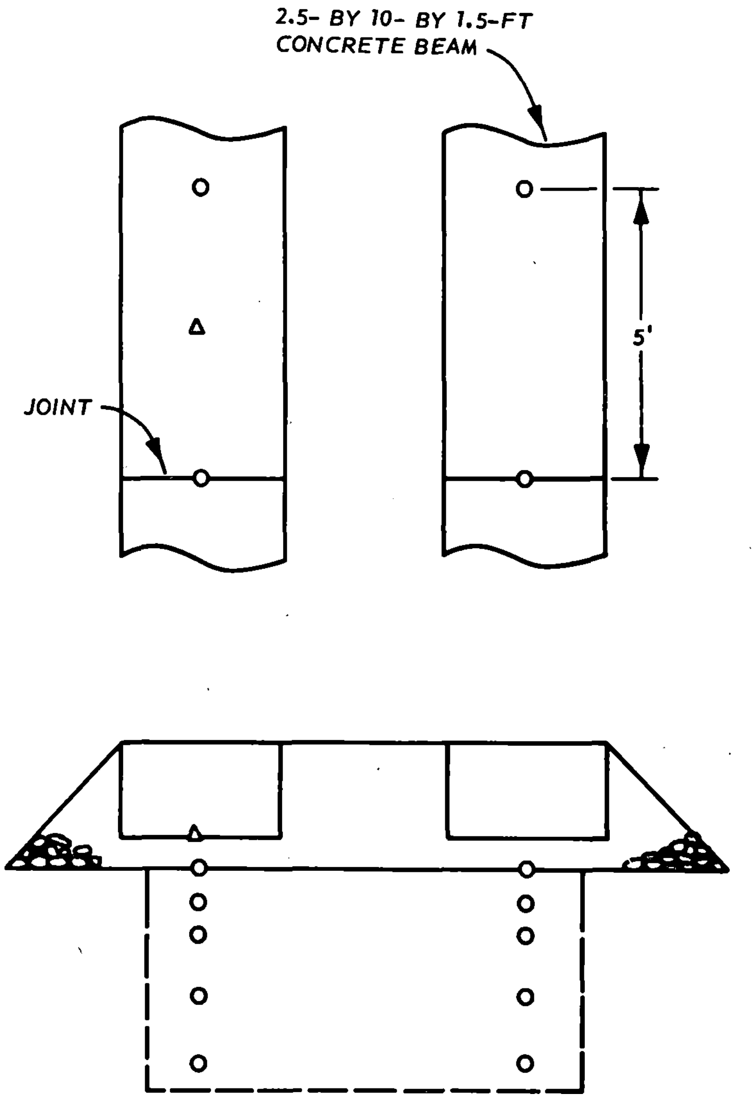
FIGURE D-17. CROSS SECTION OF SUBGRADE SURFACE (NOTE BEAM EDGES ARE RESTING ON SHOULDER SUBGRADE INDICATING 3-1/2- TO 4-IN. RELATIVE DEFORMATION UNDER TRACK STRUCTURE)



LEGEND

- Δ LOCATION OF PLATE BEARING TEST ON BALLAST
- ⬡ LOCATION OF CBR, MOISTURE, AND DENSITY TEST AREAS ON SUBGRADE (SURFACE ONLY)
- ○ LOCATION OF CBR, MOISTURE, AND DENSITY TEST AREAS ON SUBGRADE (SURFACE, 6-, 12-, 24-, AND 36-IN. DEPTHS)

FIGURE D-18. TYPICAL LOCATIONS OF FIELD TESTS ON TIE SECTIONS



LEGEND

Δ LOCATION OF PLATE BEARING TEST

O LOCATION OF CBR, MOISTURE, AND DENSITY TESTS

FIGURE D-19. TYPICAL LOCATIONS OF FIELD TESTS ON BEAM SECTIONS

FIGURE D-20.

CALIFORNIA BEARING RATIO (CBR)

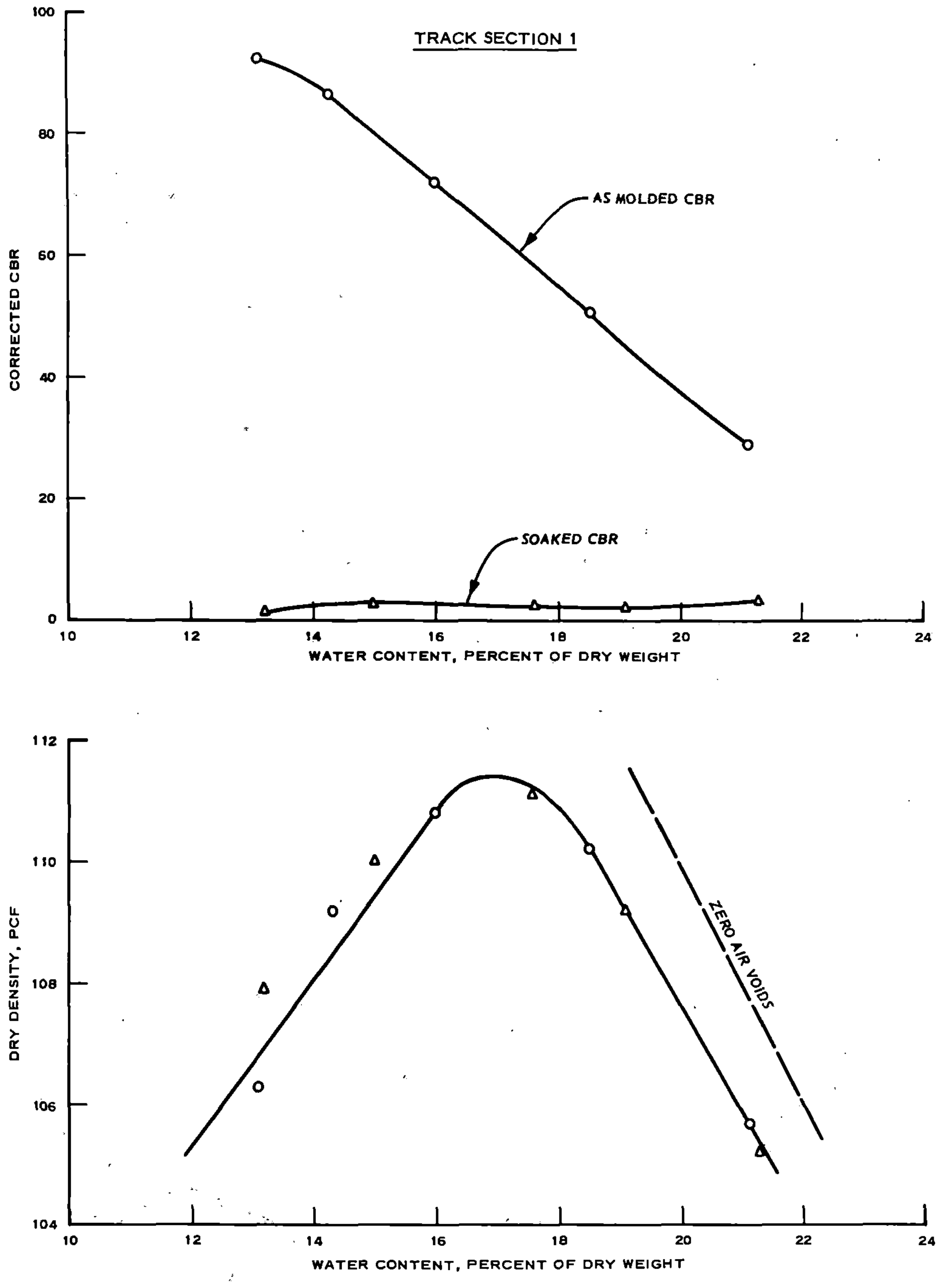


FIGURE D-21. LABORATORY COMPACTION TEST RESULTS (MODIFIED AASHO EFFORT), TRACK SECTION 1

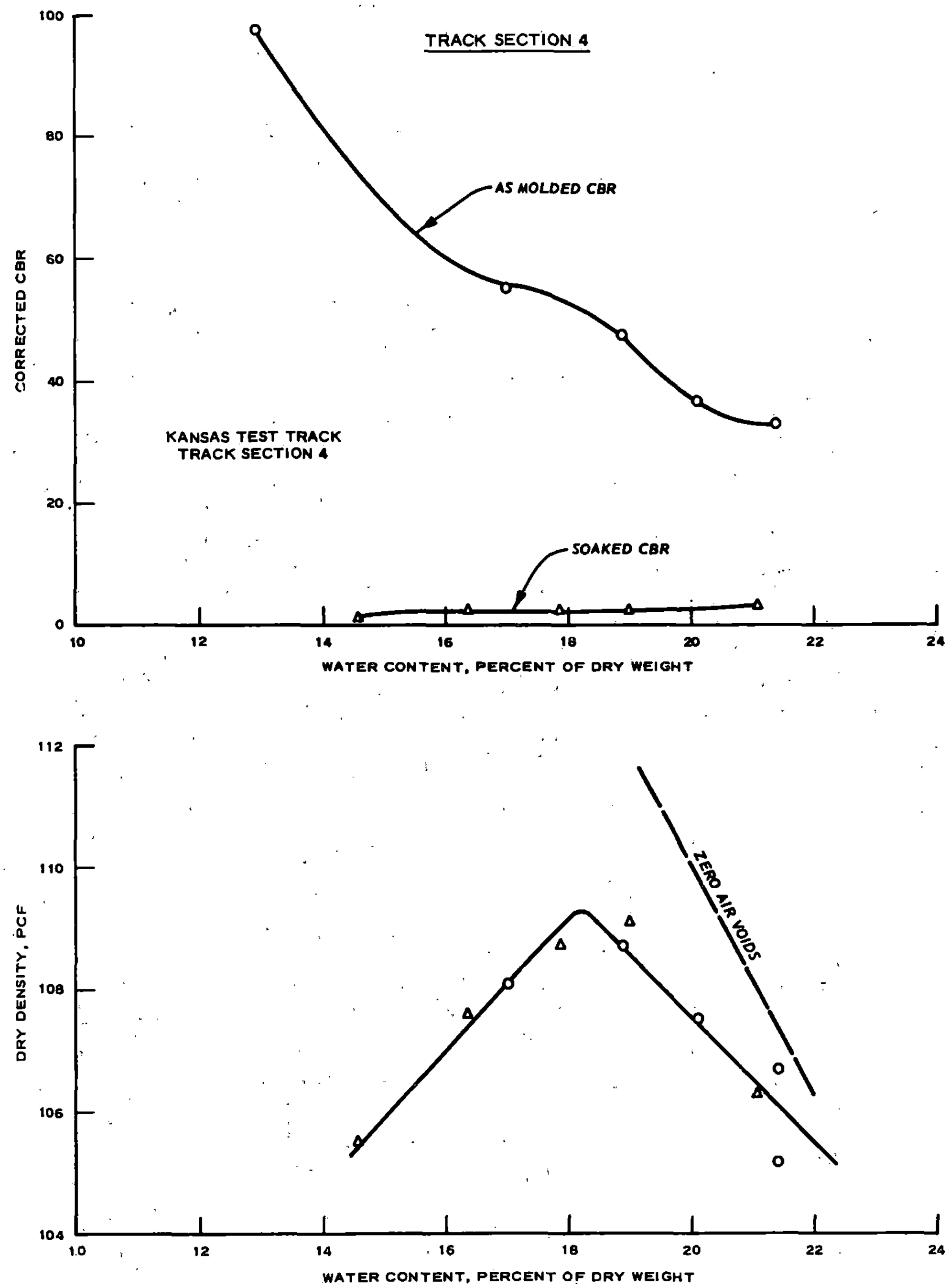


FIGURE D-22. LABORATORY COMPACTION TEST RESULTS (MODIFIED AASHO EFFORT), TRACK SECTION 4

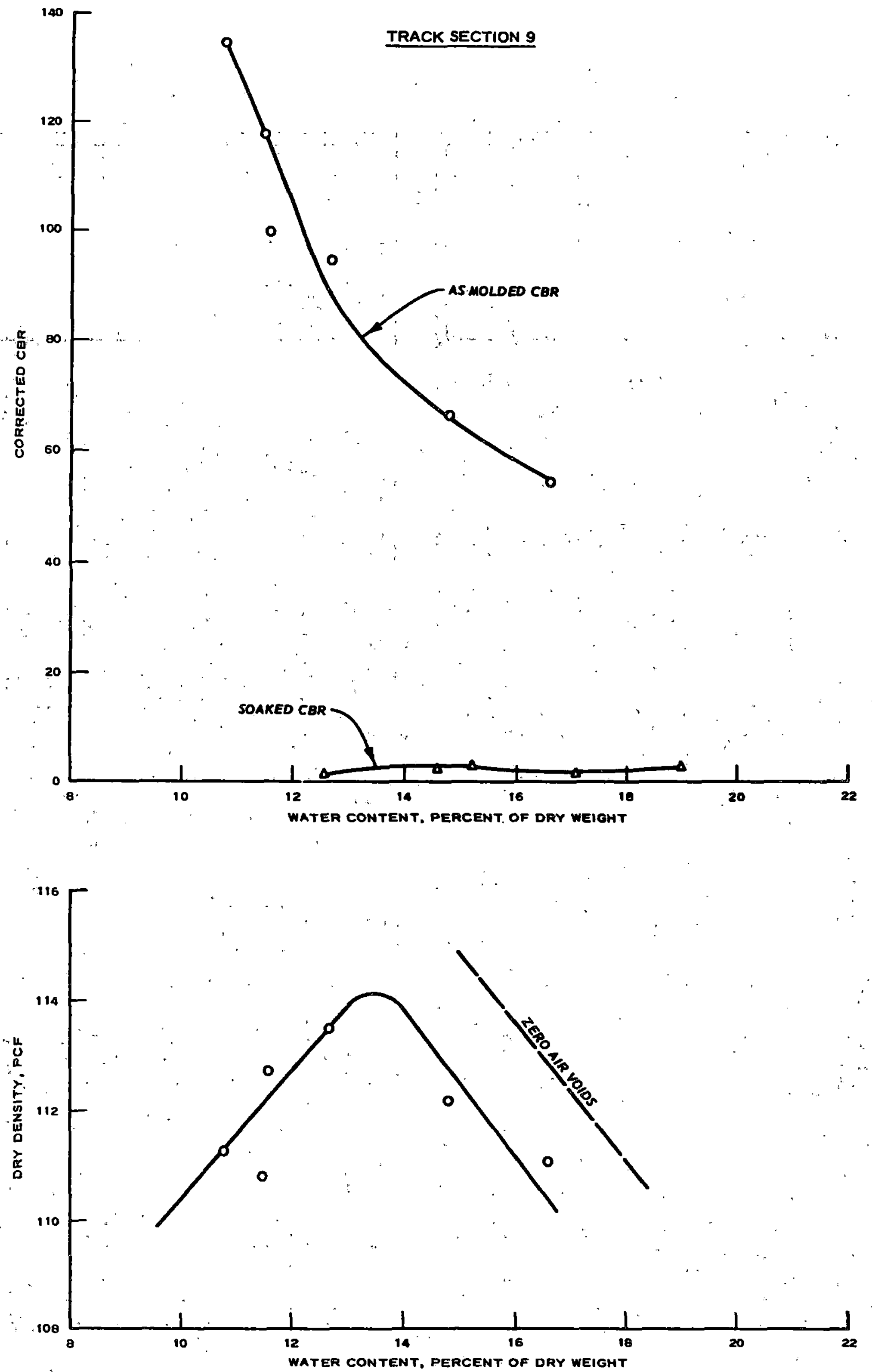
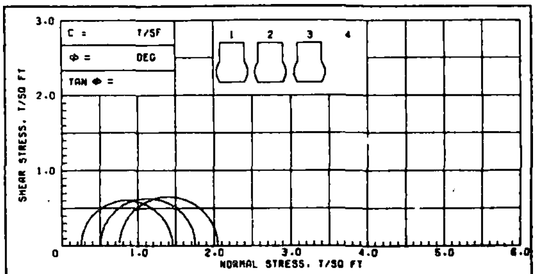
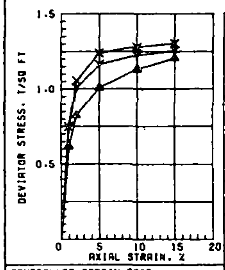


FIGURE D-23. LABORATORY COMPACTION TEST RESULTS (MODIFIED AASHO EFFORT), TRACK SECTION 9





	SPECIMEN NO.	△1	Y2	X3	4
INITIAL	WATER CONTENT, %	28.4	31.0	30.4	
	DRY DENSITY, PCF	91.9	90.4	89.7	
	SATURATION, %	95.2	96.8	93.4	
	VOID RATIO	0.834	0.865	0.879	
BEFORE SHEAR	WATER CONTENT, %				
	DRY DENSITY, PCF				
	SATURATION, %				
	VOID RATIO				
	BACK PRESS., TSF				
	MIN PRIN. STRESS, TSF	0.3	0.5	0.8	
	MAX. DEV. STRESS, TSF	1.20	1.26	1.30	
	TIME TO FAILURE, MIN.	21	25	24	
	RATE OF STRAIN INCR				
	INITIAL DIAMETER, IN.	1.38	1.38	1.38	
	INITIAL HEIGHT, IN.	3.00	3.00	3.00	

CONTROLLED-STRAIN TEST

DESCRIPTION OF SPECIMENS: PLASTIC CLAY (CH), REDDISH BROWN

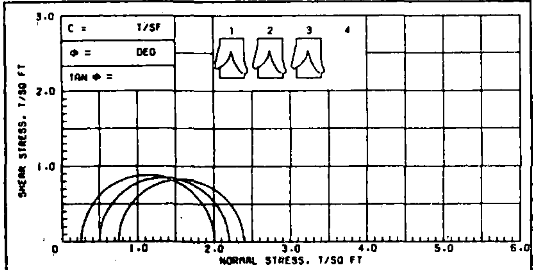
LL	PL	PI	GS 2.70	UNDISTURBED SPECIMEN	Q TEST

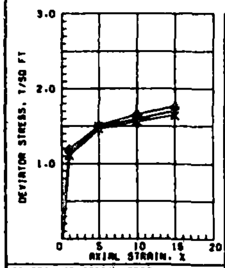
REMARKS:

PROJECT KANSAS TEST TRACK
POST MORTEM INVESTIGATION

BORING NO. UNDISTURBED	SAMPLE NO. 1T
DEPTH/ELEV 0-12"	TECH. KOC
LABORATORY USAE WES	DATE 15 JUN 78

TRIAXIAL COMPRESSION TEST REPORT





	SPECIMEN NO.	△1	Y2	X3	4
INITIAL	WATER CONTENT, %	27.9	27.7	28.4	
	DRY DENSITY, PCF	93.2	93.3	93.3	
	SATURATION, %	92.7	92.2	94.5	
	VOID RATIO	0.816	0.814	0.814	
BEFORE SHEAR	WATER CONTENT, %				
	DRY DENSITY, PCF				
	SATURATION, %				
	VOID RATIO				
	BACK PRESS., TSF				
	MIN PRIN. STRESS, TSF	0.3	0.5	0.8	
	MAX. DEV. STRESS, TSF	1.76	1.70	1.64	
	TIME TO FAILURE, MIN.	35	75	67	
	RATE OF STRAIN INCR				
	INITIAL DIAMETER, IN.	1.38	1.38	1.39	
	INITIAL HEIGHT, IN.	3.00	3.00	3.00	

CONTROLLED-STRAIN TEST

DESCRIPTION OF SPECIMENS: TOP 1/2: GRAVELLY CLAY (CL) LT BROWN; HAIR ROOTS
BOTTOM 1/2: CLAY (CH) DARK BROWN; HAIR ROOTS

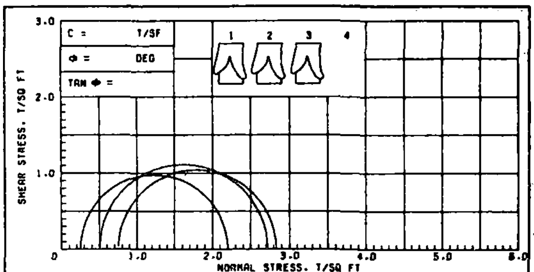
LL	PL	PI	GS 2.71	UNDISTURBED SPECIMEN	Q TEST

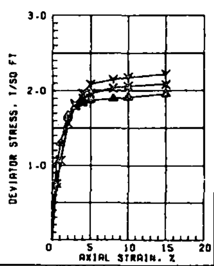
REMARKS:

PROJECT KANSAS TEST TRACK
POST MORTEM INVESTIGATION

BORING NO. BLOCK	SAMPLE NO. 4T
DEPTH/ELEV 0-12"	TECH. PJR
LABORATORY USAE WES	DATE 16 JUN 78

TRIAXIAL COMPRESSION TEST REPORT





	SPECIMEN NO.	△1	Y2	X3	4
INITIAL	WATER CONTENT, %	25.0	25.0	26.1	
	DRY DENSITY, PCF	94.3	95.3	94.1	
	SATURATION, %	89.7	91.8	93.2	
	VOID RATIO	0.728	0.711	0.731	
BEFORE SHEAR	WATER CONTENT, %				
	DRY DENSITY, PCF				
	SATURATION, %				
	VOID RATIO				
	BACK PRESS., TSF				
	MIN PRIN. STRESS, TSF	0.3	0.5	0.8	
	MAX. DEV. STRESS, TSF	1.95	2.22	2.08	
	TIME TO FAILURE, MIN.	56	52	54	
	RATE OF STRAIN INCR				
	INITIAL DIAMETER, IN.	1.40	1.39	1.40	
	INITIAL HEIGHT, IN.	3.00	3.00	3.00	

CONTROLLED-STRAIN TEST

DESCRIPTION OF SPECIMENS: PLASTIC CLAY (CH), BROWN;
COARSE SAND TO 3/16"

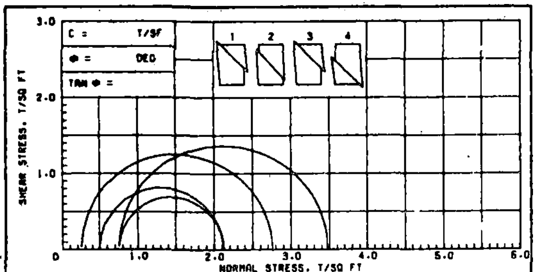
LL	PL	PI	GS 2.61	UNDISTURBED SPECIMEN	Q TEST

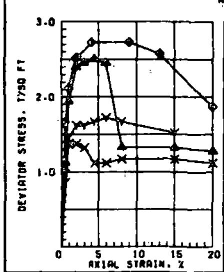
REMARKS:

PROJECT KANSAS TEST TRACK
POST MORTEM INVESTIGATION

BORING NO. UNDISTURBED	SAMPLE NO. 4B
DEPTH/ELEV 12-24"	TECH. RE
LABORATORY USAE WES	DATE 16 JUN 78

TRIAXIAL COMPRESSION TEST REPORT





	SPECIMEN NO.	△1	Y2	X3	◇4
INITIAL	WATER CONTENT, %	27.4	28.6	30.7	26.8
	DRY DENSITY, PCF	94.9	90.5	88.9	95.3
	SATURATION, %	94.8	89.1	92.1	93.7
	VOID RATIO	0.783	0.870	0.904	0.775
BEFORE SHEAR	WATER CONTENT, %				
	DRY DENSITY, PCF				
	SATURATION, %				
	VOID RATIO				
	BACK PRESS., TSF				
	MIN PRIN. STRESS, TSF	0.3	0.5	0.8	0.8
	MAX. DEV. STRESS, TSF	2.50	1.62	1.38	2.73
	TIME TO FAILURE, MIN.	23	7	6	12
	RATE OF STRAIN INCR	4		2	
	INITIAL DIAMETER, IN.	1.39	1.39	1.39	1.39
	INITIAL HEIGHT, IN.	3.00	3.00	3.00	3.00

CONTROLLED-STRAIN TEST

DESCRIPTION OF SPECIMENS: PLASTIC CLAY (CH), BROWN;
SOME COARSE SAND TO 3/16"

LL	PL	PI	GS 2.71	UNDISTURBED SPECIMEN	Q TEST

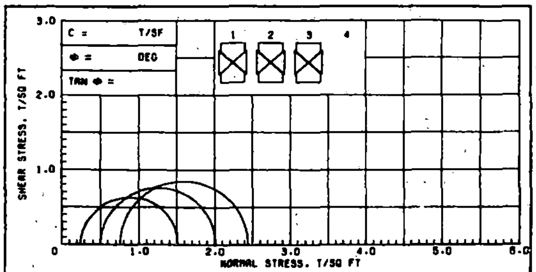
REMARKS:

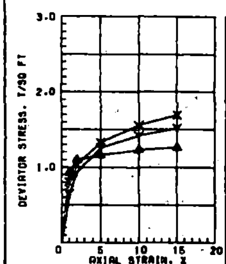
PROJECT KANSAS TEST TRACK
POST MORTEM INVESTIGATION

BORING NO. UNDISTURBED	SAMPLE NO. 1B
DEPTH/ELEV 12"-24"	TECH. RE
LABORATORY USAE WES	DATE 15 JUN 78

TRIAXIAL COMPRESSION TEST REPORT

FIGURE D-24. UNCONSOLIDATED, UNDRAINED (Q) TRIAXIAL TEST RESULTS FROM TEST PITS 1 AND 4





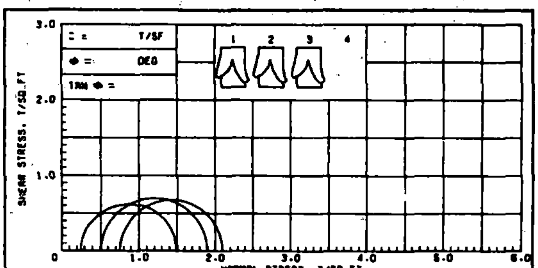
SPECIMEN NO.		▲1	Y2	X3	4
INITIAL	WATER CONTENT, %	27.9	26.0	28.0	
	DRY DENSITY, PCF	94.9	96.6	95.3	
	SATURATION, %	96.6	93.7	90.8	
	VOID RATIO	0.783	0.752	0.776	
BEFORE SHEAR	WATER CONTENT, %				
	DRY DENSITY, PCF				
	SATURATION, %				
	VOID RATIO				
	BACK PRESS., TSF				
MIN PRIN. STRESS, TSF		0.3	0.5	0.8	
MAX. DEV. STRESS, TSF		1.28	1.52	1.68	
TIME TO FAILURE, MIN.		58	28	27	
RATE OF STRAIN INCR					
INITIAL DIAMETER, IN.		1.38	1.39	1.38	
INITIAL HEIGHT, IN.		3.00	3.00	3.00	

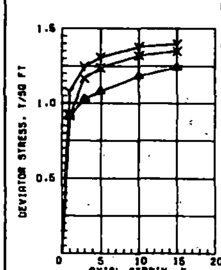
CONTROLLED-STRAIN TEST

DESCRIPTION OF SPECIMENS: PLASTIC CLAY (CH), REDDISH BROWN

LL	PL	PI	GS 2.71	UNDISTURBED SPECIMEN	Q TEST

REMARKS:	
	PROJECT KANSAS TEST TRACK
	POST MORTEM INVESTIGATION
	BORING NO. UNDISTURBED — SAMPLE NO. 9T
	DEPTH/ELEV 0-12" — TECH. RCH
	LABORATORY USAE WES — DATE 18 JUN 78
	TRIAXIAL COMPRESSION TEST REPORT





SPECIMEN NO.		▲1	Y2	X3	4
INITIAL	WATER CONTENT, %	26.3	28.1	28.1	
	DRY DENSITY, PCF	95.8	97.1	97.0	
	SATURATION, %	92.2	94.4	94.1	
	VOID RATIO	0.779	0.755	0.758	
BEFORE SHEAR	WATER CONTENT, %				
	DRY DENSITY, PCF				
	SATURATION, %				
	VOID RATIO				
	BACK PRESS., TSF				
MIN PRIN. STRESS, TSF		0.3	0.5	0.8	
MAX. DEV. STRESS, TSF		1.24	1.40	1.35	
TIME TO FAILURE, MIN.		35	40	35	
RATE OF STRAIN INCR					
INITIAL DIAMETER, IN.		1.39	1.40	1.40	
INITIAL HEIGHT, IN.		3.00	3.00	3.00	

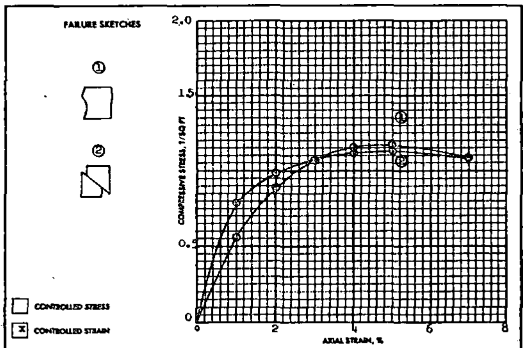
CONTROLLED-STRAIN TEST

DESCRIPTION OF SPECIMENS: PLASTIC CLAY (CH), REDDISH BROWN; COARSE SAND

LL	PL	PI	GS 2.73	UNDISTURBED SPECIMEN	Q TEST

REMARKS:	
	PROJECT KANSAS TEST TRACK
	POST MORTEM INVESTIGATION
	BORING NO. BLOCK — SAMPLE NO. 9B
	DEPTH/ELEV 12-24" — TECH. PJR
	LABORATORY USAE WES — DATE 17 JUN 78
	TRIAXIAL COMPRESSION TEST REPORT

FIGURE D-25. UNCONSOLIDATED, UNDRAINED (Q) TRIAXIAL TEST RESULTS FROM TEST PIT 9



TEST NO.		1	2		
TYPE OF SPECIMEN		Undist.	Undist.		
INITIAL WATER CONTENT	w_o	27.5 %	28.3 %	%	%
INITIAL VOID RATIO	e_o	0.800	0.772		
INITIAL SATURATION	S_o	92.8 %	99.0 %	%	%
INITIAL DRY DENSITY, LB/CU FT	γ_d	94.7	95.1		
TIME TO FAILURE, MIN	t_f	9	10		
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	1.17	1.13		
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	0.58	0.56		
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.41	1.41		
INITIAL SPECIMEN HEIGHT, IN.	H_o	3.00	3.00		

CLASSIFICATION PLASTIC CLAY (CH), reddish brown;gravel up to 1/4"

LL - PL - PI - G_s 2.70

REMARKS

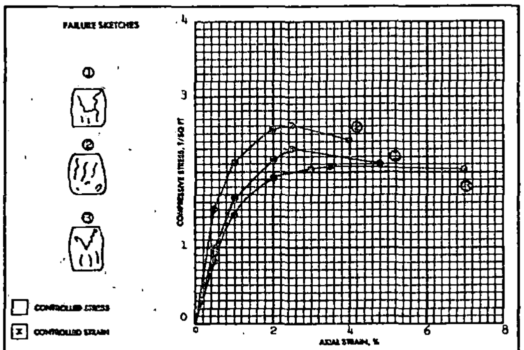
PROJECT KANSAS TEST TRACK
POST MORTEM INVESTIGATION

AREA

BORING NO. - SAMPLE NO. 1T

DEPTH 0-12" DATE 15 June 1976

KOC UNCONFINED COMPRESSION TEST REPORT



TEST NO.		1	2	3	
TYPE OF SPECIMEN		Undist.	Undist.	Undist.	
INITIAL WATER CONTENT	w_o	28.7 %	28.0 %	28.1 %	%
INITIAL VOID RATIO	e_o	0.881	0.856	0.838	
INITIAL SATURATION	S_o	88.0 %	88.3 %	90.5 %	%
INITIAL DRY DENSITY, LB/CU FT	γ_d	89.6	90.8	91.7	
TIME TO FAILURE, MIN	t_f	2	4	13	
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	2.30	2.61	2.08	
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	1.15	1.30	1.04	
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.40	1.40	1.39	
INITIAL SPECIMEN HEIGHT, IN.	H_o	3.00	3.00	3.00	

CLASSIFICATION PLASTIC CLAY(CH),brown

LL 62 PL 24 PI 38 G_s 2.70 (Est.)

REMARKS

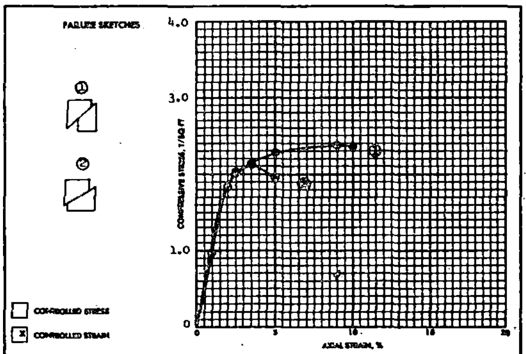
PROJECT KANSAS TEST TRACK
POST MORTEM INVESTIGATION

AREA

BORING NO. SAMPLE NO. 2AT

DEPTH 0-12 DATE 23 Sept. 1976

UNCONFINED COMPRESSION TEST REPORT



TEST NO.		1	2		
TYPE OF SPECIMEN		Undist.	Undist.		
INITIAL WATER CONTENT	w_o	27.0 %	27.4 %	%	%
INITIAL VOID RATIO	e_o	0.766	0.770		
INITIAL SATURATION	S_o	95.5 %	96.4 %	%	%
INITIAL DRY DENSITY, LB/CU FT	γ_d	95.8	95.6		
TIME TO FAILURE, MIN	t_f	7	14		
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	2.40	2.11		
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	1.20	1.06		
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.40	1.40		
INITIAL SPECIMEN HEIGHT, IN.	H_o	3.00	3.00		

CLASSIFICATION PLASTIC CLAY(CH),brown

LL - PL - PI - G_s 2.71

REMARKS

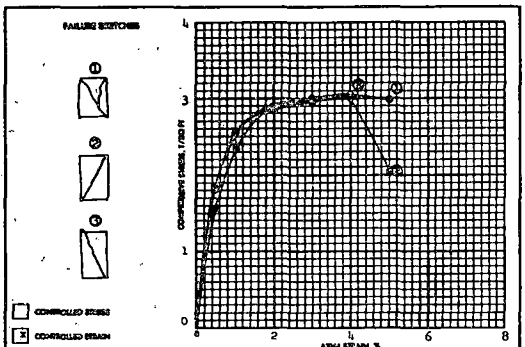
PROJECT KANSAS TEST TRACK
POST MORTEM INVESTIGATION

AREA

BORING NO. SAMPLE NO. 1-B

DEPTH 12"-24" DATE

KOC UNCONFINED COMPRESSION TEST REPORT



TEST NO.		1	2	3	
TYPE OF SPECIMEN		Undist.	Undist.	Undist.	
INITIAL WATER CONTENT	w_o	28.1 %	28.0 %	28.0 %	%
INITIAL VOID RATIO	e_o	0.805	0.805	0.805	
INITIAL SATURATION	S_o	94.2 %	93.9 %	93.9 %	%
INITIAL DRY DENSITY, LB/CU FT	γ_d	93.4	93.4	93.4	
TIME TO FAILURE, MIN	t_f	37	20	26	
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	3.04	3.02	3.04	
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	1.52	1.51	1.52	
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.39	1.40	1.39	
INITIAL SPECIMEN HEIGHT, IN.	H_o	3.00	3.00	3.00	

CLASSIFICATION PLASTIC CLAY(CH), reddish brown

LL PL PI G_s 2.70 (Est.)

REMARKS

PROJECT KANSAS TEST TRACK
POST MORTEM INVESTIGATION

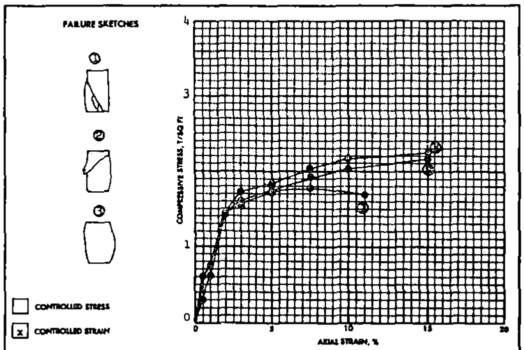
AREA

BORING NO. SAMPLE NO. 2A

DEPTH 12"-24" DATE 23 Sept. 1976

UNCONFINED COMPRESSION TEST REPORT

FIGURE D-26. UNCONFINED COMPRESSION TEST RESULTS FROM TEST PITS 1 AND 2A



TEST NO.		1	2	3	
TYPE OF SPECIMEN		Undist.	Undist.	Undist.	
INITIAL WATER CONTENT	w_o	27.9 %	27.6 %	27.6 %	%
INITIAL VOID RATIO	e_o	0.789	0.774	0.778	
INITIAL SATURATION	S_o	95.5 %	96.3 %	95.8 %	%
INITIAL DRY DENSITY, LB/CU FT	γ_d	94.2	98.0	94.8	
TIME TO FAILURE, MIN	t_f	20	40	43	
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	1.79	2.16	2.24	
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	0.90	1.08	1.12	
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.40	1.40	1.40	
INITIAL SPECIMEN HEIGHT, IN.	H_o	3.00	3.00	3.00	

CLASSIFICATION PLASTIC CLAY(CH),reddish brown;a few pea pravel

LL 59 | PL 23 | PI 36 | G_s 2.70 (Est.)

REMARKS Top of block hard and crumbly;specimens taken from bottom of block.

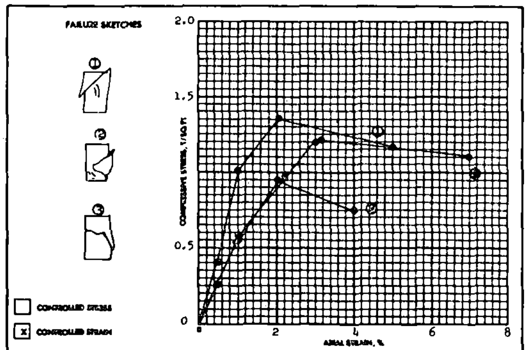
PROJECT KANSAS TEST TRACK POST MORTEM INVESTIGATION

AREA

BORING NO. | SAMPLE NO. 2ET

DEPTH 0-12" | DATE 23 Sept. 1976

JMS UNCONFINED COMPRESSION TEST REPORT



TEST NO.		1	2	3	
TYPE OF SPECIMEN		Undist.	Undist.	Undist.	
INITIAL WATER CONTENT	w_o	29.2 %	30.3 %	30.7 %	%
INITIAL VOID RATIO	e_o	0.836	0.888	0.902	
INITIAL SATURATION	S_o	94.3 %	92.1 %	91.9 %	%
INITIAL DRY DENSITY, LB/CU FT	γ_d	91.8	89.3	88.6	
TIME TO FAILURE, MIN	t_f	7	8	4	
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	1.35	1.22	0.97	
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	0.68	0.61	0.48	
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.40	1.38	1.41	
INITIAL SPECIMEN HEIGHT, IN.	H_o	3.00	3.00	3.00	

CLASSIFICATION PLASTIC CLAY(CH), mottled reddish brown and brown

LL 59 | PL 23 | PI 36 | G_s 2.70 (Est.)

REMARKS

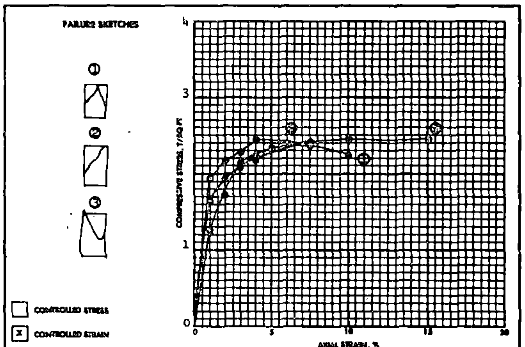
PROJECT KANSAS TEST TRACK FOST MORTEM INVESTION

AREA

BORING NO. | SAMPLE NO. 3AT

DEPTH 0"-12" | DATE 24 Sept. 1976

JMS UNCONFINED COMPRESSION TEST REPORT



TEST NO.		1	2	3	
TYPE OF SPECIMEN		Undist.	Undist.	Undist..	
INITIAL WATER CONTENT	w_o	25.7 %	25.6 %	26.1 %	%
INITIAL VOID RATIO	e_o	0.743	0.729	0.767	
INITIAL SATURATION	S_o	93.4 %	94.8 %	91.9 %	%
INITIAL DRY DENSITY, LB/CU FT	γ_d	96.7	97.5	95.4	
TIME TO FAILURE, MIN	t_f	28	23	19	
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	2.38	2.43	2.45	
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	1.19	1.21	1.22	
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.39	1.39	1.39	
INITIAL SPECIMEN HEIGHT, IN.	H_o	3.00	3.00	3.00	

CLASSIFICATION PLASTIC CLAY(CH),reddish brown

LL - | PL - | PI - | G_s 2.70 (Est.)

REMARKS

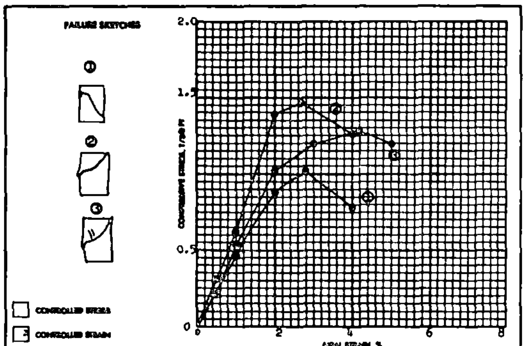
PROJECT KANSAS TEST TRACK POST MORTEM INVESTIGATION

AREA

BORING NO. | SAMPLE NO. 2B

DEPTH 12"-24" | DATE 24 Sept. 1976

UNCONFINED COMPRESSION TEST REPORT



TEST NO.		1	2	3	
TYPE OF SPECIMEN		Undist.	Undist.	Undist.	
INITIAL WATER CONTENT	w_o	30.2 %	31.2 %	33.8 %	%
INITIAL VOID RATIO	e_o	0.880	0.869	0.944	
INITIAL SATURATION	S_o	92.6 %	97.9 %	96.7 %	%
INITIAL DRY DENSITY, LB/CU FT	γ_d	89.6	90.2	86.7	
TIME TO FAILURE, MIN	t_f	6	4	8	
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	1.03	1.47	1.28	
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	0.52	0.74	0.64	
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.37	1.39	1.38	
INITIAL SPECIMEN HEIGHT, IN.	H_o	3.00	3.00	3.00	

CLASSIFICATION PLASTIC CLAY(CH), brown

LL 60 | PL 22 | PI 38 | G_s 2.70 (Est.)

REMARKS

PROJECT KANSAS TEST TRACK POST MORTEM INVESTIGATION

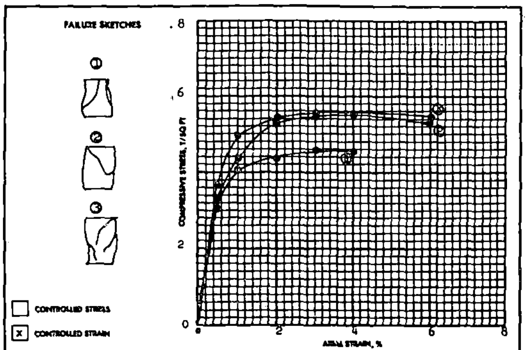
AREA

BORING NO. | SAMPLE NO. 3AB

DEPTH 12"-24" | DATE 24 Sept. 1976

JMS UNCONFINED COMPRESSION TEST REPORT

FIGURE D-27. UNCONFINED COMPRESSION TEST RESULTS FROM TEST PITS 2B AND 3A



TEST NO.		1	2	3	
TYPE OF SPECIMEN		Undist.	Undist.	Undist.	
INITIAL — WATER CONTENT	w_o	27.9 %	26.4 %	27.8 %	%
INITIAL — VOID RATIO	e_o	0.852	0.776	0.808	
INITIAL — SATURATION	S_o	88.4 %	91.8 %	92.9 %	%
INITIAL — DRY DENSITY, LB/CU FT	γ_d	91.0	94.9	93.2	
TIME TO FAILURE, MIN	t_f	10	15	12	
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	4.59	5.47	5.57	
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	2.30	2.73	2.78	
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.39	1.39	1.39	
INITIAL SPECIMEN HEIGHT, IN.	H_o	3.00	3.00	3.00	

CLASSIFICATION PLASTIC CLAY(CH),brown

LL 53 | PL 23 | PI 30 | G_s 2.70(Est.)

REMARKS Specimens from bottom of sample;top was too crumbly.

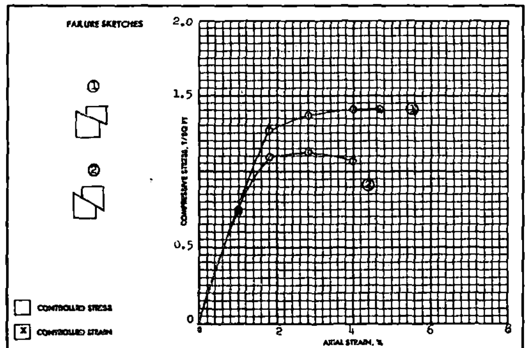
PROJECT KANSAS TEST TRACK POST MORTEM INVESTIGATION

AREA

BORING NO. | SAMPLE NO. 3B

DEPTH 0"-12" | DATE 4 Oct.1976

RE UNCONFINED COMPRESSION TEST REPORT



TEST NO.		1	2		
TYPE OF SPECIMEN		Undist.	Undist.		
INITIAL — WATER CONTENT	w_o	31.2 %	27.2 %	%	%
INITIAL — VOID RATIO	e_o	0.831	0.798		
INITIAL — SATURATION	S_o	91.5 %	92.4 %	%	%
INITIAL — DRY DENSITY, LB/CU FT	γ_d	92.4	94.1		
TIME TO FAILURE, MIN	t_f	8	11		
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	1.41	1.13		
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	0.70	0.56		
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.40	1.40		
INITIAL SPECIMEN HEIGHT, IN.	H_o	3.00	3.00		

CLASSIFICATION LEAN CLAY (CL), light brown;roots;gravel up to 1/4"

LL - | PL - | PI - | G_s 2.71

REMARKS

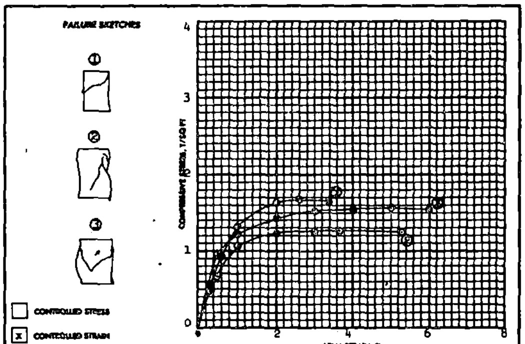
PROJECT KANSAS TEST TRACK POST MORTEM INVESTIGATION

AREA

BORING NO. | SAMPLE NO. 4T

DEPTH 0-12" | DATE 16 June 1976

LOC UNCONFINED COMPRESSION TEST REPORT



TEST NO.		1	2	3	
TYPE OF SPECIMEN		UNDIST.	UNDIST.	UNDIST.	
INITIAL — WATER CONTENT	w_o	37.2 %	25.8 %	27.2 %	%
INITIAL — VOID RATIO	e_o	0.896	0.848	0.816	
INITIAL — SATURATION	S_o	100+ %	82.1 %	90.0 %	%
INITIAL — DRY DENSITY, LB/CU FT	γ_d	88.9	91.2	92.8	
TIME TO FAILURE, MIN	t_f	8	12	19	
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	1.66	1.27	1.58	
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	0.83	0.64	0.79	
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.39	1.38	1.38	
INITIAL SPECIMEN HEIGHT, IN.	H_o	3.00	3.00	3.00	

CLASSIFICATION PLASTIC CLAY(CH), brown

LL | PL | PI | G_s 2.70 Est.

REMARKS

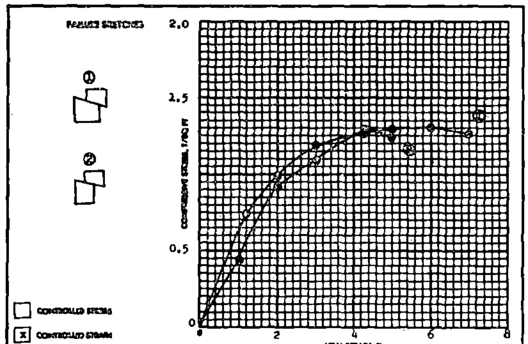
PROJECT KANSAS TEST TRACK POST MORTEM INVESTIGATION

AREA

BORING NO. | SAMPLE NO. 3B

DEPTH 12"-24" | DATE 18 Oct. 1976

RE UNCONFINED COMPRESSION TEST REPORT



TEST NO.		1	2		
TYPE OF SPECIMEN		Undist.	Undist.		
INITIAL — WATER CONTENT	w_o	26.9 %	26.8 %	%	%
INITIAL — VOID RATIO	e_o	0.746	0.730		
INITIAL — SATURATION	S_o	94.1 %	95.8 %	%	%
INITIAL — DRY DENSITY, LB/CU FT	γ_d	93.3	94.2		
TIME TO FAILURE, MIN	t_f	11	9		
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	1.30	1.29		
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	0.65	0.64		
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.40	1.40		
INITIAL SPECIMEN HEIGHT, IN.	H_o	3.00	3.00		

CLASSIFICATION PLASTIC CLAY(CH),brown;coarse sand

LL - | PL - | PI - | G_s 2.61

REMARKS

PROJECT KANSAS TEST TRACK POST MORTEM INVESTIGATION

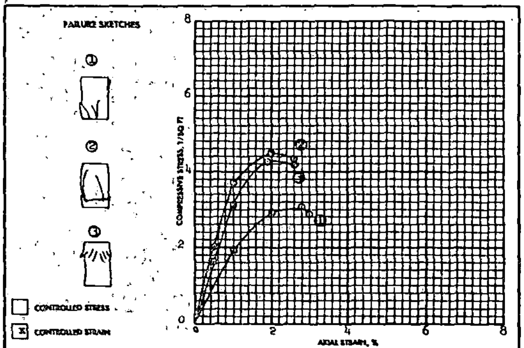
AREA

BORING NO. | SAMPLE NO. 4B

DEPTH 12-24 | DATE 16 June 1976

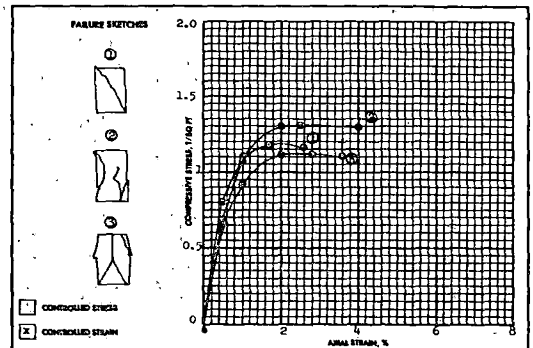
KOC UNCONFINED COMPRESSION TEST REPORT

FIGURE D-28. UNCONFINED COMPRESSION TEST RESULTS FROM TEST PITS 3B AND 4



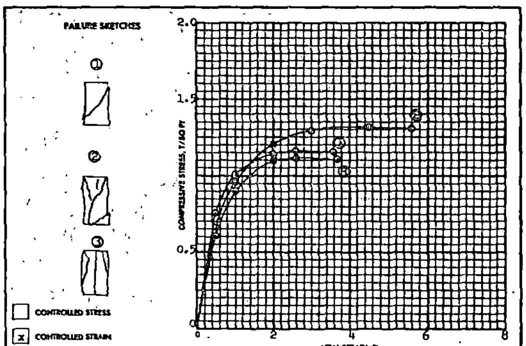
TEST NO.		1	2	3	
TYPE OF SPECIMEN		Undist.	Undist.	Undist.	
INITIAL WATER CONTENT	w_o	29.1 %	29.4 %	29.6 %	%
INITIAL VOID RATIO	e_o	0.856	0.867	0.885	
INITIAL SATURATION	S_o	91.8 %	91.6 %	90.3 %	%
INITIAL DRY DENSITY, LB/CU FT	γ_d	90.8	90.3	89.4	
TIME TO FAILURE, MIN	t_f	11	11	8	
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	3.07	4.52	4.23	
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	1.54	2.26	2.12	
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.40	1.40	1.40	
INITIAL SPECIMEN HEIGHT, IN	H_o	3.00	3.00	3.00	

CLASSIFICATION PLASTIC CLAY(CH), brown
LL 63 PL 20 PI 43 G_s 2.70 Est.
REMARKS
PROJECT KANSAS TEST TRACK
POST MORTEM INVESTIGATION
AREA
BORING NO. SAMPLE NO. 5T
DEPTH 0"-12" DATE 19 Oct. 1976
UNCONFINED COMPRESSION TEST REPORT



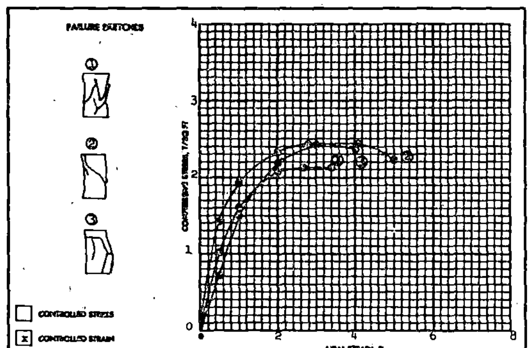
TEST NO.		1	2	3	
TYPE OF SPECIMEN		Undist.	Undist.	Undist.	
INITIAL WATER CONTENT	w_o	27.4 %	27.1 %	26.5 %	%
INITIAL VOID RATIO	e_o	0.767	0.761	0.782	
INITIAL SATURATION	S_o	96.4 %	96.1 %	91.5 %	%
INITIAL DRY DENSITY, LB/CU FT	γ_d	95.4	95.7	94.6	
TIME TO FAILURE, MIN	t_f	6	8	8	
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	1.18	1.31	1.13	
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	0.59	0.66	0.56	
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.39	1.39	1.39	
INITIAL SPECIMEN HEIGHT, IN	H_o	3.00	3.00	3.00	

CLASSIFICATION PLASTIC CLAY(CH), brown, specimens trimmed from bottom of block
LL 58 PL 24 PI 34 G_s 2.70
REMARKS
PROJECT KANSAS TEST TRACK
POST MORTEM INVESTIGATION
AREA
BORING NO. SAMPLE NO. 7T
DEPTH 0"-12" DATE 20 Oct. 1976
UNCONFINED COMPRESSION TEST REPORT



TEST NO.		1	2	3	
TYPE OF SPECIMEN		Undist.	Undist.	Undist.	
INITIAL WATER CONTENT	w_o	28.0 %	26.8 %	29.8 %	%
INITIAL VOID RATIO	e_o	0.801	0.745	0.826	
INITIAL SATURATION	S_o	94.4 %	97.1 %	97.4 %	%
INITIAL DRY DENSITY, LB/CU FT	γ_d	93.6	96.6	92.3	
TIME TO FAILURE, MIN	t_f	10	17	9	
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	1.16	1.33	1.12	
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	0.58	0.66	0.56	
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.39	1.39	1.39	
INITIAL SPECIMEN HEIGHT, IN	H_o	3.00	3.00	3.00	

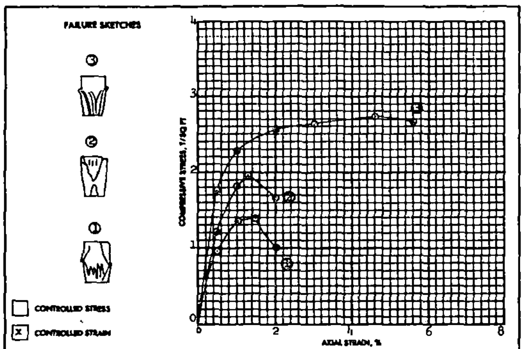
CLASSIFICATION PLASTIC CLAY(CH), reddish brown
LL 59 PL 25 PI 34 G_s 2.70 Est.
REMARKS
PROJECT KANSAS TEST TRACK
POST MORTEM INVESTIGATION
AREA
BORING NO. SAMPLE NO. 5B
DEPTH DATE 19 Oct. 1976
UNCONFINED COMPRESSION TEST REPORT



TEST NO.		Undist.	Undist.	Undist.	
TYPE OF SPECIMEN					
INITIAL WATER CONTENT	w_o	25.0 %	25.3 %	24.6 %	%
INITIAL VOID RATIO	e_o	0.697	0.718	0.684	
INITIAL SATURATION	S_o	96.8 %	95.1 %	97.1 %	%
INITIAL DRY DENSITY, LB/CU FT	γ_d	99.3	98.1	100.1	
TIME TO FAILURE, MIN	t_f	9	15	9	
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	2.13	2.45	2.43	
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	1.06	1.22	1.22	
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.40	1.39	1.39	
INITIAL SPECIMEN HEIGHT, IN	H_o	3.00	3.00	3.00	

CLASSIFICATION PLASTIC CLAY(CH), reddish brown
LL PL PI G_s
REMARKS
PROJECT KANSAS TEST TRACK
POST MORTEM INVESTIGATION
AREA
BORING NO. SAMPLE NO. 7B
DEPTH 12"-24" DATE 20 Oct. 1976
UNCONFINED COMPRESSION TEST REPORT

FIGURE D-29. UNCONFINED COMPRESSION TEST RESULTS FROM TESTS PITS 5 AND 7



☐ CONTROLLED STRESS
☒ CONTROLLED STRAIN

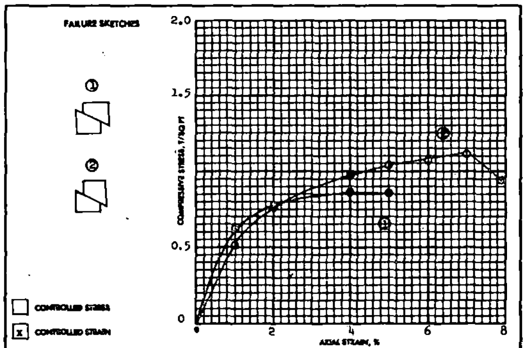
TEST NO.		1	2	3	
TYPE OF SPECIMEN		Undist.	Undist.	Undist.	
INITIAL: WATER CONTENT	w_o	31.3 %	33.0 %	32.9 %	%
INITIAL: VOID RATIO	e_o	1.01	1.04	1.00	
INITIAL: SATURATION	S_o	83.7 %	85.7 %	88.8 %	%
INITIAL: DRY DENSITY, LB/CU FT	γ_d	84.0	82.8	84.2	
TIME TO FAILURE, MIN	t_f	6	6	5	
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	1.38	1.96	2.72	
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	0.69	0.98	1.36	
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.40	1.40	1.39	
INITIAL SPECIMEN HEIGHT, IN	H_o	3.00	3.00	3.00	

CLASSIFICATION: PLASTIC CLAY(CH), brown

LL 56 | PL 23 | PI 33 | G_s 2.70 Est.

REMARKS

PROJECT: KANSAS TEST TRACK POST MORTEM INVESTIGATION
AREA
BORING NO. | SAMPLE NO. 8T
DEPTH 0"-12" | DATE
UNCONFINED COMPRESSION TEST REPORT



☐ CONTROLLED STRESS
☒ CONTROLLED STRAIN

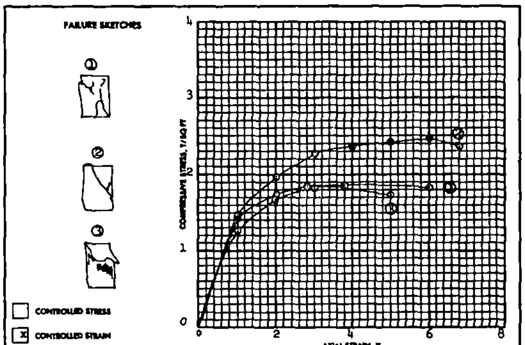
TEST NO.		1	2		
TYPE OF SPECIMEN		Undist.	Undist.		
INITIAL: WATER CONTENT	w_o	26.2 %	27.8 %	%	%
INITIAL: VOID RATIO	e_o	0.764	0.785		
INITIAL: SATURATION	S_o	92.9 %	96.0 %	%	%
INITIAL: DRY DENSITY, LB/CU FT	γ_d	95.9	94.8		
TIME TO FAILURE, MIN	t_f	8	14		
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	0.855	1.12		
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	0.427	0.56		
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.40	1.40		
INITIAL SPECIMEN HEIGHT, IN	H_o	3.00	3.00		

CLASSIFICATION: PLASTIC CLAY(CH), reddish brown

LL - | PL - | PI - | G_s 2.71

REMARKS

PROJECT: KANSAS TEST TRACK POST MORTEM INVESTIGATION
AREA
BORING NO. | SAMPLE NO. 9T
DEPTH 0-12 | DATE 16 June 1976
UNCONFINED COMPRESSION TEST REPORT



☐ CONTROLLED STRESS
☒ CONTROLLED STRAIN

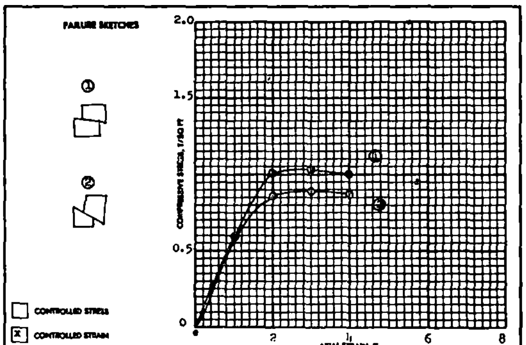
TEST NO.		1	2	3	
TYPE OF SPECIMEN		Undist.	Undist.	Undist.	
INITIAL: WATER CONTENT	w_o	25.2 %	25.2 %	24.6 %	%
INITIAL: VOID RATIO	e_o	0.713	0.713	0.727	
INITIAL: SATURATION	S_o	95.4 %	95.4 %	91.4 %	%
INITIAL: DRY DENSITY, LB/CU FT	γ_d	98.4	98.4	97.6	
TIME TO FAILURE, MIN	t_f	11	18	8	
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	1.86	2.47	1.83	
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	0.93	1.24	0.92	
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.40	1.39	1.39	
INITIAL SPECIMEN HEIGHT, IN	H_o	3.00	3.00	3.00	

CLASSIFICATION: PLASTIC CLAY(CH), reddish brown

LL 58 | PL 19 | PI 39 | G_s 2.70 Est.

REMARKS

PROJECT: KANSAS TEST TRACK POST MORTEM INVESTIGATION
AREA
BORING NO. | SAMPLE NO. 8B
DEPTH 12"-24" | DATE 22 Oct. 1976
UNCONFINED COMPRESSION TEST REPORT



☐ CONTROLLED STRESS
☒ CONTROLLED STRAIN

TEST NO.		1	2		
TYPE OF SPECIMEN		Undist.	Undist.		
INITIAL: WATER CONTENT	w_o	24.7 %	27.0 %	%	%
INITIAL: VOID RATIO	e_o	0.741	0.798		
INITIAL: SATURATION	S_o	91.0 %	92.4 %	%	%
INITIAL: DRY DENSITY, LB/CU FT	γ_d	97.9	94.8		
TIME TO FAILURE, MIN	t_f	6	7		
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	1.03	0.889		
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	0.51	0.444		
SENSITIVITY RATIO	S_t				
INITIAL SPECIMEN DIAMETER, IN	D_o	1.41	1.40		
INITIAL SPECIMEN HEIGHT, IN	H_o	3.00	3.00		

CLASSIFICATION: PLASTIC CLAY(CH), reddish brown; small percentage coarse sand

LL - | PL - | PI - | G_s 2.73

REMARKS

PROJECT: KANSAS TEST TRACK POST MORTEM INVESTIGATION
AREA
BORING NO. | SAMPLE NO. 9B
DEPTH 12-24 | DATE
UNCONFINED COMPRESSION TEST REPORT

FIGURE D-30. UNCONFINED COMPRESSION TEST RESULTS FROM TEST PITS 8 AND 9

APPENDIX E: INSTRUMENTATION

General

There had been three major data acquisition periods in the brief life of KTT, but parts of these data, notably moisture measurements and some of the final readings of the vertical extensometers, were thought to be unreliable. The Federal Railroad Administration (FRA) desired an evaluation of the embankment instrumentation to include its design, function, calibration, and condition. This work was carried out in Phase II of the field investigations.

This section documents the investigation of instrumentation arrays installed in the Kansas Test Track (KTT) embankment by Shannon and Wilson, Inc. (S&W),* and the data recording system owned and operated by the Portland Cement Association (PCA). The items of interest in this study are the soil pressure cells, temperature and moisture meters, vertical, partial, and total deflection meters, and the recording system. The horizontal extensometers will not be considered since they were not permanently installed and could be examined and calibrated as needed.

Transducers

A standard Schaevitz Model 1000HR Linear Variable Differential Transformer (LVDT) was installed in the extensometers as the transducer element. The pressure cell assembly manufactured by Slope Indicator Company employed the Schaevitz Model PT-7 pressure transducer. The Soiltest, Inc., Model MC-300A soil moisture and temperature meter was used to detect the soil temperature and moisture at various locations in the embankment test sections.

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* Shannon and Wilson, Inc., "Embankment Support for a Railroad Test Track, Construction Report," Aug 1972, U. S. Department of Transportation Federal Railroad Administration, Washington, D. C.

Dynamic Recording Equipment

The information detected by the embedded transducers was recorded with equipment housed in the PCA field recording van. Recording equipment in the van included carrier amplifiers, power supplies, oscillographs, and other equipment necessary to simultaneously record 30 channels of data.

The amplifier, which furnished a carrier (excitation voltage) to the LVDT-type transducers, has the capability of suppressing the transducer output to zero volts within the limits allowed by the amplifier gage factor setting. All cables and interconnections in the van were permanently wired including external bulkhead transducer connectors.

Provisions were also made to attenuate large, full-scale static transducer output signals to be compatible with Sanborn recording equipment.

The Sanborn "150" recording system used has a flat frequency response up to 20 Hz and is within ± 8 percent up to approximately 70 Hz. Additional details concerning recording equipment are given in a report by H. C. Greer.*

Field Calibrations and Measurements

Extensive tests were conducted at the main arrays at Test Sections 2, 7, and 9. Readings were recorded from the embedded vertical extensometers, soil pressure cells, and the soil moisture and temperature sensors to define the final settlement and soil pressure of the embankment.

LVDT calibrations were referenced to a micrometer having a 0.0001-in. accuracy and a John Fluke digital voltmeter (DVM) as shown schematically in Figure E-1. With the LVDT core adjusted to its electrical zero, a DVM reading (V_o) was made. The Standard LVDT core was

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* H. C. Greer, Memorandum for Record, Subject: Trip to Portland Cement Association at Skokie, Illinois, May 1976, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

displaced exactly 1.000 in., as measured with the micrometer, and another DVM reading (V_1) was made. The excitation voltage (V_E) was also read and recorded. The sensitivity of the LVDT can be expressed as

$$\frac{V_1 - V_o}{V_E} = 0.257/0.7319 = 351 \text{ mv/v/in.} \qquad \text{(E-1)}$$

The Schaevitz Model TR-100 indicator was calibrated to indicate 1 in. on its readout when the Standard LVDT was deflected 1 in. Therefore, by knowing that the sensitivity of the Standard LVDT is 351 mv/v/in. and that a deflection of one is indicated on the TR-100, transducers of other sensitivities can be read with the TR-100. The equation for displacement is

$$\text{Displacement} = \frac{S_1}{S_2} \times \text{TR-100 Indicator Reading} \qquad \text{(E-2)}$$

where S_1 equals 351 mv/v/in., S_2 is the known sensitivity of other LVDT in mv/v/in., and TR-100 reading is in inches. The equation for pressure is

$$\text{Pressure} = \frac{S_1}{S_2} \times \text{TR-100 Indicator Reading} \qquad \text{(E-3)}$$

where S_1 equals 351 mv/v/in., S_2 is the sensitivity of pressure transducer in mv/v/psi , and TR-100 indicator reading is in inches.

The static readings from the extensometers and soil pressure cells were made with the TR-100 using the above equations, and the final readings taken are listed in Table E-1. Readings from the soil moisture and temperature sensors were made for documentation purposes, were not converted to temperature and moisture units, and are recorded in Table E-2. Insulation to ground readings of all transducers in the main instrumentation arrays in Test Sections 2, 7, and 9 are listed in Tables E-3, E-4, and E-5, respectively.

Field Observations

The main instrumentation arrays at Test Sections 2, 7, and 9 were excavated to a depth which included position 1 pressure transducer located approximately 3 ft below the top plate of the multiple vertical extensometer (Figures E-2 and E-3) and the extensometer locations 01 and 02.

Soil was very carefully removed from transducer areas to prevent damage to pressure cell diaphragms and cables or disturbance of interfaces between soil and transducers. Pressure cell extensometer terminal box and PCA pressure cell elevations were measured with a surveyor's level and are recorded in Figures E-4 through E-9.

Diaphragms of the soil pressure cells were depressed (in place), and indications were observed on the TR-100 LVDT, which verified that the units were operable and had the proper polarity. Pressure cells excavated had a good interface with the soil as shown in Figures E-10, E-14, E-15, and E-21. All pressure cells were operable with the exception of those located at 2201 and 2202 which had open circuits in LVDT secondary windings. Sound anchor prong-soil interfaces were found after excavation and are shown in Figures E-11 (Test Section 2), E-16 and E-17 (Test Section 7), and E-22 (Test Section 9).

Extensometer terminal boxes were opened for inspection, and loose mechanical connections were found, as shown in Figures E-12, E-13, E-18, E-19, E-24, and E-25. These loose connections may be the source of phase reversals, noisy signals, and questionable data which were encountered during the testing period. Although other main instrumentation arrays were not scheduled to be excavated, it was convenient to remove the ballast from the main arrays at Test Sections 1, 3, 6, and 8 in order that the multiple vertical extensometer terminal boxes could also be opened for inspection. Condition of the internal parts of these extensometers and appropriate photographs are tabulated in Table E-6. The presence of mud and water inside terminal boxes required further examination of extensometers in Test Section 7. This inspection revealed that pumping had occurred between the construction joints of the two polyurethane foam lifts. Evidence of pumping is shown in Figure E-20 and can best be seen on extensometer 7401 (right side of the picture). The dark area in the cut out area long the construction joint indicates that mud had impregnated the white polyurethane foam.

Soil samples were taken beneath extensometers 2401 and 2402 where the water content was determined to be 28.4 and 29.0 percent by weight, respectively. Soil samples were also taken between pressure cells 9201 and 9202 and beneath extensometers 9401 and 9402 where the water content was found to be 28.0, 29.0, and 30.0 percent, respectively. Evidence of the high water content below 9402 is shown in Figure E-23 where water was seeping from higher elevations and pooling just below the extensometer terminal box.

LVDT's located in Test Sections 2, 7, and 9 were calibrated in place using a carpenter's rule as a standard. These values are considered as checks on the performance of the transducers after subjection to a hazardous environment for a lengthly period of time. Data from these calibrations are in Table E-7.

Posttest Laboratory Calibration of Soil Pressure Cells

Soil pressure cells excavated from the KTT embankment were check calibrated at the WES using laboratory standards and equipment (Figure E-26). These calibrations were performed to determine after-test transducer sensitivity and linearity so that an evaluation could be made as to the validity of test data retrieved from these instruments. During the calibrations, the LVDT output voltage was recorded at several different pressure levels set by use of a laboratory test pressure gage with an accuracy of ±0.25 percent full-scale and with the LVDT excitation voltage and frequency held constant. Linearity curves for each transducer calibrated are shown in Figures E-27 through E-32. Tabulated values of applied calibration pressures, output voltages measured at each pressure, and the error expressed in terms of percent full-scale deviation from the best straight-line fit drawn through all points is shown in Tables E-8 through E-13. The calibration history of the pressure transducers is shown in Table E-14.

Soil Moisture and Temperature Sensors

The temperature sensors produced reliable data, but as indicated by Shannon and Wilson* the moisture sensor readings were erratic and undependable. Several sensors were removed from the KTT and returned to the factory in hopes of getting some indication of the cause for gross failures. Soiltest, Inc., furnished a letter report (Figure E-33) concerning their evaluation of these transducer failures.

PCA Carlson Pressure Cells

No electrical readings were made by the WES on the PCA pressure cells, but several interesting items were noted in photographs taken at the site. The photograph in Figure E-34 shows typical settlement under the ties and the heaving between them. Figure E-35 gives an indication of the construction problem involved where the reinforcing metal was very close to the pressure cell. Figure E-36 shows where a repairman inadvertently drove a wooden wedge between one of the pressure cells and the concrete when attempting to level the slab. Figures E-37 and E-38 show the effects of pumping where the pumped lime-like materials are attached to the pressure cell. Note in E-38 that the material installed on the cells to protect the groove (pressure sensing area) from becoming contaminated with foreign particles is deteriorated and has allowed particles to contaminate the area. Information obtained from pressure cells operating in this type environment and condition would be questionable.

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* Shannon and Wilson, Inc., "Embankment Support for a Railroad Test Track, Analysis of Embankment Instrument Data," Vol 1, Jan 1976, U. S. Department of Transportation Federal Railroad Administration, Washington, D. C.

TABLE E-1. FINAL EXTENSOMETER INDICATIONS

Gage Location	TR100 Indication	Gage Sensitivity* mv/v/in	Deflection in.	Date
2401-1	1.25L**	382.3	1.15L	5/20/76
2401-2	1.10L	378.2	1.02L	5/20/76
2401-4	1.25L	372.3	1.18L	5/20/76
2402-1	1.45L	379.2	1.34L	5/20/76
2402-2	1.40L	379.0	1.30L	5/20/76
2402-4	1.30L	381.2	1.20L	5/20/76
2403-1	0.55R†	379.3	0.51R	5/20/76
2403-2	0.00	377.5	0.00	5/20/76
2404-4	0.03R	379.0	0.028R	5/20/76
7401-1	0.82L	377.7	0.76L	5/18/76
7401-2	0.90L	378.0	0.841L	5/18/76
7401-4	1.20L	375.8	1.12L	5/18/76
7402-1	0.50R	380.0	0.46L	5/18/76
7402-2	1.50L	374.2	1.41L	5/18/76
7402-4	0.045L	377.3	0.042L	5/18/76
7403-1	0.27L	379.8	0.25L	5/18/76
7403-2	0.55L	374.0	0.516L	5/18/76
7404-4	1.10L	378.7	1.02L	5/18/76
9401-1	1.05L	377.3	0.97L	5/19/76
9401-2	0.95L	380.2	0.88L	5/19/76
9401-3	0.55L	377.3	0.51L	5/19/76
9401-4	0.45L	376.5	0.42L	5/19/76
9402-1	1.35L	372.8	1.27L	5/19/76
9402-2	1.25L	376.3	1.17L	5/19/76
9402-3	1.30L	381.0	1.20L	5/19/76
9402-4	1.30L	374.0	1.22L	5/19/76
9403-1	0.30R	379.2	0.28R	5/19/76
9403-2	0.60R	375.8	0.56R	5/19/76
9403-3	0.90R	370.5	0.85R	5/19/76
9403-4	1.45R	378.0	1.35R	5/19/76

* From Shannon and Wilson, Inc., op. cit., p. E-1.

** L – down.

† R – up.

TABLE E-2. FINAL INDICATIONS, MOISTURE AND TEMPERATURE FROM MC300A METER

Gage	Temperature	Moisture
2301	125L*	185L
2302	130L	190L
2303	125L	140L
2304	130L	185L
2305	130L	200L
2306	30L	18H
2307	149L	110L
2308	140L	165L
2309	130L	175L
2310	10H**	10H
2311	135L	50L
2312	140L	45L
2313	135L	165L
7301	12L	55H
7302	128L	91L
7303	133L	76L
7304	128L	191L
7305	122L	186L
7306	118L	196L
7307	114L	200L
7308	112L	186L
7309	128L	197L
7310	184L	197L
7311	134L	194L
7312	164L	OPEN
7313	OPEN	175L
9301	130L	45H
9302	135L	30H
9303	130L	15H
9804	125L	10H
9305	190L	190L
9306	15H	15H
9307	-	-
9308	-	-
9309	130L	170L
9310	140L	185L
9311	140L	175L
9312	135L	50L
9313	125L	87L

* Indicates low range on MC300A meter.
** Indicates high range on MC300A meter.

TABLE E-3. INSULATION TO GROUND, TEST SECTION 2, 20 MAY 1976

Gage	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	α	Connector
2401-1	>20M	>20M	>20M	>20M	>20M																				1
2401-2						1.5M	1.5M	700K	700K	700K															1
2401-4																100K	120K	120K	120K	285K					1
2402-1	20M	7M	20M	20M	1M																				2
2402-2						20M	720K	800K	800K	720K															2
2402-4																>20M	>20M	>20M	>20M	>20M					2
2403-1	20M	20M	20M	20M	20M																				3
2403-2						>20M	>20M	>20M	>20M	>20K															3
2403-4																1M	1M	500K	500K	230K					3
2201	7M	5M	3M	>20M	>20M	5M																			4
2202							7M	7M	350K	720K	20M	120K													4
2203													20M	20M	20M	20M	20M	20M							4
2301	10K	5K	8K																						5
2302				19K	15K	19K																			5
2303							20K	17K	19K																5
2304										17K	14K	14K													5
2305													18K	14K	15K										5
2306																70K	90K	40K							5
2307																			30K	26K	30K				5
2308																						30K	13K	17K	5
2309	15K	15K	12K																						6
2310				80K	100K	3M																			6
2311							40K	25K	40K																6
2312										40K	25K	40K													6
2313													15K	10K	15K										6

Note: K = 1,000 ohms
M = 1,000,000 ohms

TABLE E-4. INSULATION TO GROUND, TEST SECTION 7,
18 MAY 1976

Gage	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Z	α	Connector
7401-1	20M	20M	20M	20M	20M																			1
7401-2						20M	20M	20M	20M	20M														1
7401-4																20M	20M	20M	20M	20M				1
7402-1	2.5M	2.5M	1.5M	1.5M	250K																			2
7402-2						2.5M	2.5M	500K	650K	30K														2
7402-4																350K	350K	300K	300K	140K				2
7403-1	>20M	>20M	>20M	>20M	>20M																			3
7403-2						>20M	>20M	>20M	>20M	>20M														3
7403-4																>20M	>20M	>20M	>20M	>20M				3
7201	>20M	>20M	700K	1.5M	1.5M	500K																		4
7202							10M	10M	3M	10M	10M	3M												4
7203																710K	710K	710K	710K	710K				4

Note: K = 1,000 ohms
M = 1,000,000 ohms

TABLE E-5. INSULATION TO GROUND, TEST SECTION 9,
19 MAY 1976

Gage	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	α	Connector
9401-1	20M	20M	20M	20M	20M																				1
9401-2						15M	15M	1.5M	1.5M	15M															1
9401-3											3M	3M	450K	450K	140K										1
9401-4																1.5M	1.5M	140K	150K	260K					1
9402-1	1M	1M	900K	900K	>20M																				2
9402-2						4M	4M	1.5M	1.5M	>20M															2
9402-3											400K	400K	120K	120K	230K										2
9402-4																160K	180K	110K	110K	240K					2
9403-1	>20M	>20M	>20M	>20M	>20M																				3
9403-2						20M	20M	240K	240K	>20M															3
9403-3											>20M	>20M	>20M	>20M	800K										3
9403-4																>20M	>20M	>20M	>20M	>20M					3
9401	280K	260K	300K	150K	150K	1M																			4
9402							1.5M	2M	600K	600K	600K	600K													4
9403													550K	550K	450K	5M	5M	2M							4
9301	95K	105K	95K																						5
9302				85K	140K	90K																			5
9303							200K	300K	210K																5
9304										350K	450K	350K													5
9305													5K	18K	8K										5
9306																350K	450K	350K							5
9307																			>20M	>20M	>20M				5
9308																						>20M	>20M	>20M	5
9309	20K	16K	18K																						6
9310				45K	45K	50K																			6
9311							40K	45K	45K																6
9312										100K	150K	100K													6
9313													45K	22K	40K										6

Note: K = 1,000 ohms
M = 1,000,000 ohms

TABLE E-6. CONDITION OF EXTENSOMETER LVDT ASSEMBLY

Transducer Location	Anchor Support Broken	LVDT Bent	Core Extension Rod Jammed	Core Extension Rod Broken	Leaks/Pumping Water	Leaks/Pumping Mud	Core Resting on Bottom
1401-1					X		
1401-2					X		
1401-4					X		
1402-1	X						
1402-2	X						
1402-4	X						
2401-1			X	X			X
2401-2	X						X
2401-4							X
2402-1			X	X	X	X	
2402-2	X	X	X		X	X	
2402-4	X	X			X	X	
3401-1					X		
3401-2	X				X		
3401-4					X		
3402-1	X				X		
3402-2	X				X		
3402-4	X				X		
3403-1							
3403-2							
3403-4							
6401-1							
6401-2							
6401-3							
64C1-4							
6402-1	X				X		
6402-2					X		
6402-3	X				X		
6402-4	X				X		
7401-1							
7401-2							
7401-4							
7402-1					X	X	
7402-2					X	X	
7402-4	X		X		X	X	
8401-1							
8401-2							
8401-4							
8402-1					X		
8402-2					X		
8402-4					X		
9401-1							
9401-2			X				
9401-4							
9402-1					X		
9402-2	X				X		
9402-3					X		
9402-4					X		

TABLE E-7. INSITU CALIBRATION VALUES FOR EXTENSOMETERS, 20 MAY 1976

Gage	TR-100 Indication	LVDT Sensitivity* mv/v/in.	Displacement in.
2401-1'			
2401-2	1.1R**	378.2	1.02R
2401-4	0.97R	372.3	0.91R
2402-1'			
2402-2'			
2402-4	0.95R	379.0	0.83R
7401-1†			
7401-2	1.05R	378.0	0.98R
7401-4†			
7402-1	0.97R	380.0	0.98R
7402-2	1.05R	374.0	0.98R
7402-4	1.05R	377.3	0.98R
9401-1	1.05R	377.3	0.98R
9401-2	1.05R	380.2	0.97R
9401-3	1.05R	377.3	0.98R
9401-4††	1.5R	376.5	1.4R
9402-1‡			
9402-2	1.06R	376.3	0.99R
9402-3	1.05R	381.0	0.97R
9402-4	1.05R	374.0	0.99R

* From Shannon and Wilson, Inc., op. cit. p. E-1.
** R = up.
† Could not loosen LVDT core from reference assembly.
†† Calibrated twice.
‡ Rod jammed tube.

TABLE E-8. POST EXCAVATION CALIBRATION OF SOIL PRESSURE CELL 2203

12-1-76

1-FT CABLE

LINEAR LEAST SQUARES CALIBRATION VOLTS / PSIG
VOLTS = -.976736754479D-02 + .221103075793D-02 PSIG

PRESSURE (PSIG)	OUTPUT (VOLTS) MEASURED	PREDICTED	DIFFERENCE (VOLTS)	ERROR % FULL SCALE
10.00	.0140	.0123	-.00166	.85858
20.00	.0320	.0345	.00245	-1.27111
30.00	.0540	.0566	.00256	-1.32827
40.00	.0760	.0787	.00267	-1.38542
60.00	.1240	.1229	-.00111	.57281
80.00	.1670	.1671	.00012	-.05963
98.00	.2070	.2069	-.00009	.04474
80.00	.1680	.1671	-.00088	.45850
60.00	.1230	.1229	-.00011	.05467
40.00	.0790	.0787	-.00033	.16898
30.00	.0570	.0566	-.00044	.22614
20.00	.0360	.0345	-.00155	.80143
10.00	.0140	.0123	-.00166	.85858

30-FT CABLE

LINEAR LEAST SQUARES CALIBRATION VOLTS / PSIG
VOLTS = -.861905800567D-02 + .228796865692D-02 PSIG

PRESSURE (PSIG)	OUTPUT (VOLTS) MEASURED	PREDICTED	DIFFERENCE (VOLTS)	ERROR % FULL SCALE
10.00	.0150	.0143	-.00074	.36422
20.00	.0380	.0371	-.00086	.42349
30.00	.0610	.0600	-.00098	.48276
40.00	.0810	.0829	.00190	-.93581
60.00	.1270	.1287	.00166	-.81727
80.00	.1730	.1744	.00142	-.69874
98.00	.2180	.2156	-.00240	1.18134

TABLE E-9. POST EXCAVATION CALIBRATION OF SOIL PRESSURE CELL 7201

12-1-76

1-FT CABLE

LINEAR LEAST SQUARES CALIBRATION VOLTS / PSIG
VOLTS = -.500007435633D-03 + .307000026768D-02 PSIG

PRESSURE (PSIG)	OUTPUT (VOLTS) MEASURED	OUTPUT (VOLTS) PREDICTED	DIFFERENCE (VOLTS)	ERROR % FULL SCALE
10.00	.0300	.0302	.00020	-.16260
20.00	.0600	.0609	.00090	-.73171
30.00	.0910	.0916	.00060	-.48781
40.00	.1220	.1223	.00030	-.24391
50.00	.1530	.1530	.00000	-.00000
40.00	.1230	.1223	-.00070	.56910
30.00	.0920	.0916	-.00040	.32520
20.00	.0610	.0609	-.00010	.08130
10.00	.0310	.0302	-.00080	.65041

30-FT CABLE

LINEAR LEAST SQUARES CALIBRATION VOLTS / PSIG
VOLTS = .300000000000D-03 + .311000000000D-02 PSIG

PRESSURE (PSIG)	OUTPUT (VOLTS) MEASURED	OUTPUT (VOLTS) PREDICTED	DIFFERENCE (VOLTS)	ERROR % FULL SCALE
10.00	.0320	.0314	-.00060	.48387
20.00	.0620	.0625	.00050	-.40323
30.00	.0930	.0936	.00060	-.48387
40.00	.1250	.1247	-.00030	.24194
50.00	.1560	.1558	-.00020	.16129

TABLE E-10. POST EXCAVATION CALIBRATION OF SOIL PRESSURE CELL 7202

11-30-76

1-FT CABLE

LINEAR LEAST SQUARES CALIBRATION VOLTS / PSIG
VOLTS = -.285724589723D-03 + .425428608523D-02 PSIG

PRESSURE (PSIG)	OUTPUT (VOLTS) MEASURED	PREDICTED	DIFFERENCE (VOLTS)	ERROR % FULL SCALE
10.00	.0420	.0423	.00026	-.15126
20.00	.0840	.0848	.00080	-.47059
30.00	.1280	.1273	-.00066	.38655
40.00	.1700	.1699	-.00011	.06722
50.00	.2120	.2124	.00043	-.25211
40.00	.1700	.1699	-.00011	.06722
30.00	.1280	.1273	-.00066	.38655
20.00	.0840	.0848	.00080	-.47059
10.00	.0430	.0423	-.00074	.43698

30-FT CABLE

LINEAR LEAST SQUARES CALIBRATION VOLTS / PSIG
VOLTS = .225514051877D-16 + .440000000000D-02 PSIG

PRESSURE (PSIG)	OUTPUT (VOLTS) MEASURED	PREDICTED	DIFFERENCE (VOLTS)	ERROR % FULL SCALE
10.00	.0440	.0440	.00000	-.00000
20.00	.0880	.0880	-.00000	.00000
30.00	.1320	.1320	.00000	.00000
40.00	.1760	.1760	-.00000	.00000
50.00	.2200	.2200	-.00000	.00000

TABLE E-11. POST EXCAVATION CALIBRATION OF SOIL PRESSURE CELL 7203

12-1-76

1-FT CABLE

LINEAR LEAST SQUARES CALIBRATION VOLTS / PSIG
VOLTS = .130417253968D-02 + .178727639617D-02 PSIG

PRESSURE (PSIG)	OUTPUT (VOLTS) MEASURED	PREDICTED	DIFFERENCE (VOLTS)	ERROR % FULL SCALE
10.00	.0190	.0192	.00018	-.11270
20.00	.0370	.0370	.00005	-.03166
30.00	.0550	.0549	-.00008	.04939
40.00	.0730	.0728	-.00020	.13043
60.00	.1080	.1085	.00054	-.34443
80.00	.1440	.1443	.00029	-.18235
98.00	.1760	.1765	.00046	-.29125
80.00	.1450	.1443	-.00071	.45460
60.00	.1090	.1085	-.00046	.29251
40.00	.0730	.0728	-.00020	.13043
30.00	.0550	.0549	-.00008	.04939
20.00	.0370	.0370	.00005	-.03166
10.00	.0190	.0192	.00018	-.11270

30-FT CABLE

LINEAR LEAST SQUARES CALIBRATION VOLTS / PSIG
VOLTS = .205155237483D-02 + .183916903366D-02 PSIG

PRESSURE (PSIG)	OUTPUT (VOLTS) MEASURED	PREDICTED	DIFFERENCE (VOLTS)	ERROR % FULL SCALE
10.00	.0200	.0204	.00044	-.27361
20.00	.0390	.0388	-.00017	.10189
30.00	.0570	.0572	.00023	-.13989
40.00	.0760	.0756	-.00038	.23561
60.00	.1130	.1124	-.00060	.36932
80.00	.1490	.1492	.00019	-.11424
98.00	.1820	.1823	.00029	-.17908

TABLE E-12. POST EXCAVATION CALIBRATION OF SOIL PRESSURE CELL 9201

11-30-76

1-FT CABLE

LINEAR LEAST SQUARES CALIBRATION VOLTS / PSIG
VOLTS = -.257143842563D-02 + .813714356665D-02 PSIG

PRESSURE (PSIG)	OUTPUT (VOLTS) MEASURED	PREDICTED	DIFFERENCE (VOLTS)	ERROR % FULL SCALE
5.00	.0400	.0381	-.00189	1.15688
10.00	.0780	.0788	.00080	-.49080
15.00	.1180	.1195	.00149	-.91148
20.00	.1600	.1602	.00017	-.10517
25.00	.2030	.2009	-.00214	1.31463
20.00	.1600	.1602	.00017	-.10517
15.00	.1180	.1195	.00149	-.91148
10.00	.0780	.0788	.00080	-.49080
5.00	.0390	.0381	-.00089	.54339

30-FT CABLE

LINEAR LEAST SQUARES CALIBRATION VOLTS / PSIG
VOLTS = -.440000000000D-02 + .868000000000D-02 PSIG

PRESSURE (PSIG)	OUTPUT (VOLTS) MEASURED	PREDICTED	DIFFERENCE (VOLTS)	ERROR % FULL SCALE
5.00	.0410	.0390	-.00200	1.15607
10.00	.0810	.0824	.00140	-.80925
15.00	.1240	.1258	.00180	-1.04046
20.00	.1690	.1692	.00020	-.11561
25.00	.2140	.2126	-.00140	.80925

TABLE E-13. POST EXCAVATION CALIBRATION OF SOIL PRESSURE CELL 9202

12-1-76

1-FT CABLE

LINEAR LEAST SQUARES CALIBRATION VOLTS / PSIG
VOLTS = .157141890407D-02 + .399142891945D-02 PSIG

PRESSURE (PSIG)	OUTPUT (VOLTS) MEASURED	PREDICTED	DIFFERENCE (VOLTS)	ERROR % FULL SCALE
10.00	.0420	.0415	-.00051	.32143
20.00	.0810	.0814	.00040	-.25000
30.00	.1210	.1213	.00031	-.19643
40.00	.1610	.1612	.00023	-.14286
50.00	.2020	.2011	-.00086	.53571
40.00	.1610	.1612	.00023	-.14286
30.00	.1210	.1213	.00031	-.19643
20.00	.0810	.0814	.00040	-.25000
10.00	.0420	.0415	-.00051	.32143

30-FT CABLE

LINEAR LEAST SQUARES CALIBRATION VOLTS / PSIG
VOLTS = .500000000000D-03 + .419000000000D-02 PSIG

PRESSURE (PSIG)	OUTPUT (VOLTS) MEASURED	PREDICTED	DIFFERENCE (VOLTS)	ERROR % FULL SCALE
10.00	.0430	.0424	-.00060	.35928
20.00	.0830	.0843	.00130	-.77844
30.00	.1270	.1262	-.00080	.47904
40.00	.1680	.1681	.00010	-.05988
50.00	.2100	.2100	-.00000	.00000

TABLE E-14. CALIBRATION HISTORY OF MAIN INSTRUMENTATION ARRAY SLOPE INDICATOR COMPANY PRESSURE CELLS

Cell Number	Range in psia	Sensitivity in mv/v/psi		
		Slope Indicator Company Calibration*	WES Calibration	
			0 ft of cable	30 ft of cable
2201	25	8.667	**	**
2202	50	4.263	**	**
2203	100	2.225	2.211	2.288
7201	50	3.120	3.070	3.110
7202	50	4.303	4.254	4.400
7203	100	1.802	1.787	1.839
9201	25	8.693	8.137	8.680
9202	50	4.086	3.991	4.190
9203	100	2.000	†	†

* From Shannon and Wilson, Inc., op. cit., p. E-1.
** Defective cell.
† Leads and air tube cut too short for calibration vessel.

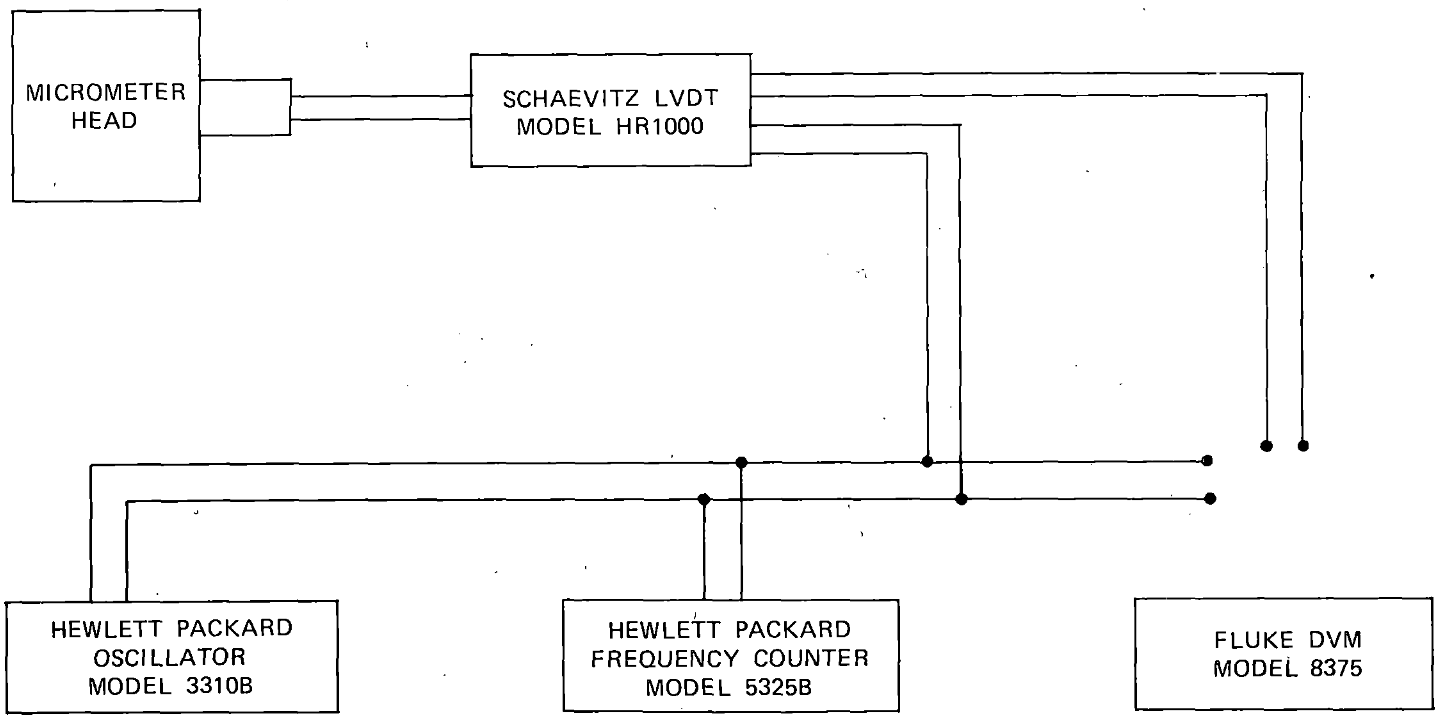


FIGURE E-1. CALIBRATION NETWORK FOR SCHAEVITZ LVDT

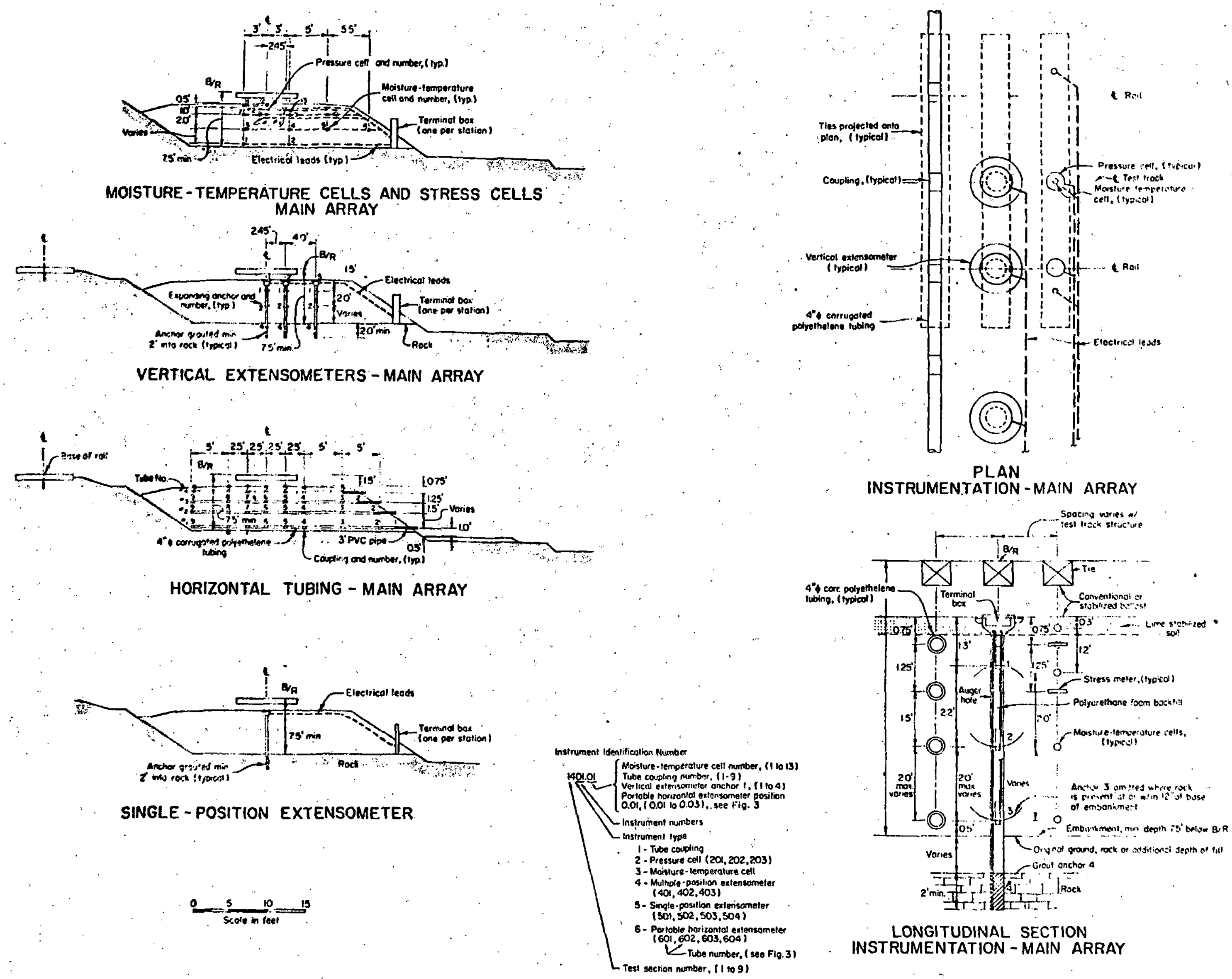
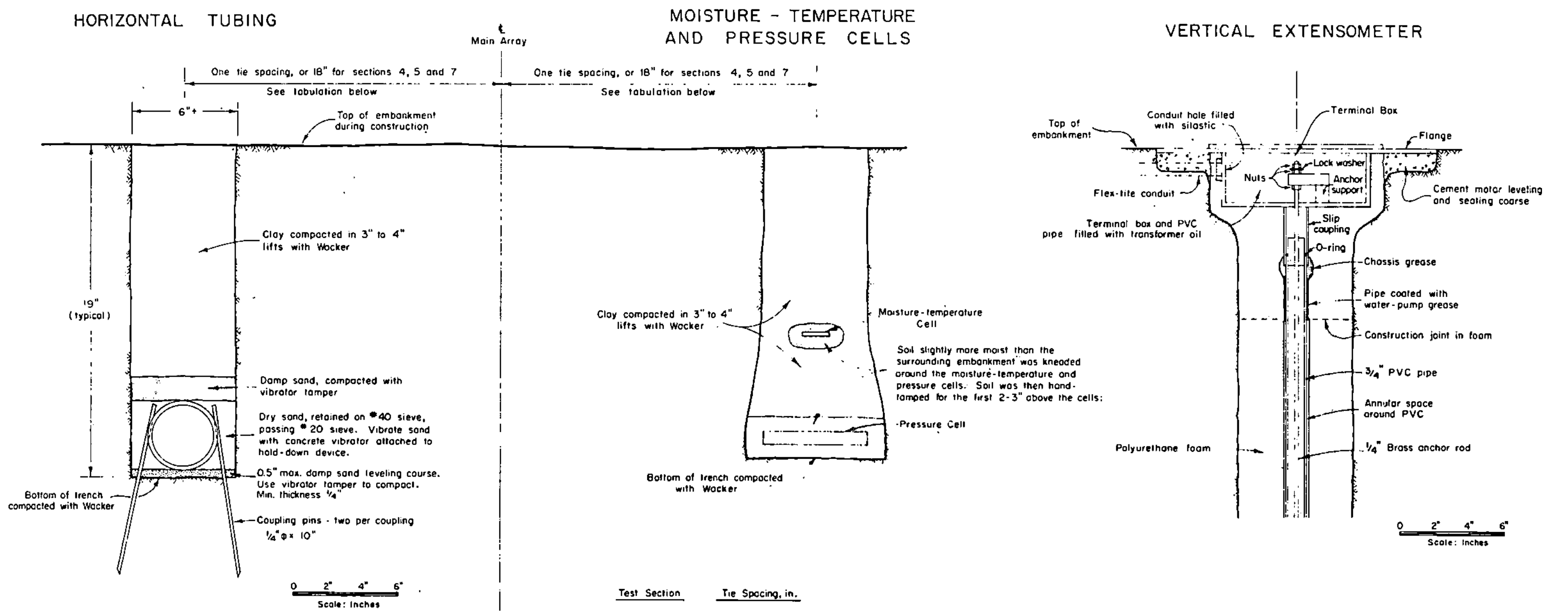


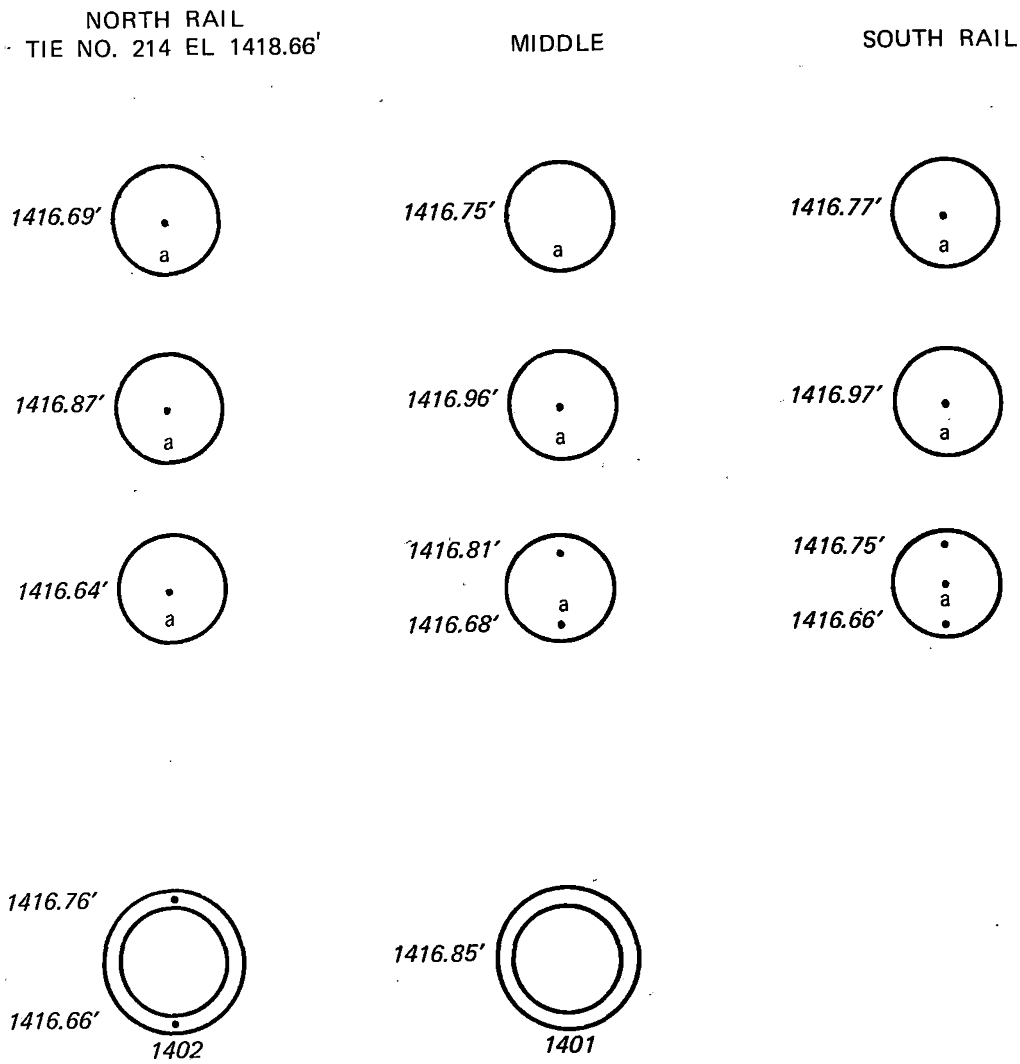
FIGURE E-2. INSTRUMENTATION LAYOUT (from Shannon and Wilson, Inc., op. cit., p. E-5)



Test Section	Tie Spacing, in.
1	30
2	27
3	24
4	19.5*
5	19.5*
6	19.5
7	19.5*
8	27
9	19.5

* No ties in test section, but spacing was taken as 19.5" for instrument installation purposes.

FIGURE E-3. INSTRUMENT INSTALLATION DETAILS (from Shannon and Wilson, Inc., op. cit., p. E-1)



a. PCA PRESSURE TRANSDUCERS

FIGURE E-4. TEST SECTION 1, TRANSDUCER ELEVATIONS AT MAIN INSTRUMENTATION ARRAY

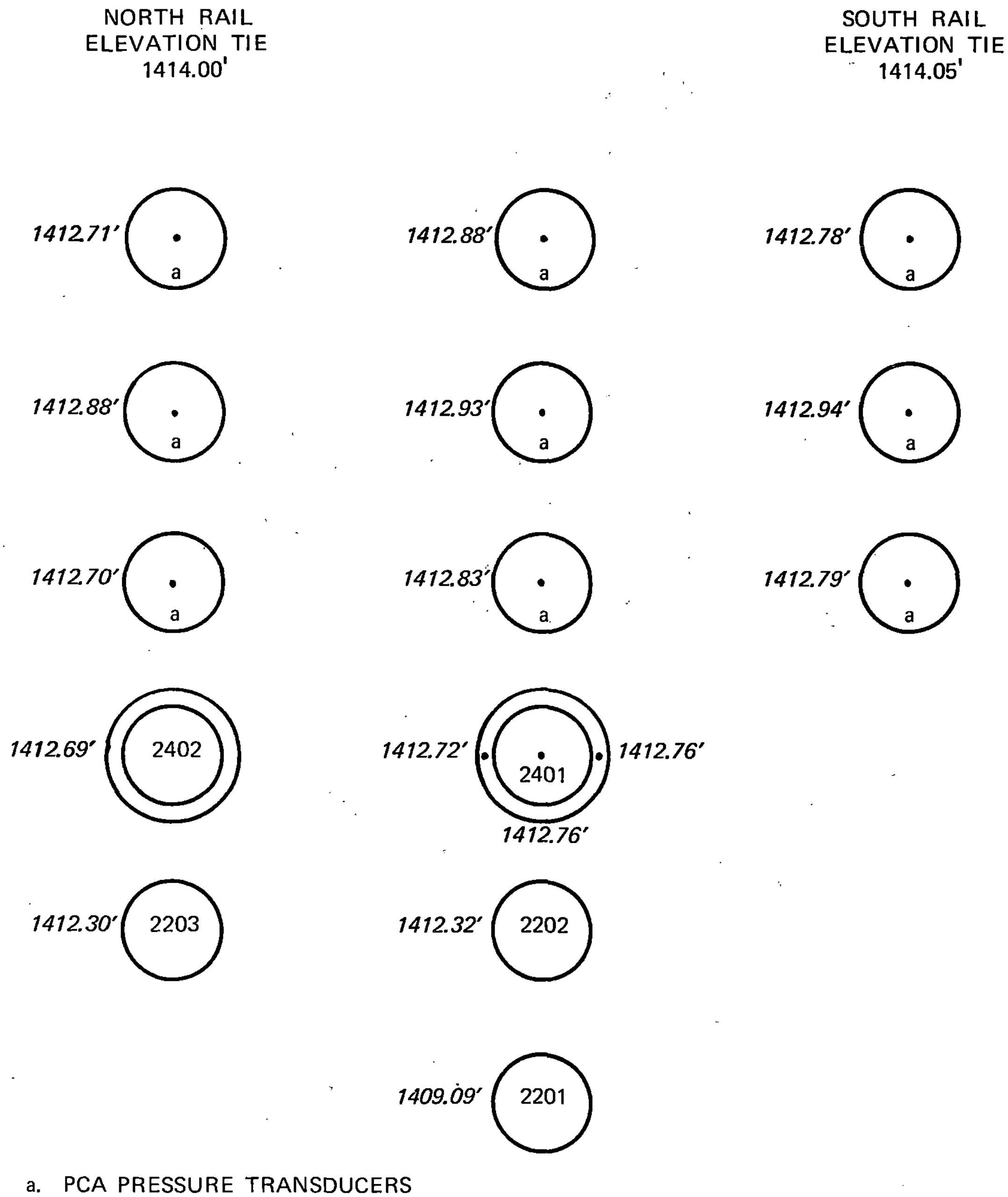
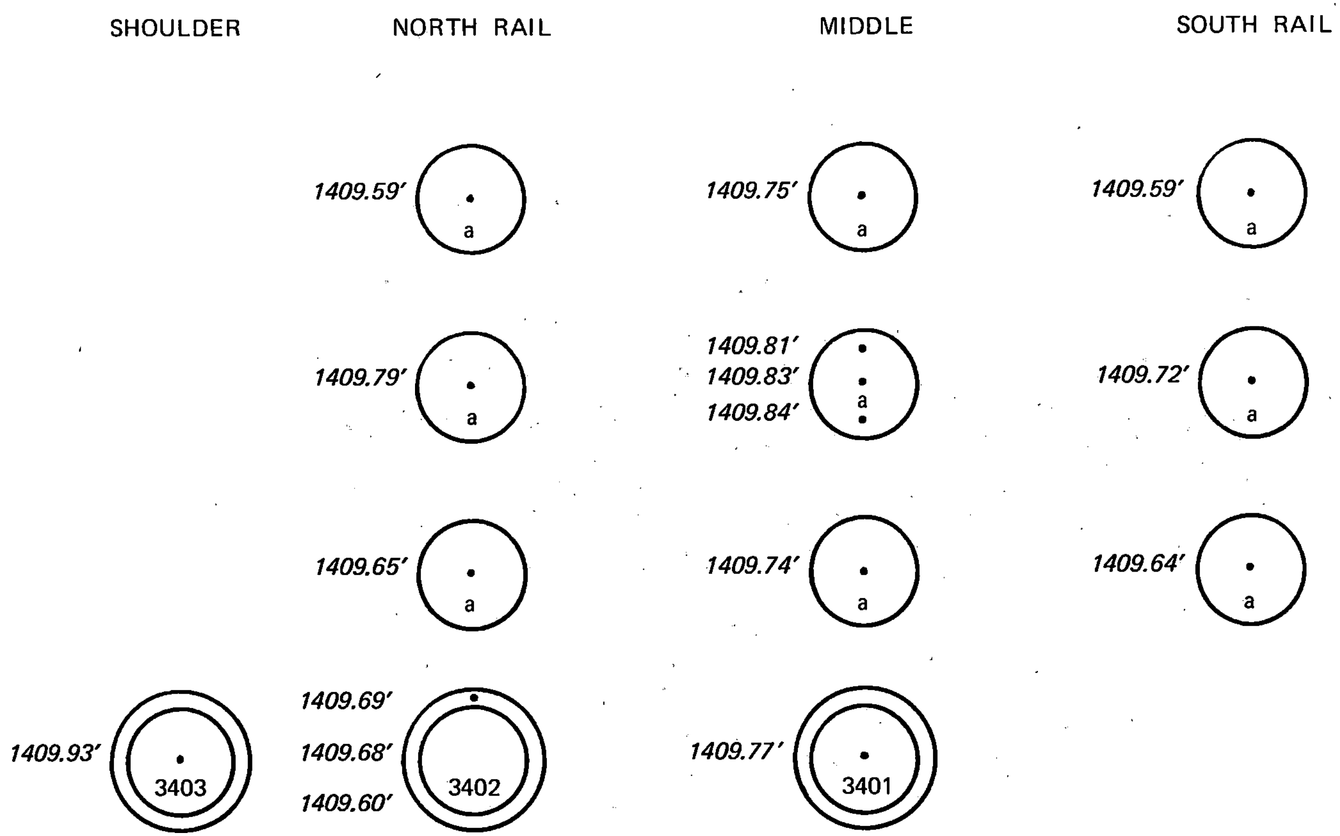


FIGURE E-5. TEST SECTION 2, TRANSDUCER ELEVATIONS AT MAIN INSTRUMENTATION ARRAY



a. PCA PRESSURE TRANSDUCERS

FIGURE E-6. TEST SECTION 3, TRANSDUCER ELEVATIONS AT MAIN INSTRUMENTATION ARRAY

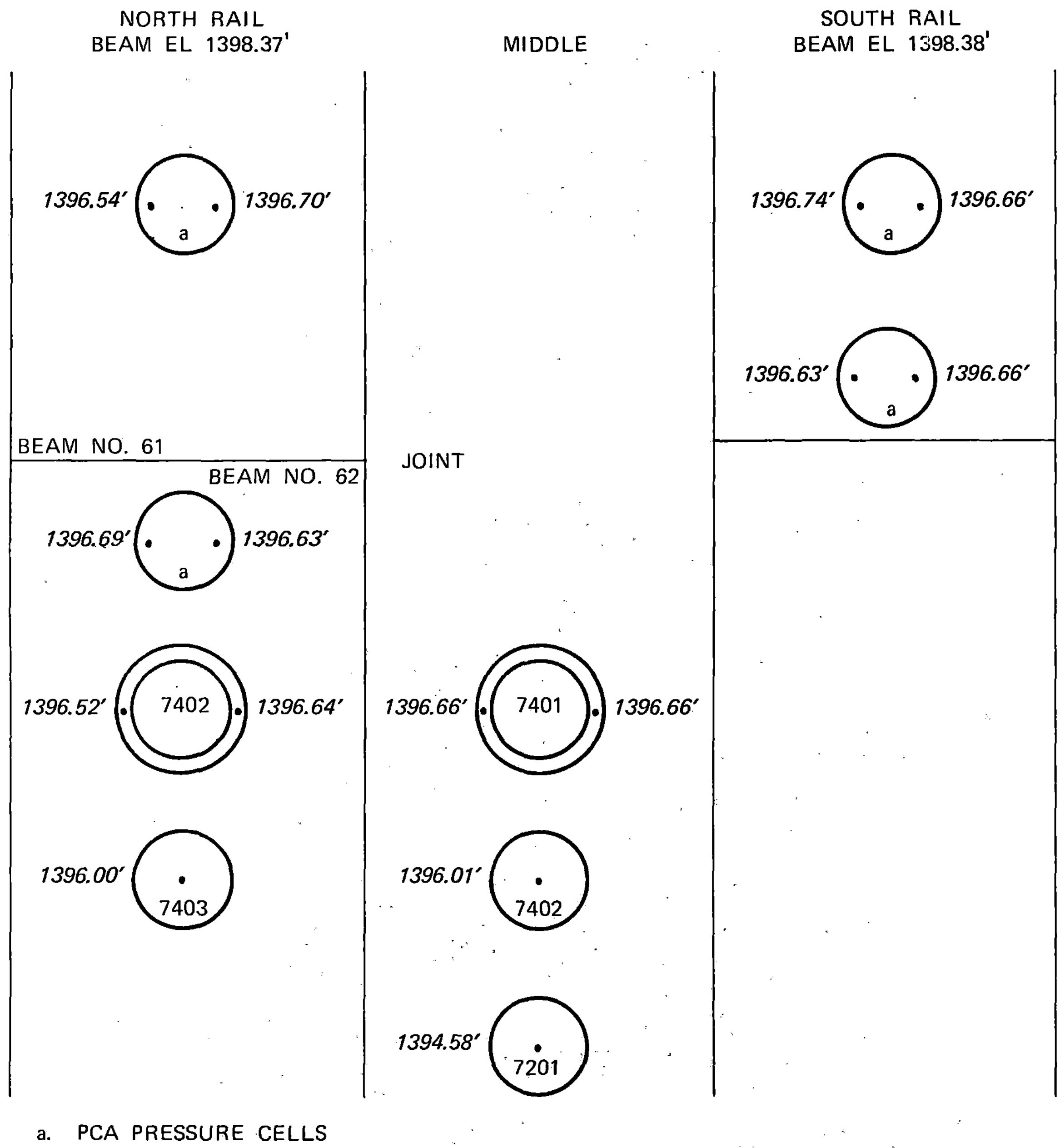
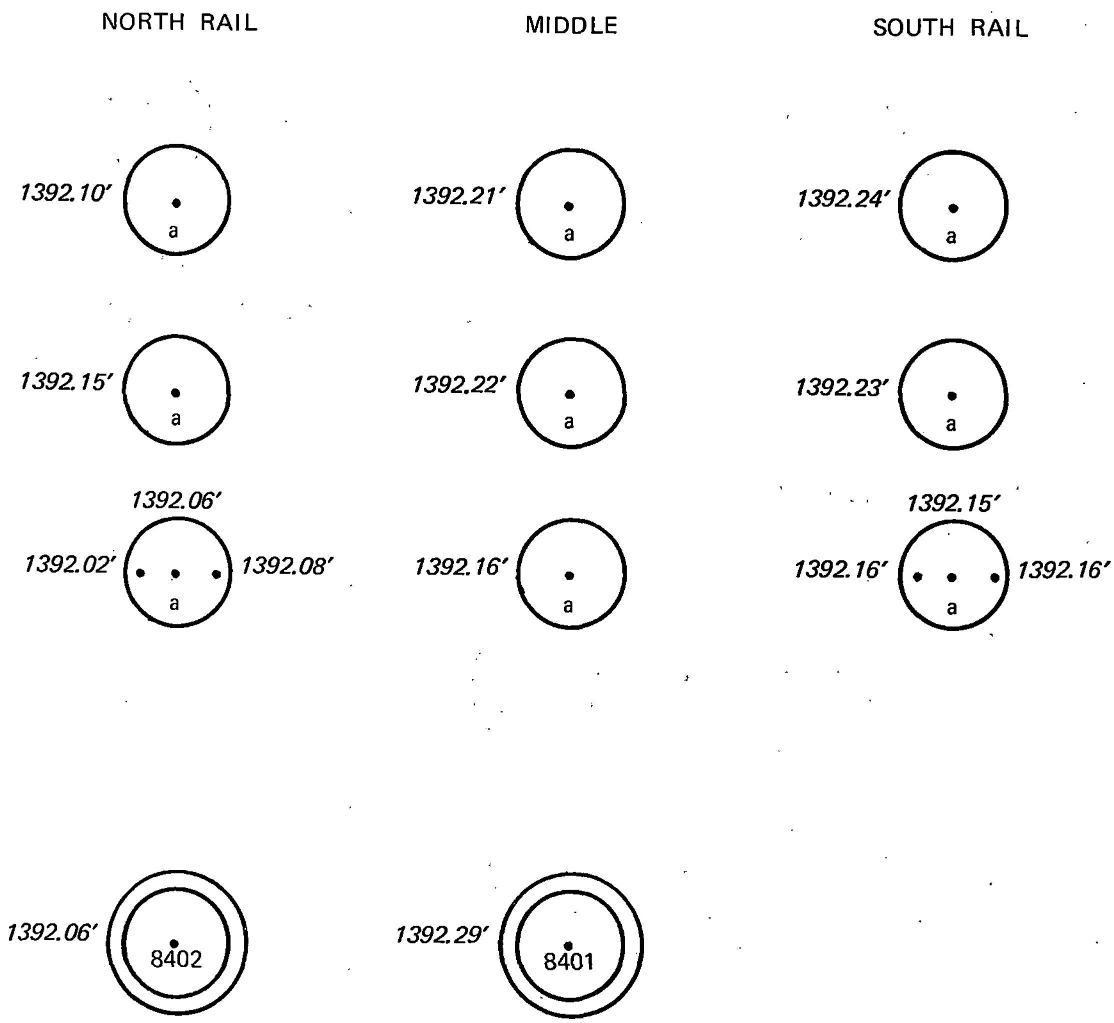
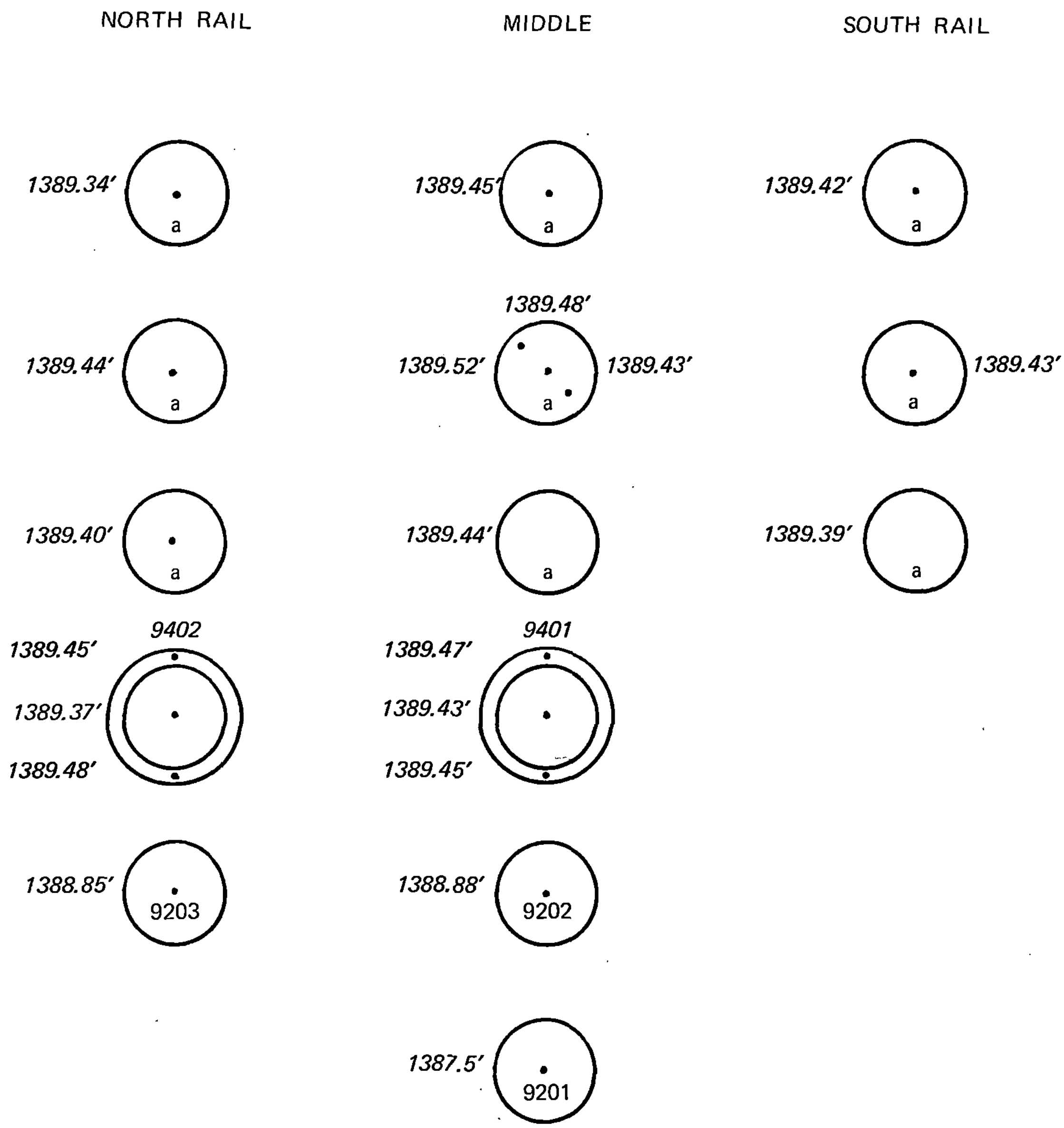


FIGURE E-7. TEST SECTION 7, TRANSDUCER ELEVATIONS AT MAIN INSTRUMENTATION ARRAY



a. PCA PRESSURE TRANSDUCERS

FIGURE E-8. TEST SECTION 8, TRANSDUCER ELEVATIONS AT MAIN INSTRUMENTATION ARRAY



a. PCA PRESSURE TRANSDUCERS

FIGURE E-9. TEST SECTION 9, TRANSDUCER ELEVATIONS AT MAIN INSTRUMENTATION ARRAY

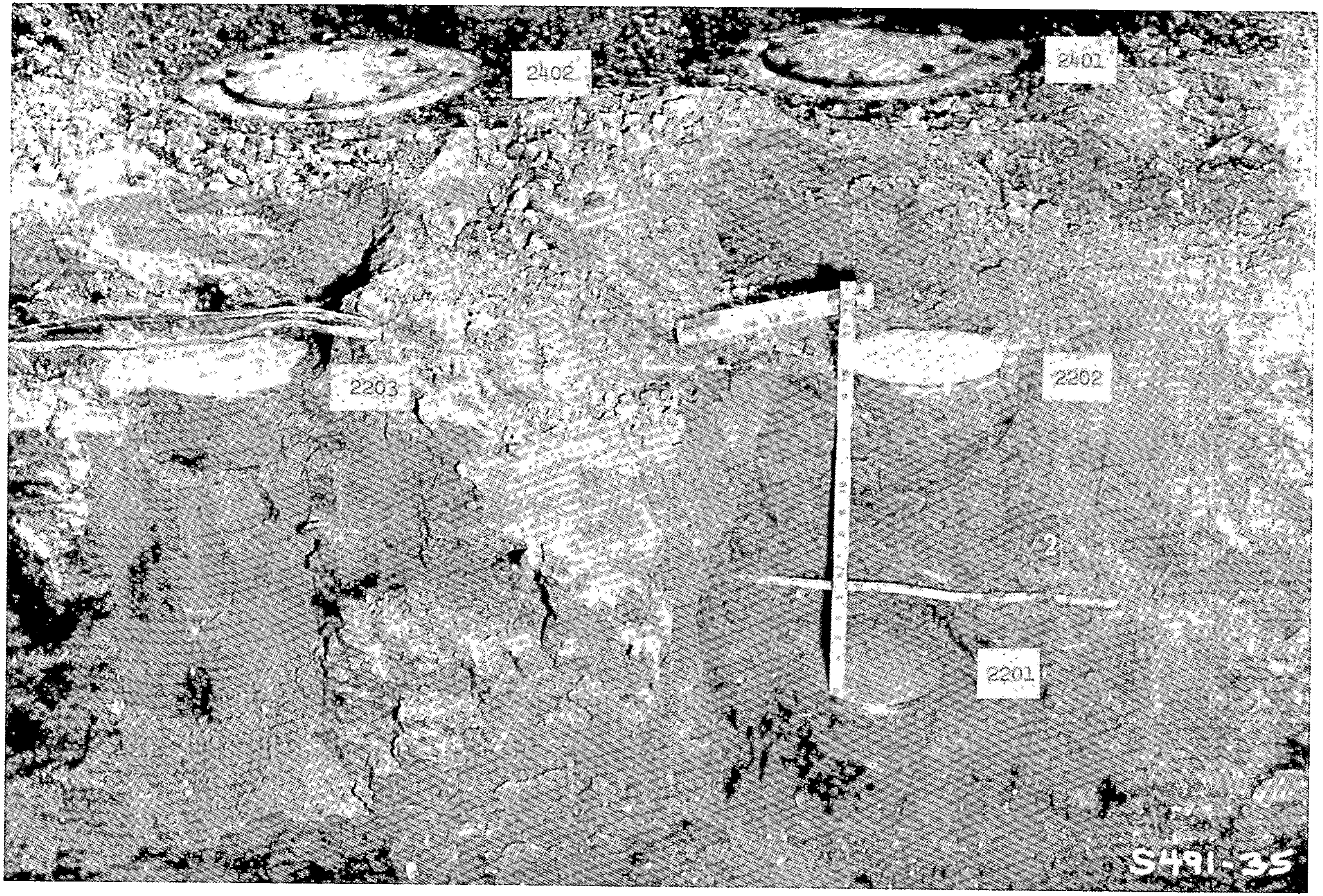


FIGURE E-10. TEST SECTION 2, MAIN INSTRUMENTATION ARRAY

FIGURE E-11. TEST SECTION 2, EXCAVATED EXTENSOMETER

FIGURE E-12. TEST SECTION 2, 2402 TERMINAL BOX

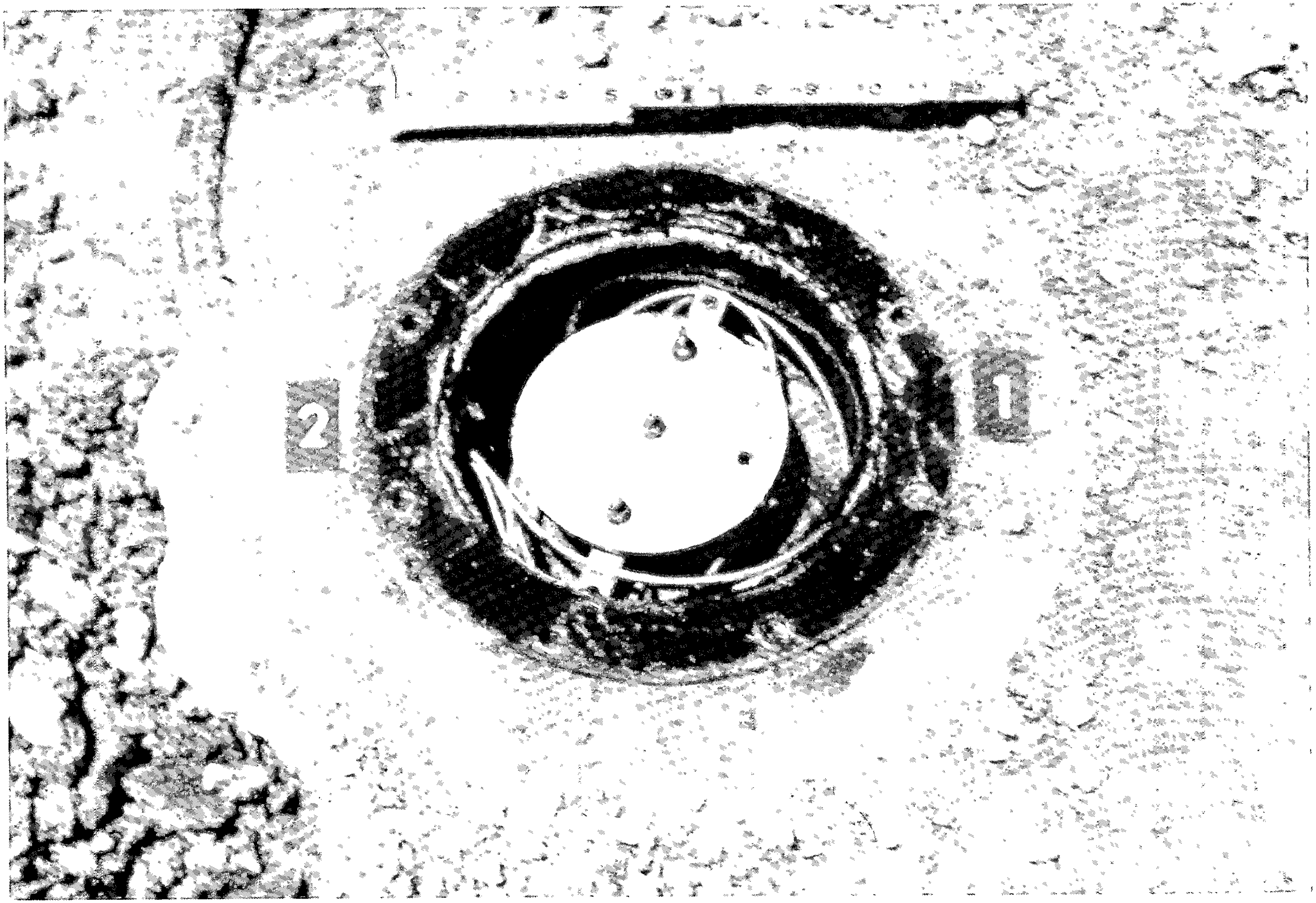


FIGURE E-13. TEST SECTION 2, 2401 TERMINAL BOX

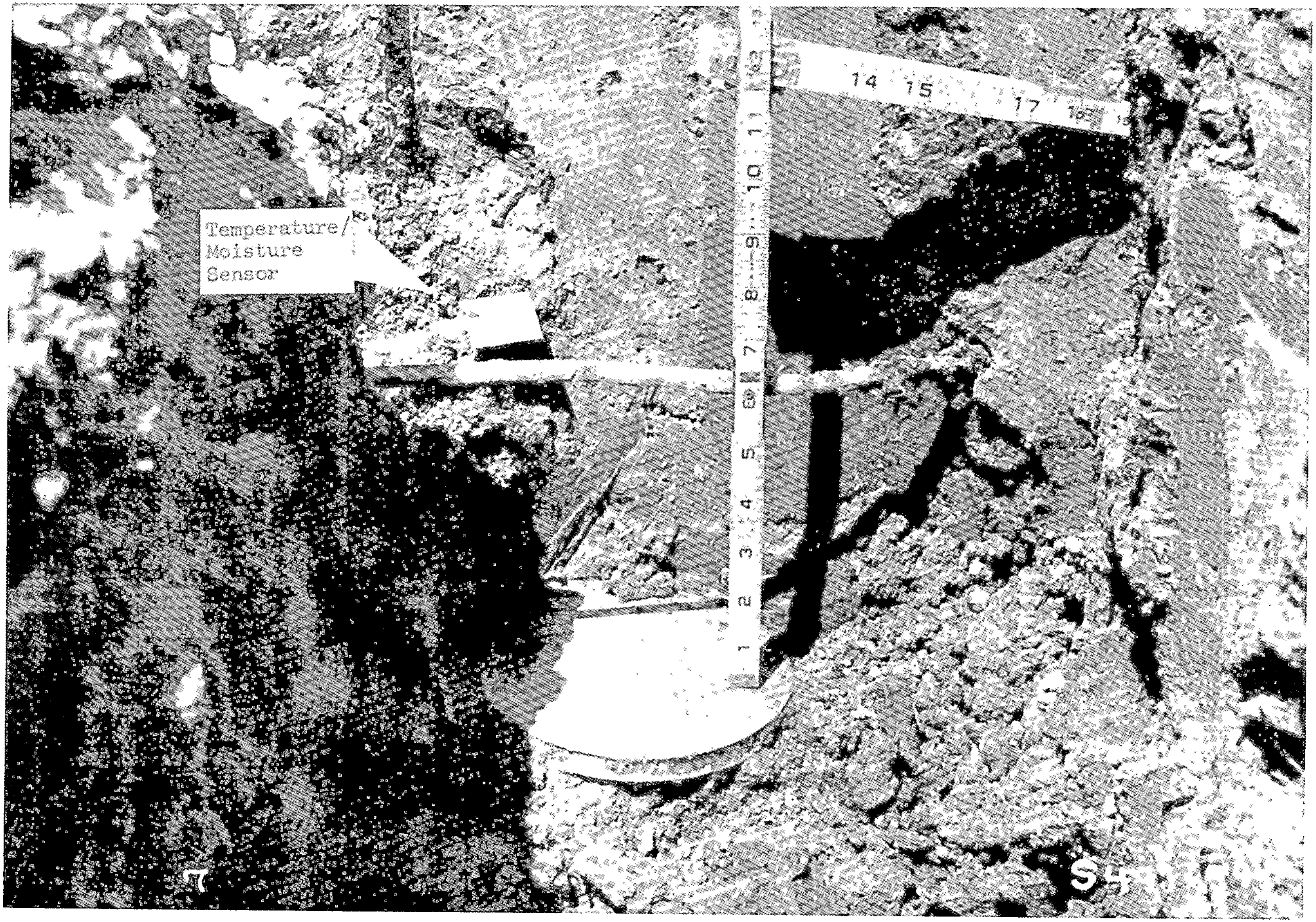


FIGURE E-14. TEST SECTION 2, EXCAVATION 2201

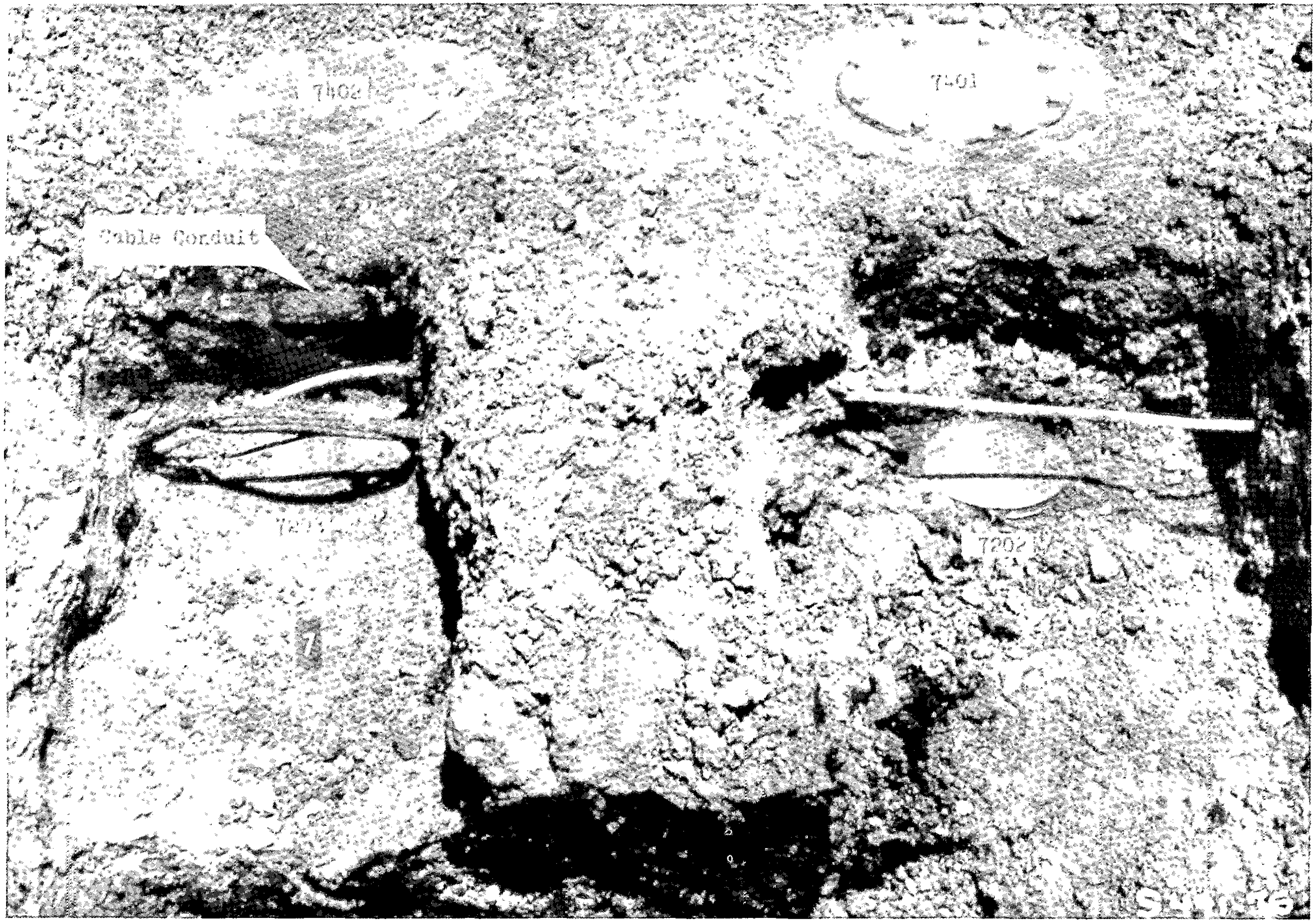


FIGURE E-15. TEST SECTION 7, MAIN INSTRUMENTATION ARRAY

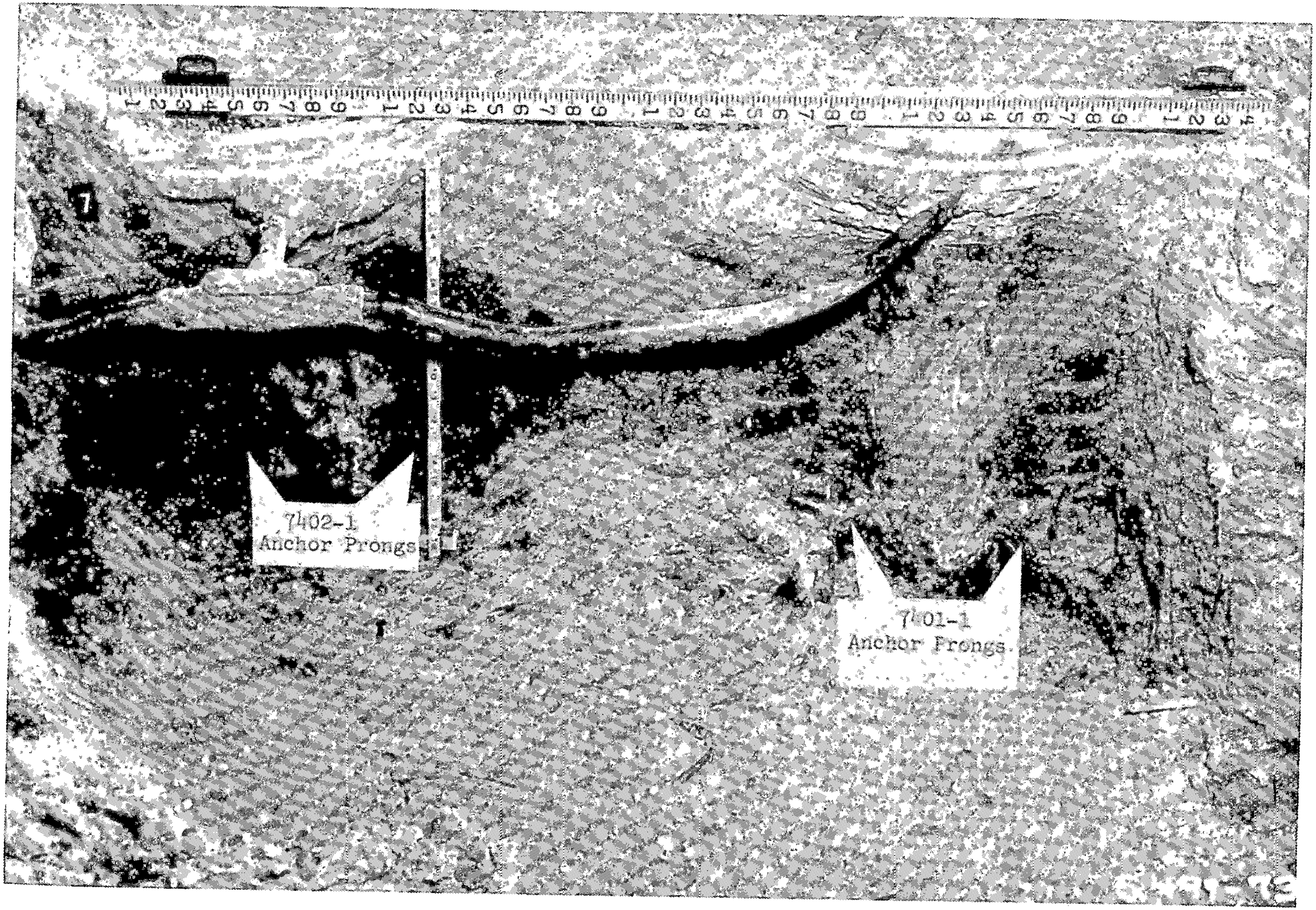


FIGURE E-16. ANCHOR PRONG-SOIL COMPLING FOR GAGES 7401-1 AND 7402-1, TEST SECTION 7

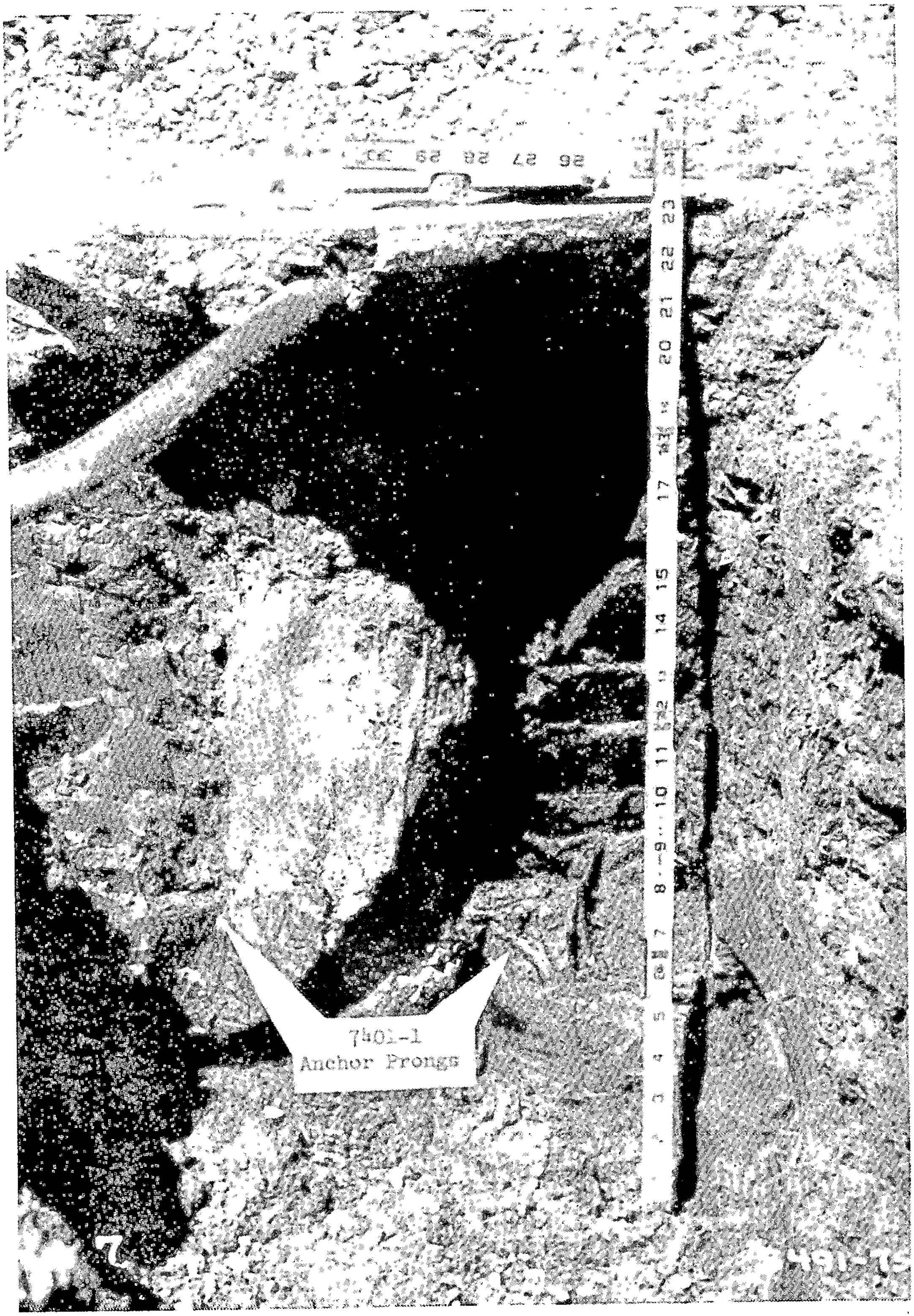


FIGURE E-17. ANCHOR PRONG-SOIL COMPLING FOR GAGE 7-01-1,
TEST SECTION 7

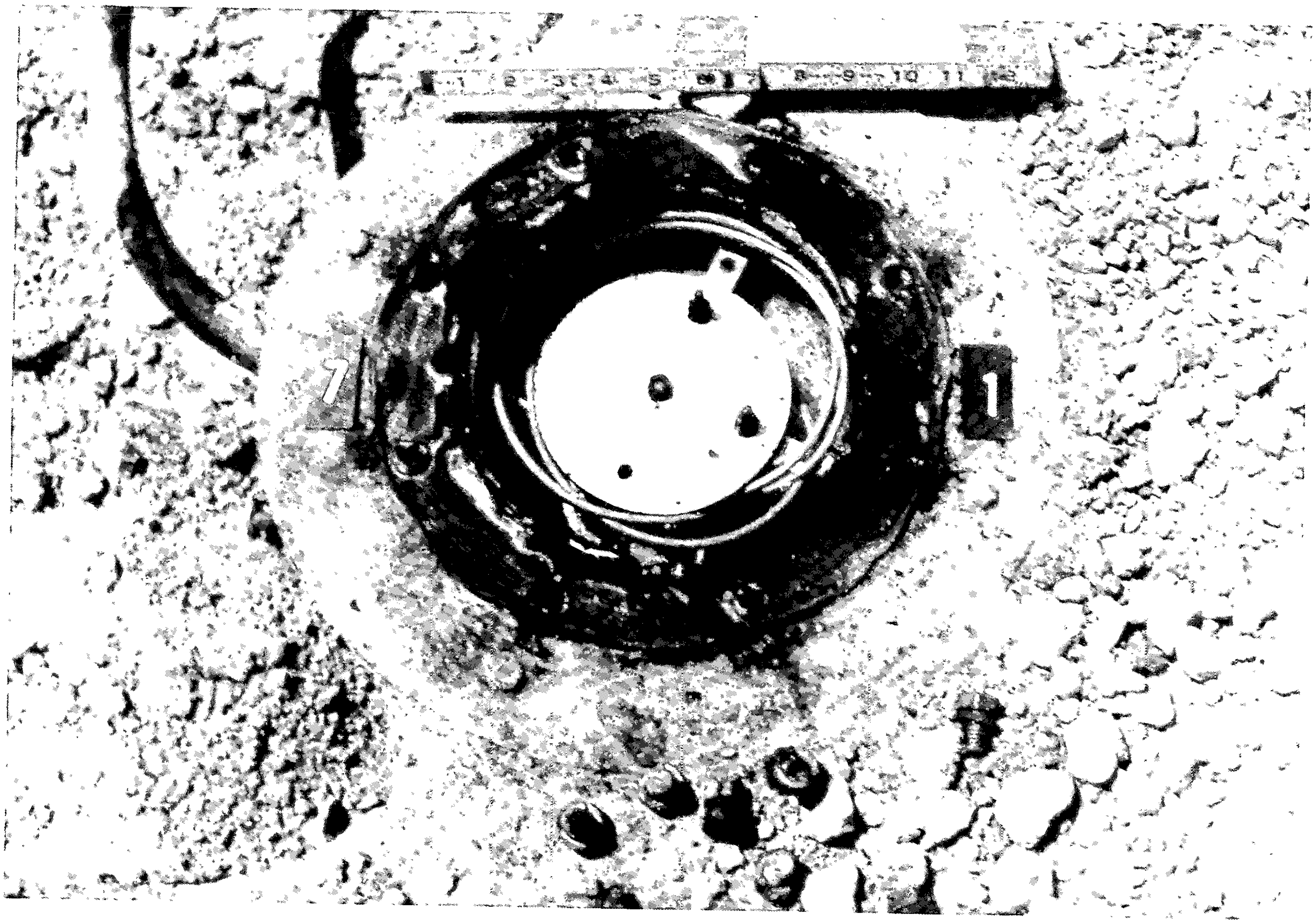


FIGURE E-18. TEST SECTION 7, 7401 TERMINAL BOX

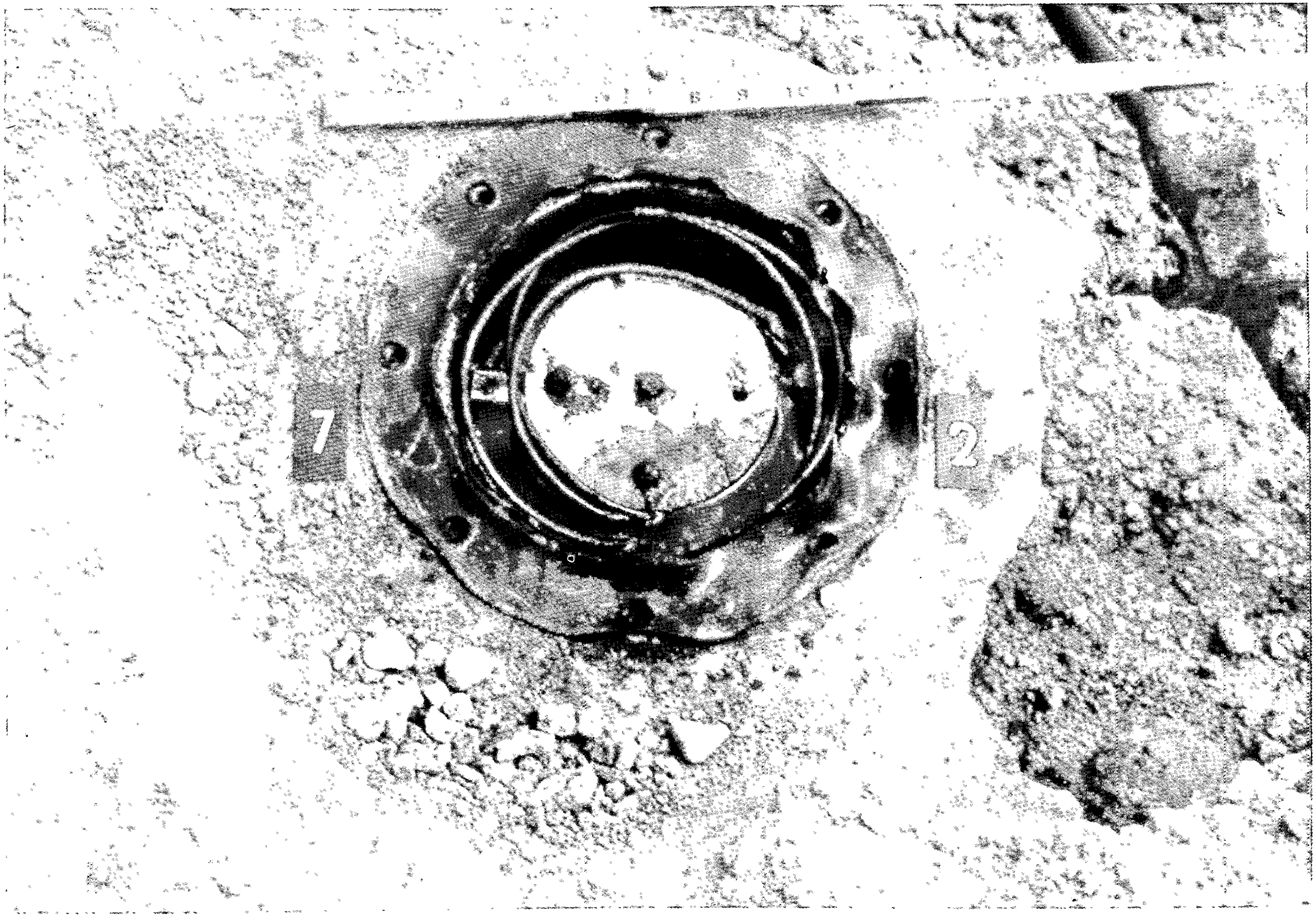


FIGURE E-19. TEST SECTION 7, 7402 TERMINAL BOX

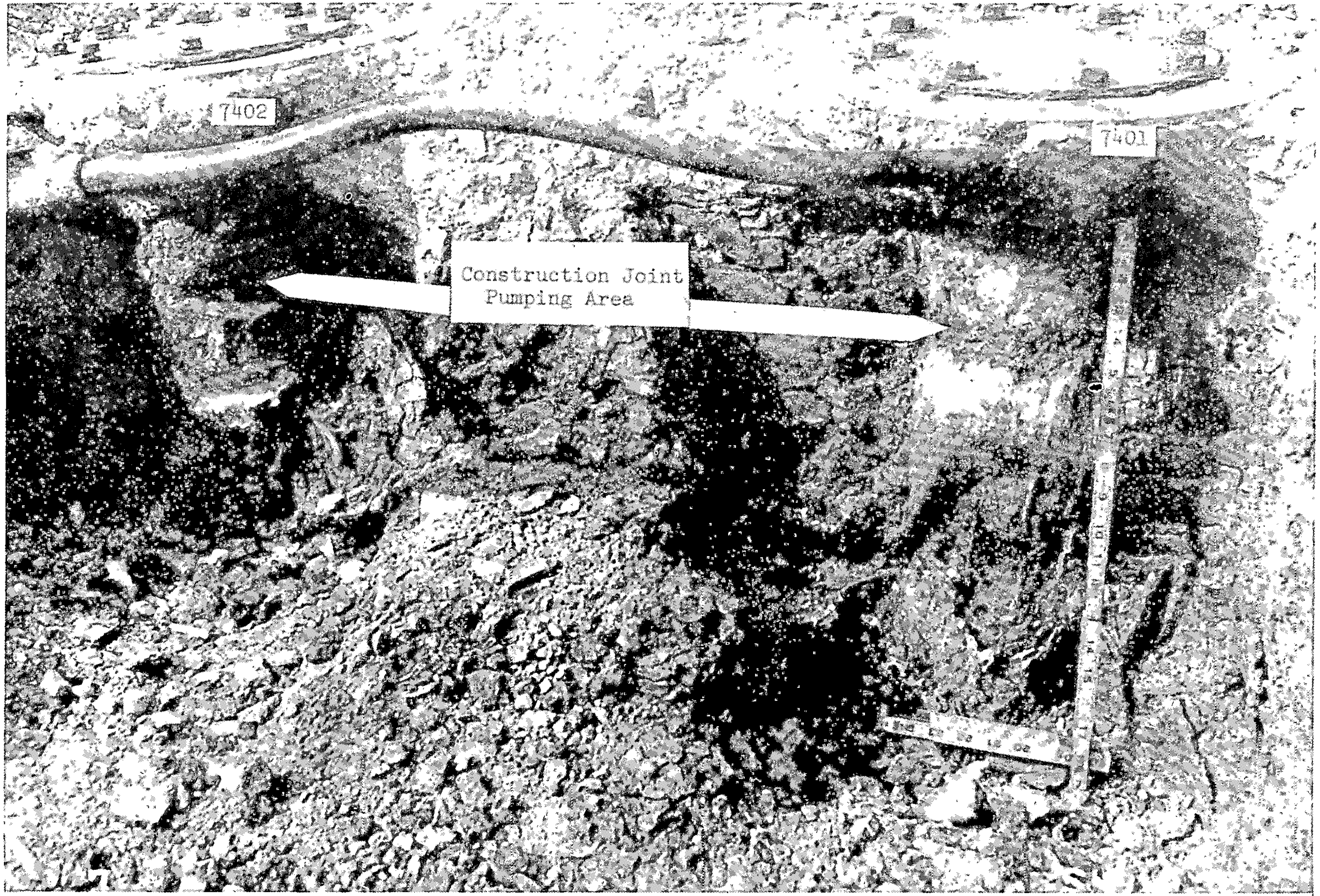


FIGURE E-20. TEST SECTION 7, EXCAVATION OF 7401 AND 7402

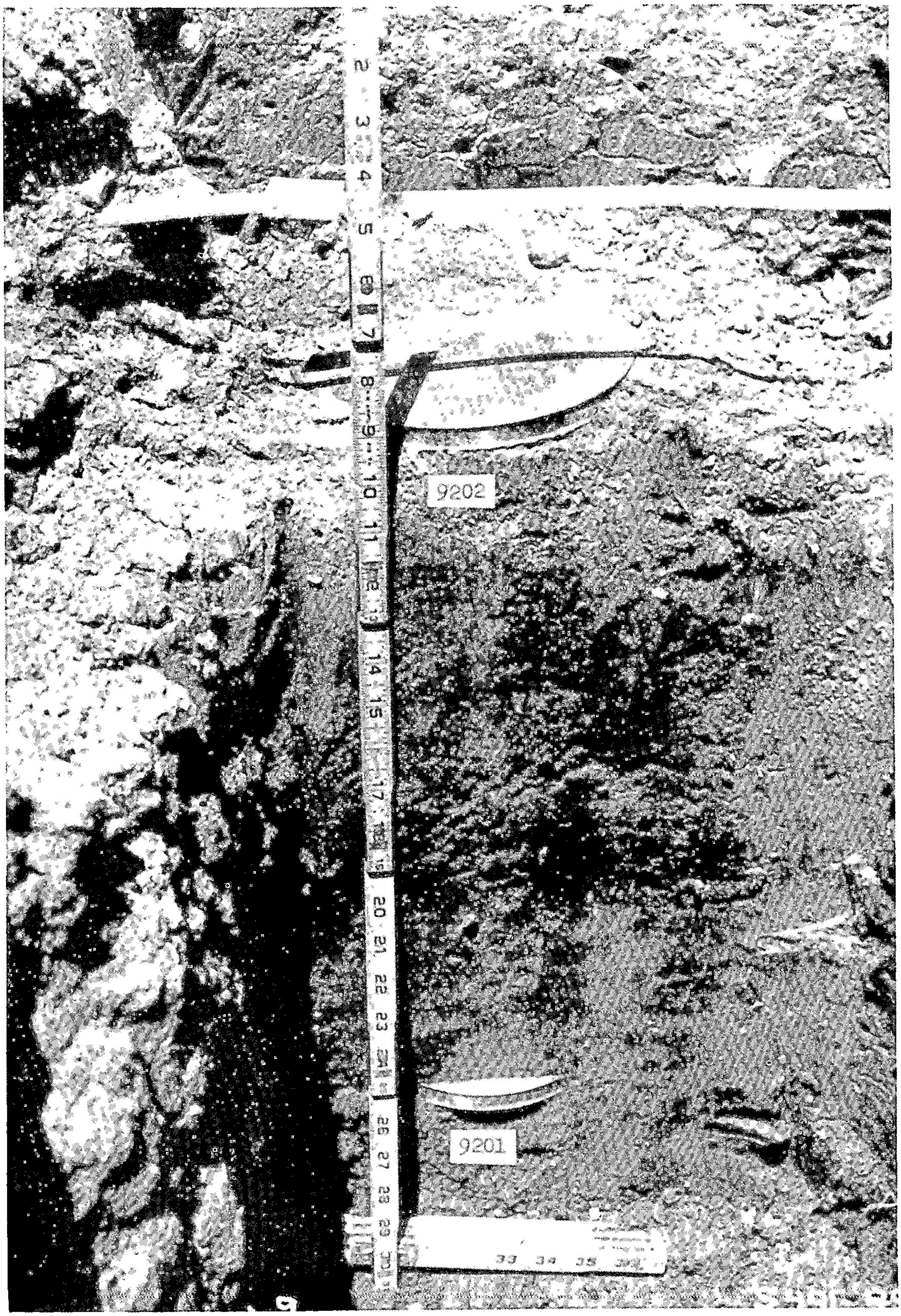


FIGURE E-21. TEST SECTION 9, PRESSURE CELLS 9201 and 9202

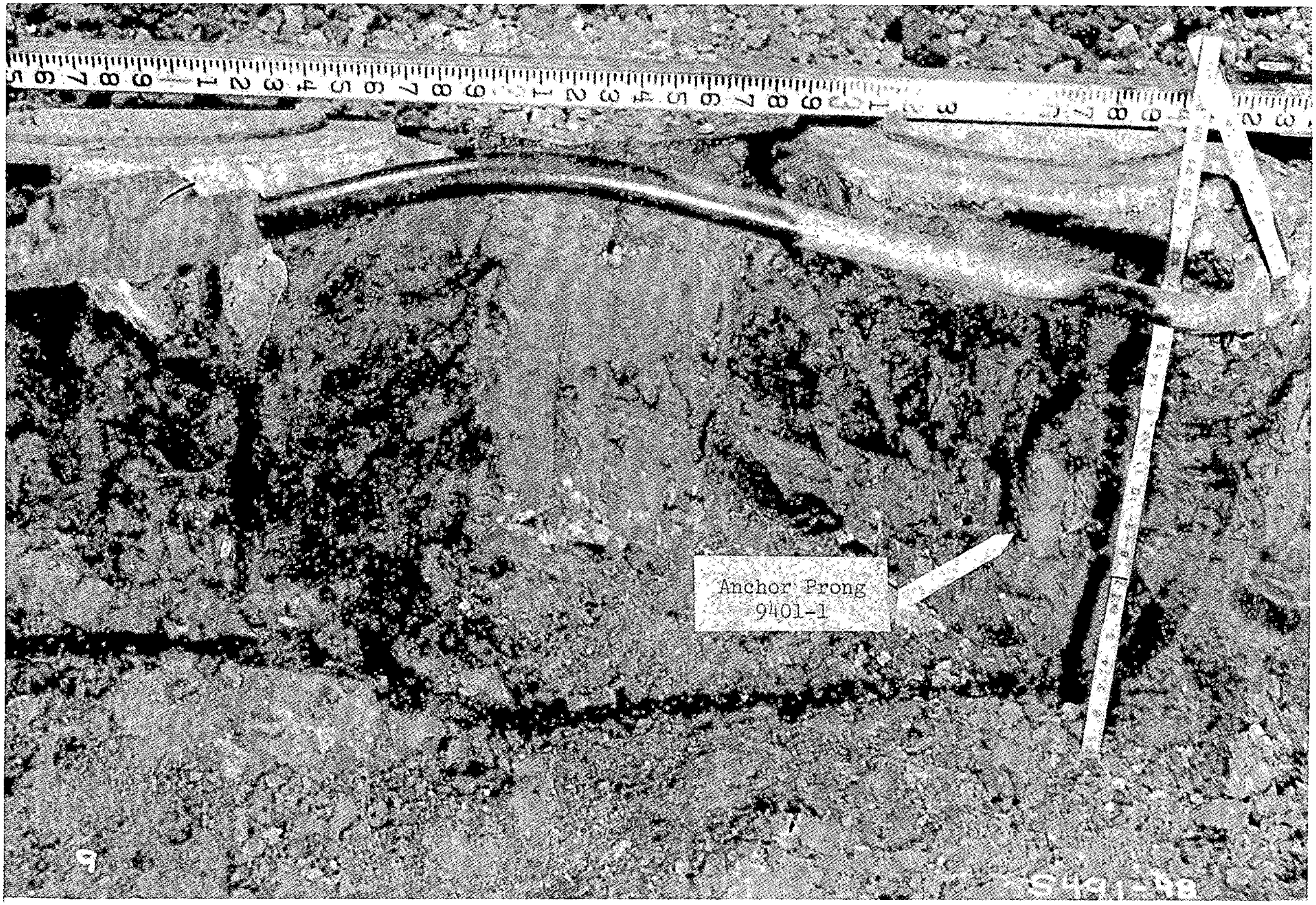


FIGURE E-22. TEST SECTION 9, EXTENSOMETER EXCAVATION

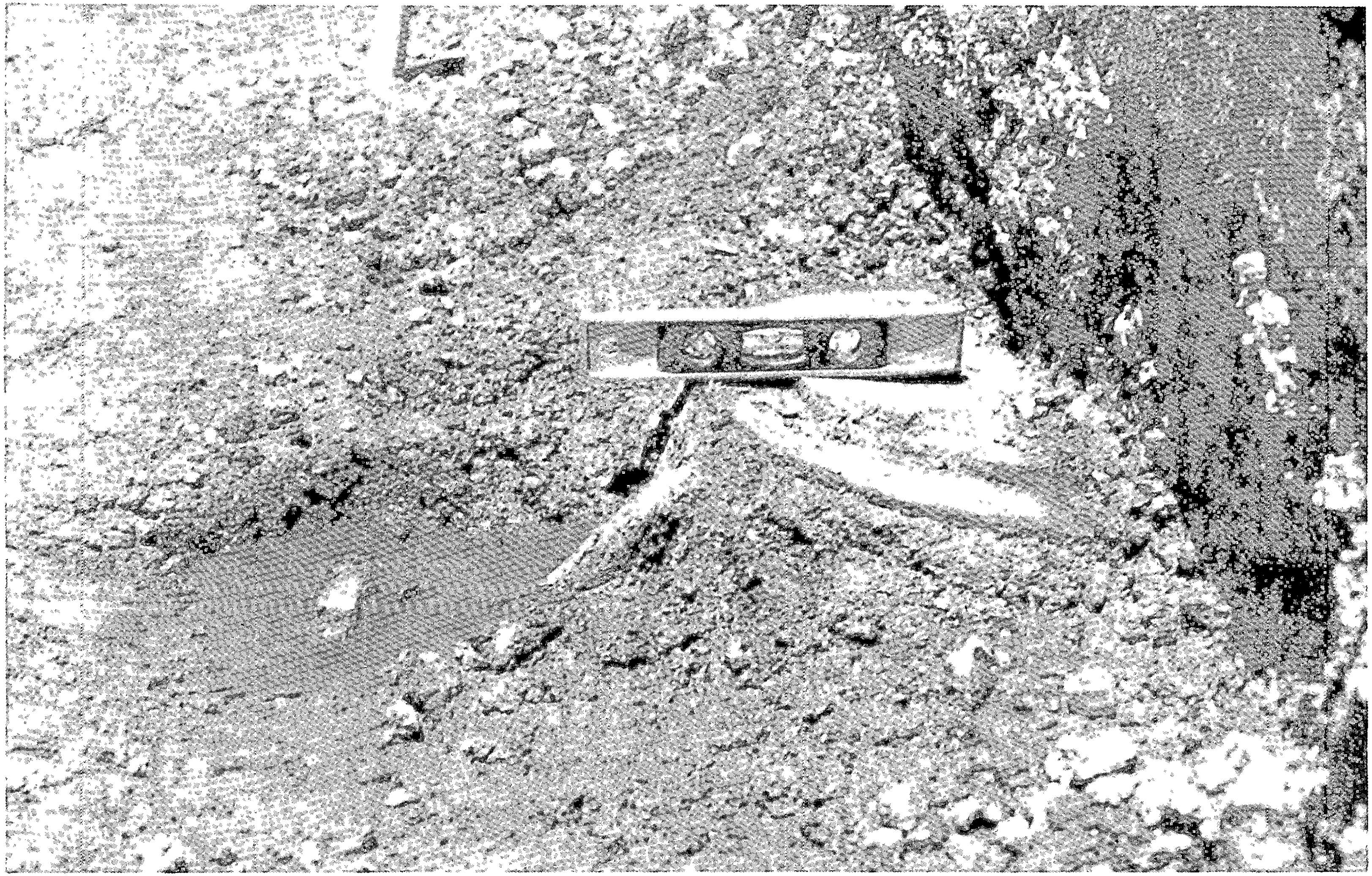


FIGURE E-23. EXTENSOMETER TERMINAL BOX EXCAVATION SHOWING TILT AND WATER SEEPAGE, TEST SECTION 9

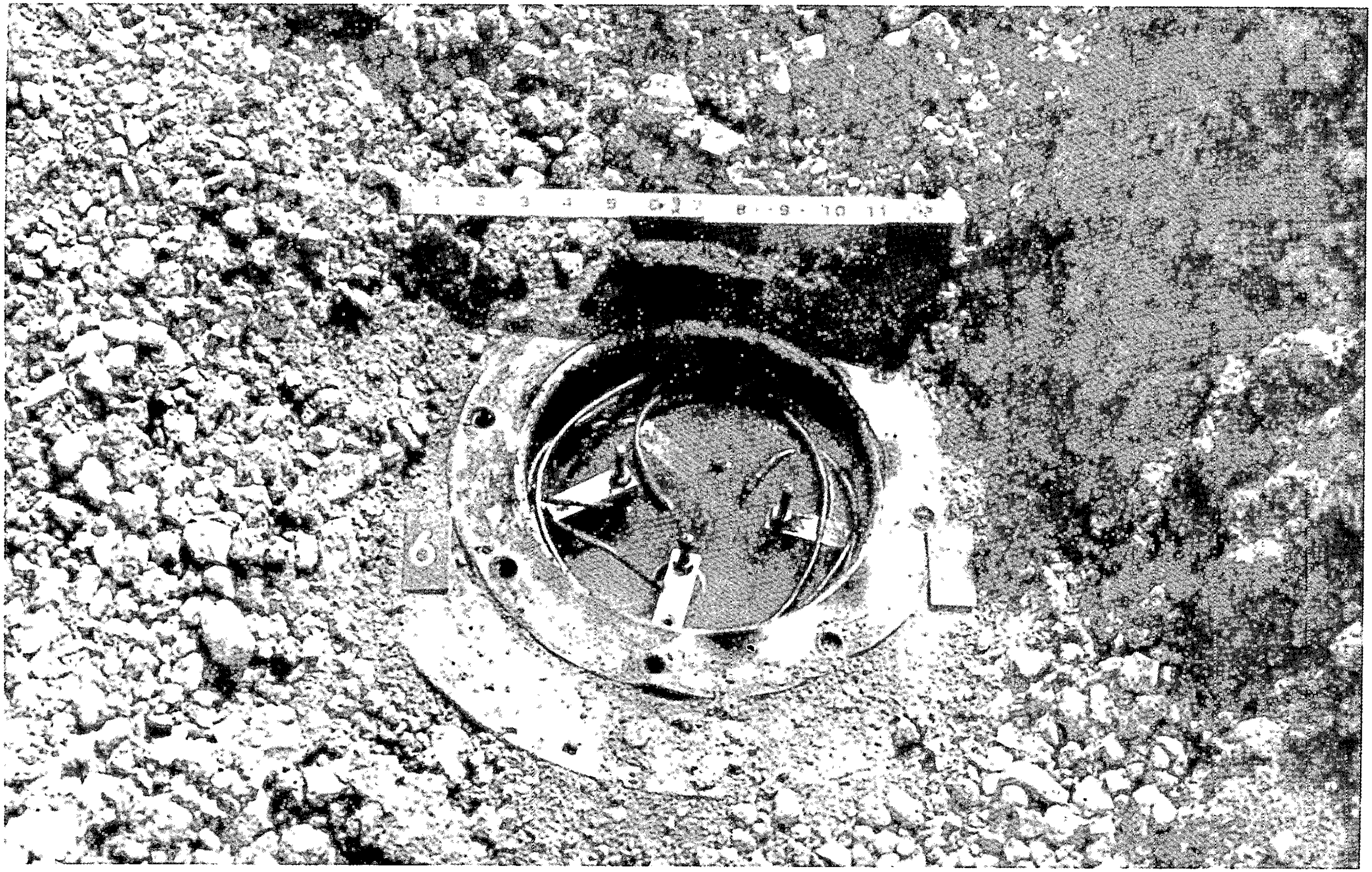


FIGURE E-24. TEST SECTION 6, FAILURE OF EXTENSOMETER 6402

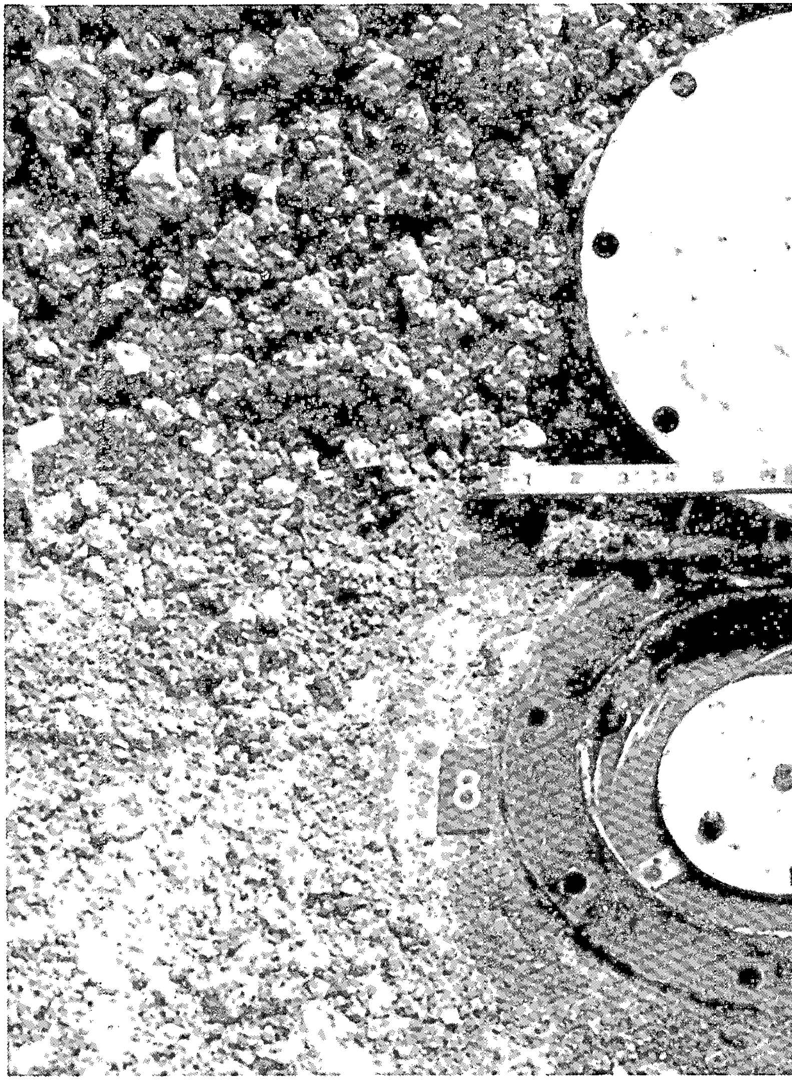
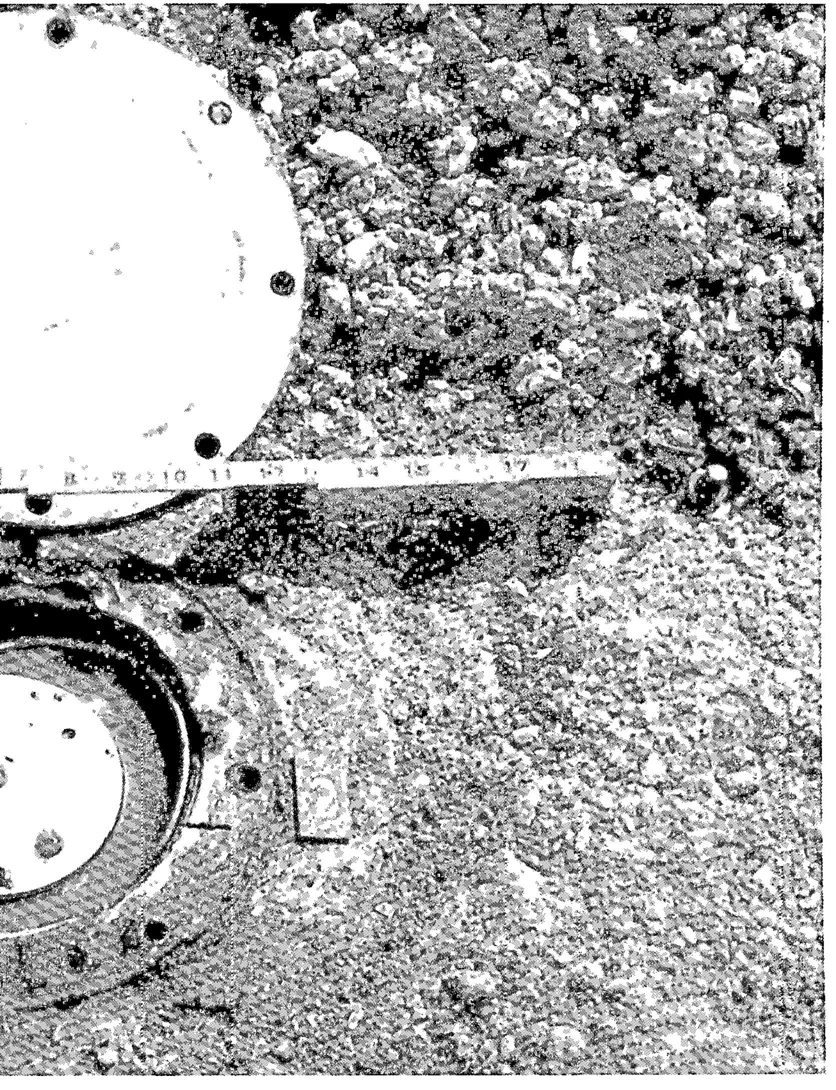


FIGURE E-25. TEST SECTION 8,



FAILURE OF EXTENSOMETER 8402

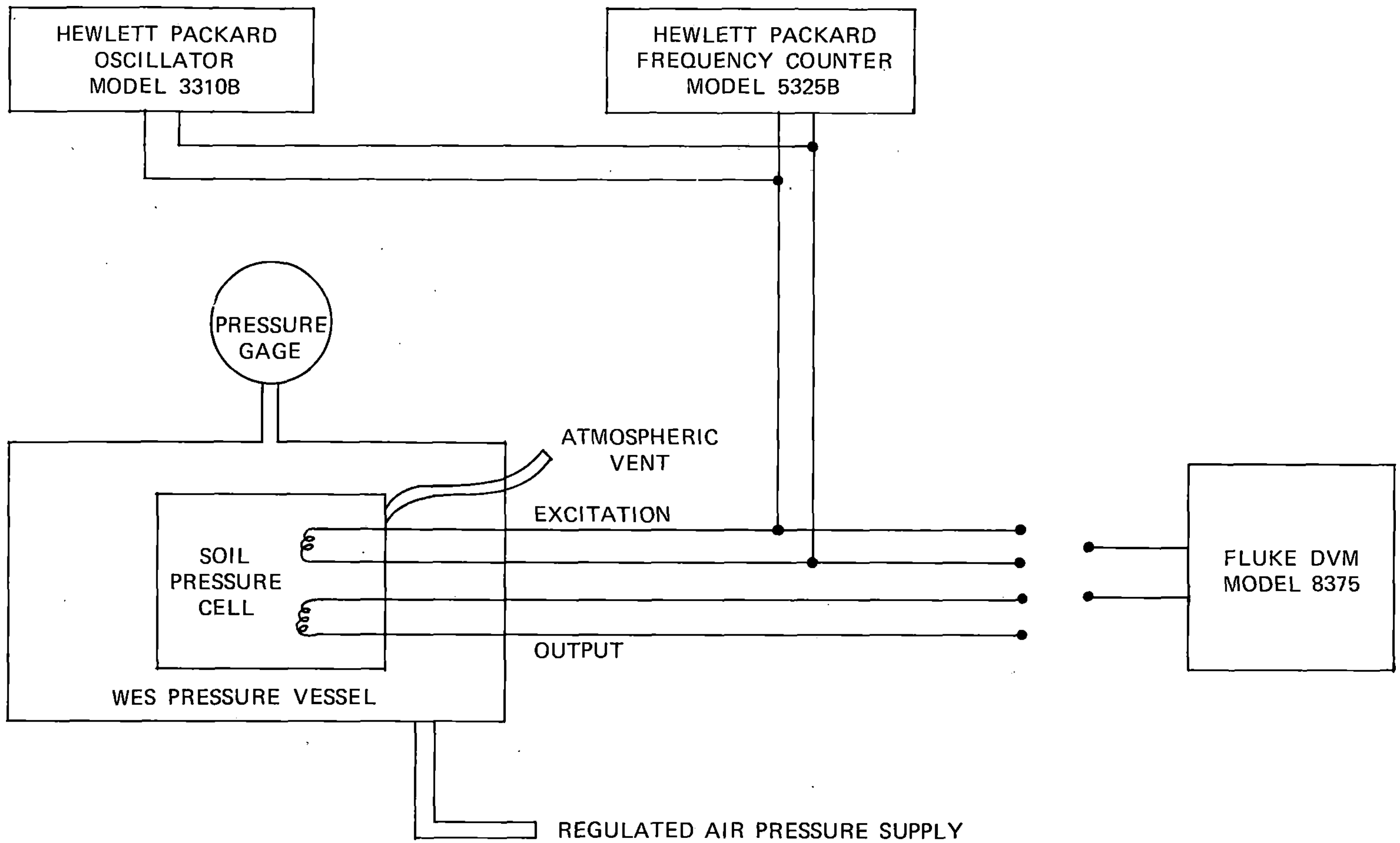


FIGURE E-26. CALIBRATION NETWORK FOR SLOPE INDICATOR COMPANY SOIL PRESSURE CELL

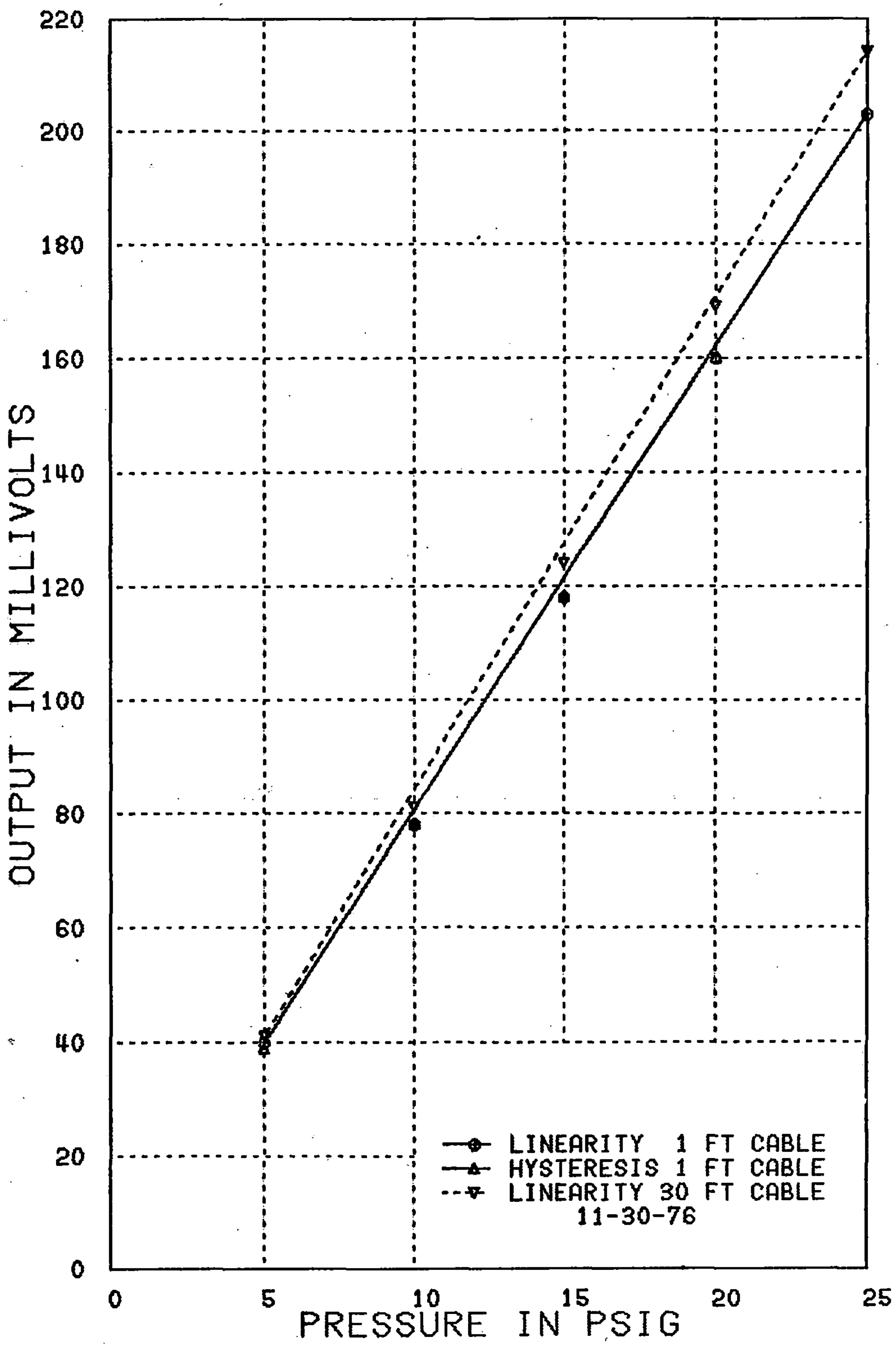


FIGURE E-27. POST EXCAVATION CALIBRATION,
SOIL PRESSURE CELL 9201

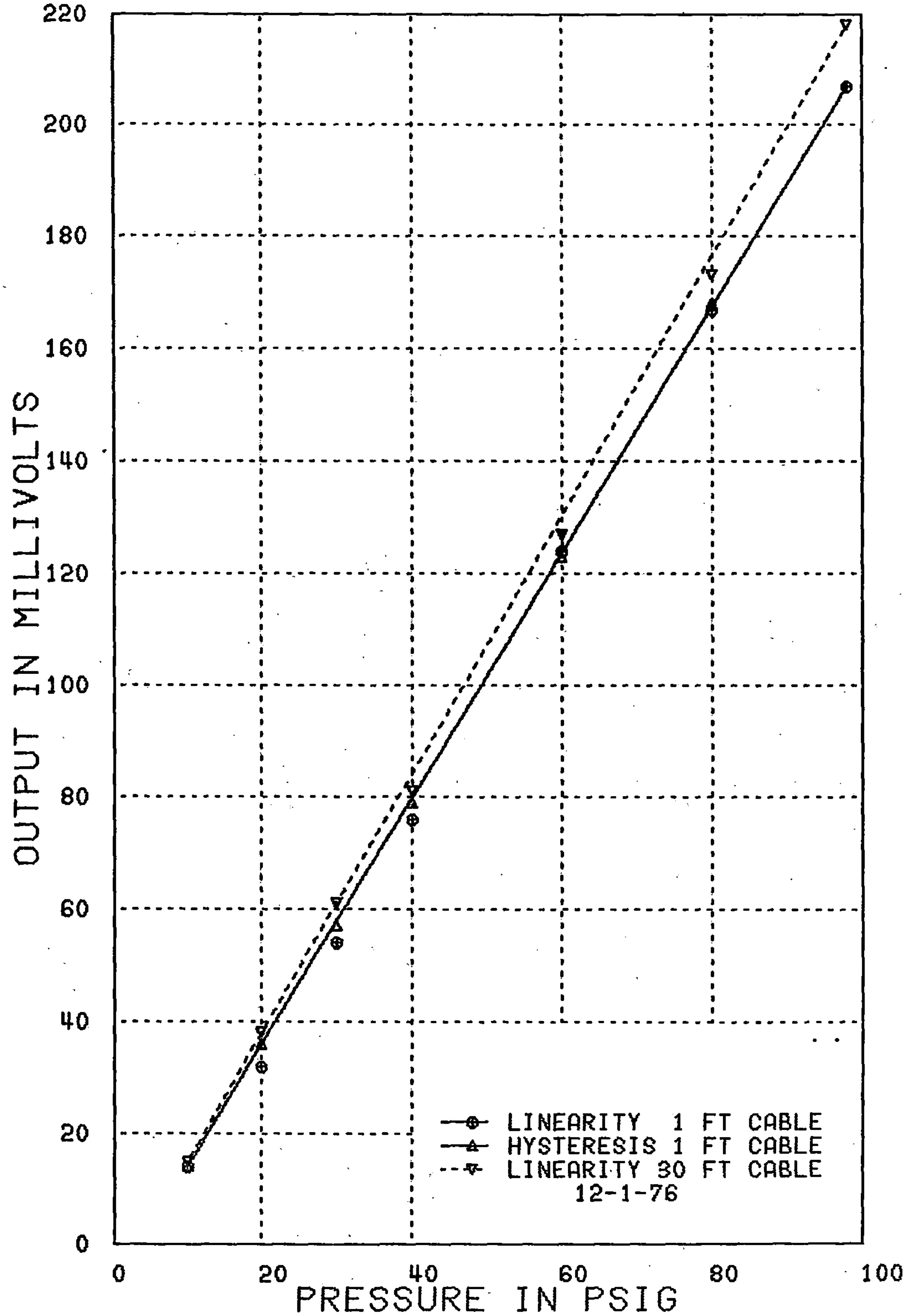


FIGURE E-28. POST EXCAVATION CALIBRATION, SOIL PRESSURE CELL 2203

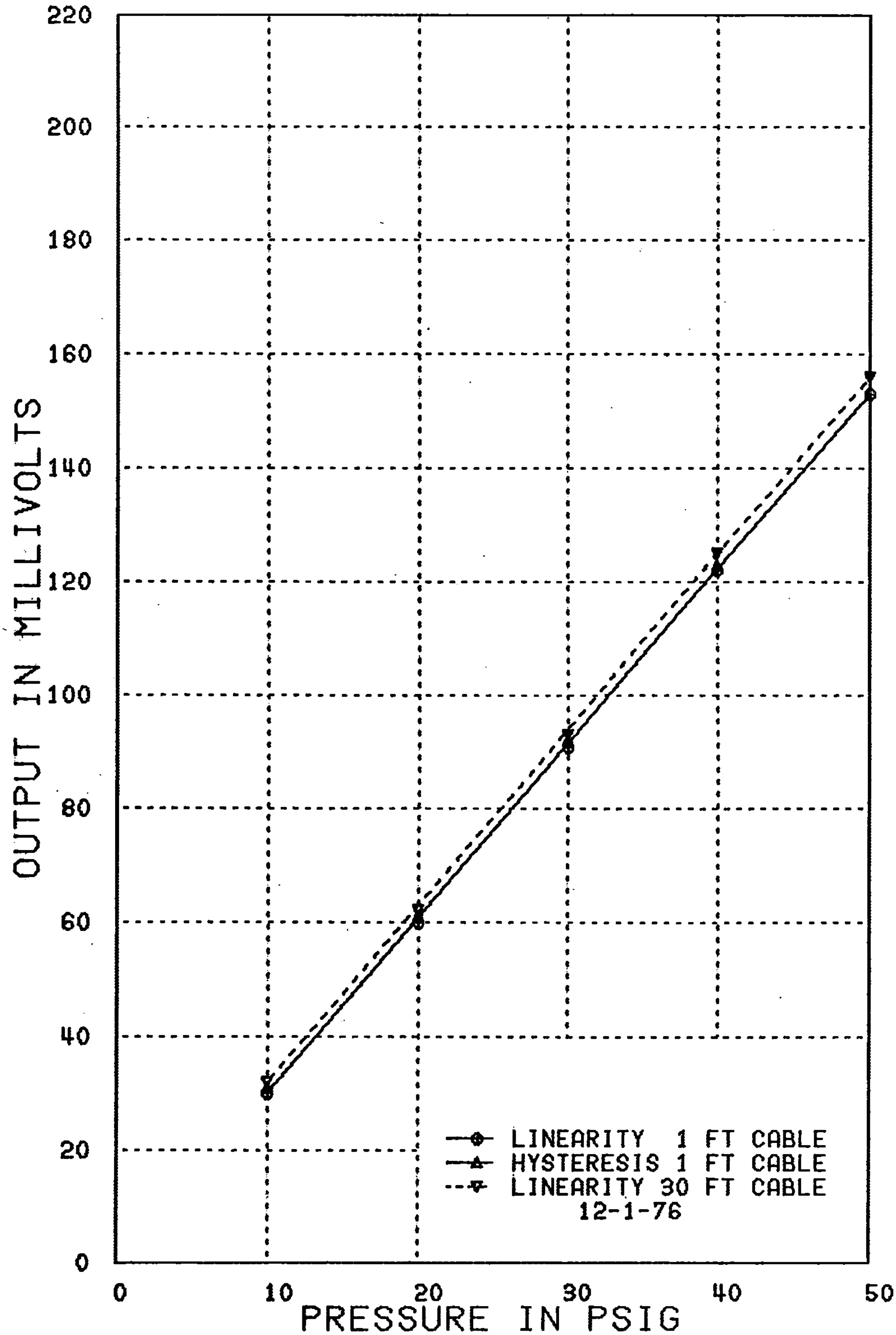


FIGURE E-29. POST EXCAVATION CALIBRATION,
SOIL PRESSURE CELL 7201

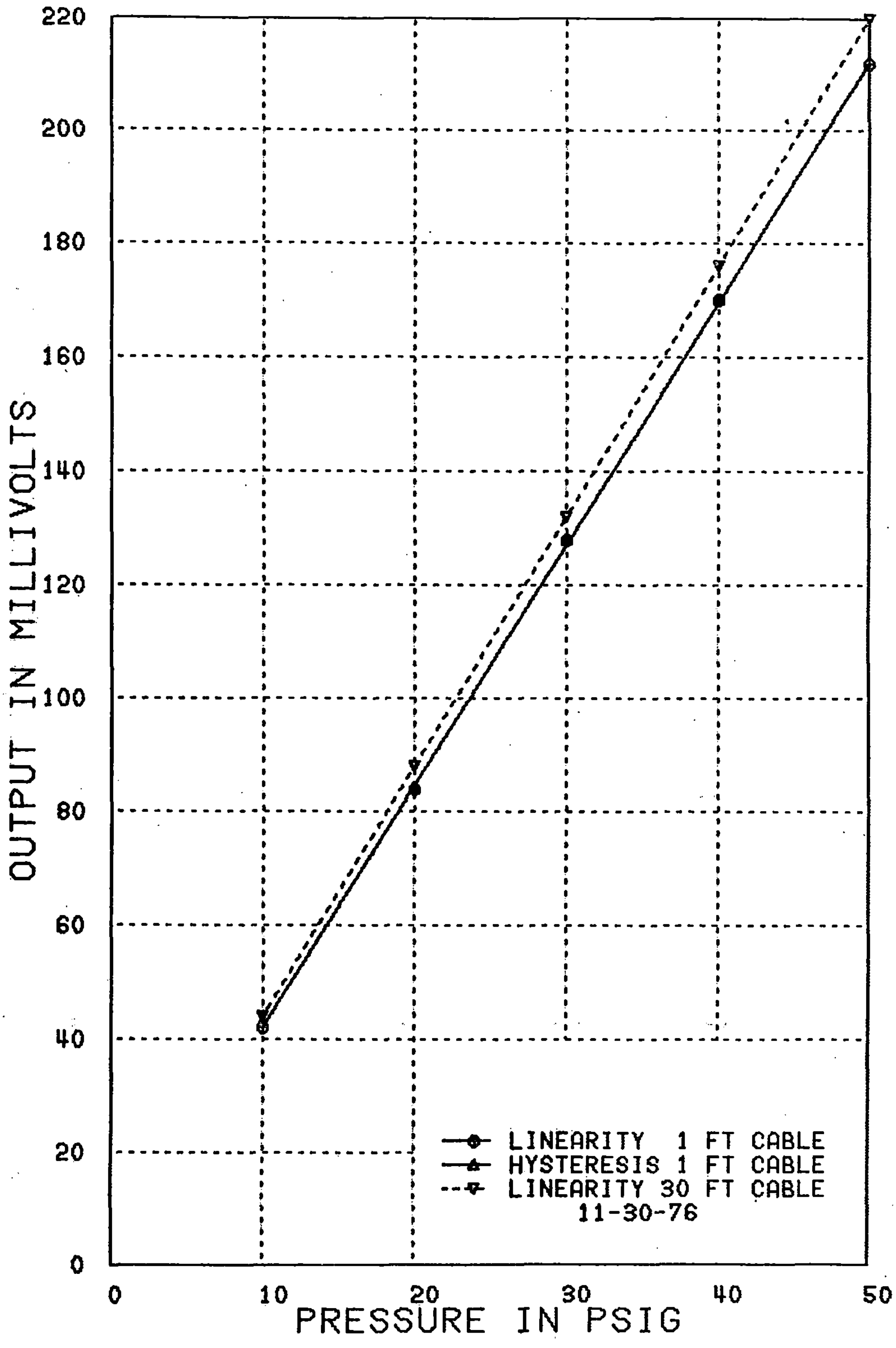


FIGURE E-30. POST EXCAVATION CALIBRATION,
SOIL PRESSURE CELL 7202

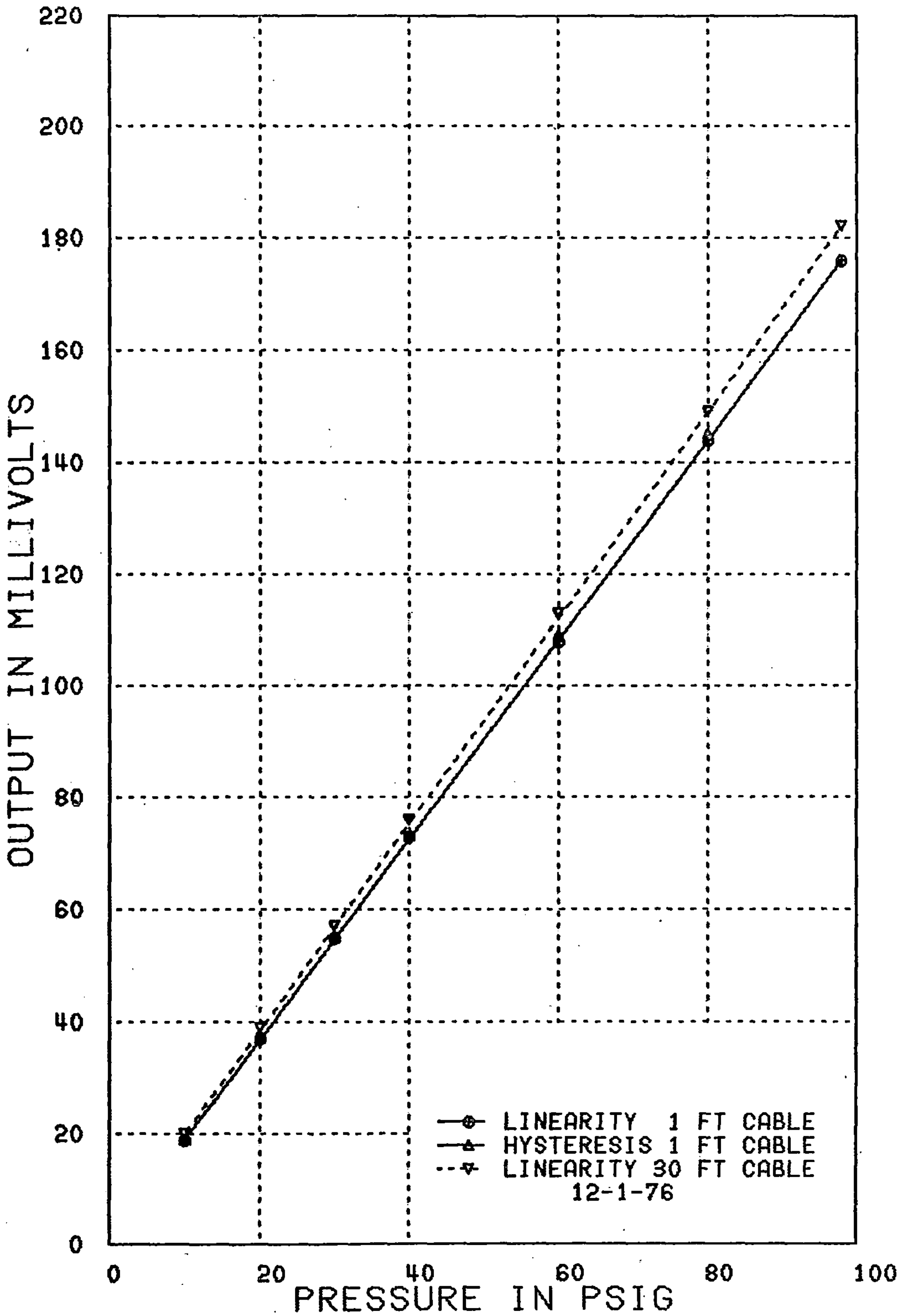


FIGURE E-31. POST EXCAVATION CALIBRATION, SOIL PRESSURE CELL 7203

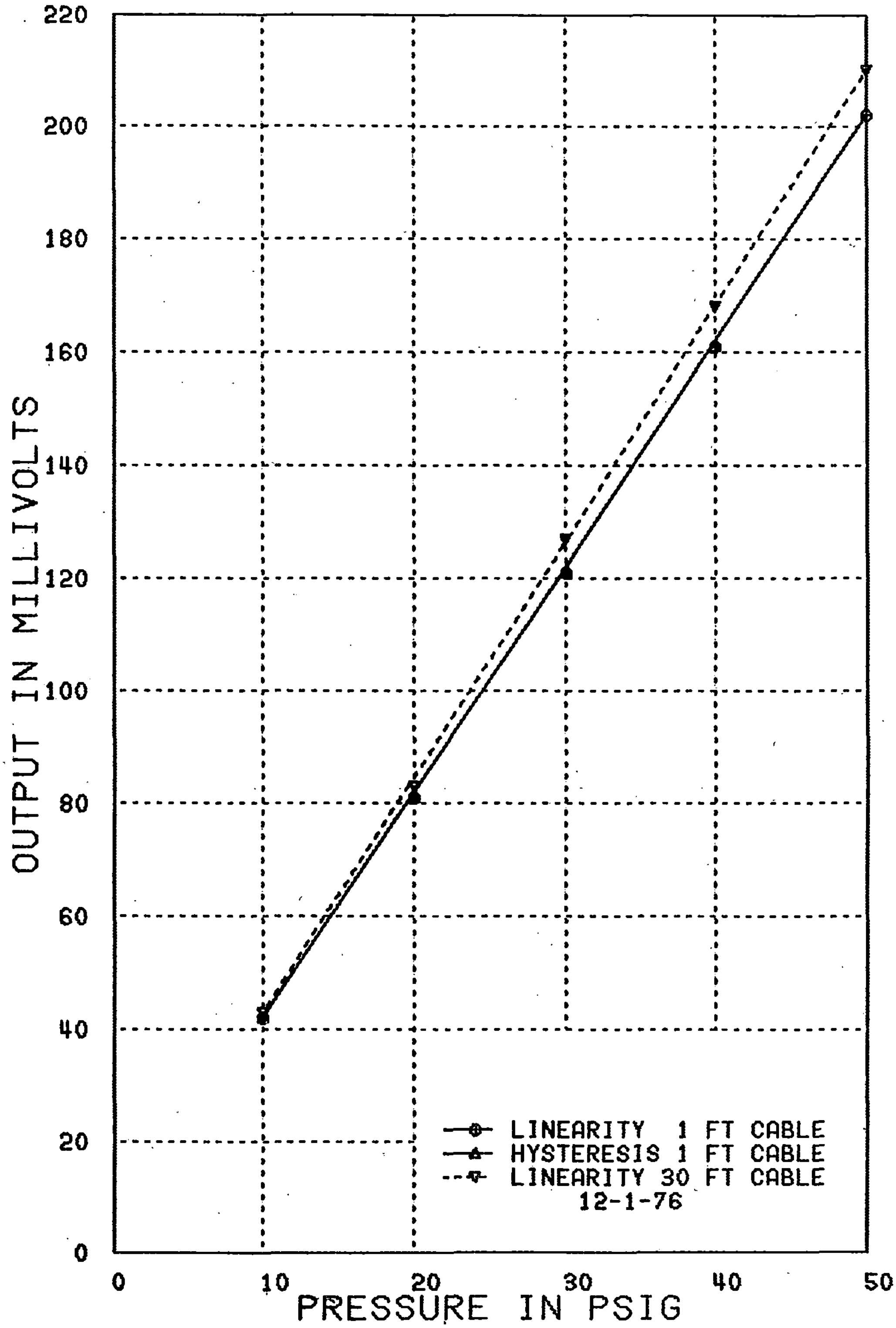


FIGURE E-32. POST EXCAVATION CALIBRATION, SOIL PRESSURE CELL 9202

SOILTEST, INC.
524 SOUTH BOULEVARD
BARABOO, WISCONSIN 53913

DIVISION OF SOILTEST, INC., EVANSTON, ILL.
SUBSIDIARY OF CENCO INCORPORATED
TELEPHONE 608/356-8777 • TELEX 265-455

REFER TO:

June 9, 1976

Department of the Army
Waterways Experiment Station, Corps of Engineers
P.O. Box 631
Vicksburg, Mississippi 39180

Dear Mr. Greer

RE: WESBP 20/1982

SUBJECT: Evaluation of Failure of (5) Soil Moisture Cells Returned to Soiltest.

Upon receipt of the (5) cells, we soaked them in a solution of isopropyl alcohol and tap water mixed at a ratio of approximately 100:1.

(Note: This solution is used because it is relatively safe, readily available, doesn't leave a residue, and yields a mid-range meter reading.)

In this test a known good cell from our stock was used as a reference.

Test Results In Alcohol-Water Solution read with a Soiltest MC-300B Soil Cell read out:

	Resistance	Temperature
Cell #1	230K	79°F
Cell #2	65K	77°F
Cell #3	1000K	80°F
Cell #4	200K	69.5°F
Cell #5	200K	78.5°F
Known good cell	11K	77°F

NOTE: Temperature readings were not corrected and are not expected to be precise due to evaporation of the alcohol.

At this point I talked to Homer C Greer, WES on June 7, 1976, and discussed our course of action in evaluating the defective soil cells.

It was decided that Soiltest, Inc. would analyze the cells free of

FIGURE E-33. LETTER REPORT FROM SOILTEST, INC., TO WES CONCERNING DEFECTIVE SOIL MOISTURE CELLS charge and submit a report to W.E.S. of our findings.

In a subsequent phone conversation on June 8, 1976, I was informed by Mr. Greer that the defective cells had been buried in the roadbed ballast of a railroad in Kansas.

This information, coupled with the results of Dr. Oestings report led us to the following conclusion.

The cells' outer shells were plated with copper, while the pores in the electrode spacer fabric were plugged by a non-conducting substance, probably a petroleum based substance such as diesel fuel or weed killer. Positive tests could not be conducted because of the initial alcohol bath.

Electric current for the plating could have come from several possible sources:

1. Galvanic currents produced by a chemical reaction between the steel rails and chemicals present in the roadbed ballast.
2. Current flow between the rails
   a. Current used for signal devices.
   b. Inter-rail current flow from the electric drive motors used in modern diesel engines.

Suggestion:

If roadbed measurements are necessary, we suggest that a representitive abandonded roadbed be choosen. Preferably one that has not been contaminated by unknown materials. Such a roadbed might be a spur line into a quarry.

Please feel free to reprint this report.

Sincerely,

M. B. Powell

M. B. Powell
Customer Service Manager

enclosure

FIGURE E-33. (CONTINUED)

June 9, 1976

To: M. B. Powell
From: R. B. Oesting
Subject: Moisture Cells

I examined two moisture cell units and found copper plated on the surfaces of them. There was no evidence of corrosion or of any other deposit being present. Iron was absent from these surface deposits.

Further test on the glass cloth spacer removed from a faulty cell showed traces of an organic compound. This test was run after immersion of the cell in alcohol and no more detailed conclusion is possible. The organic compound was not isopropyl alcohol but was some high molecular weight residue.

R. B. Oesting

R. B. Oesting PhD.
Professor of Chemistry
University of Wisconsin

FIGURE E-33. (CONCLUDED)

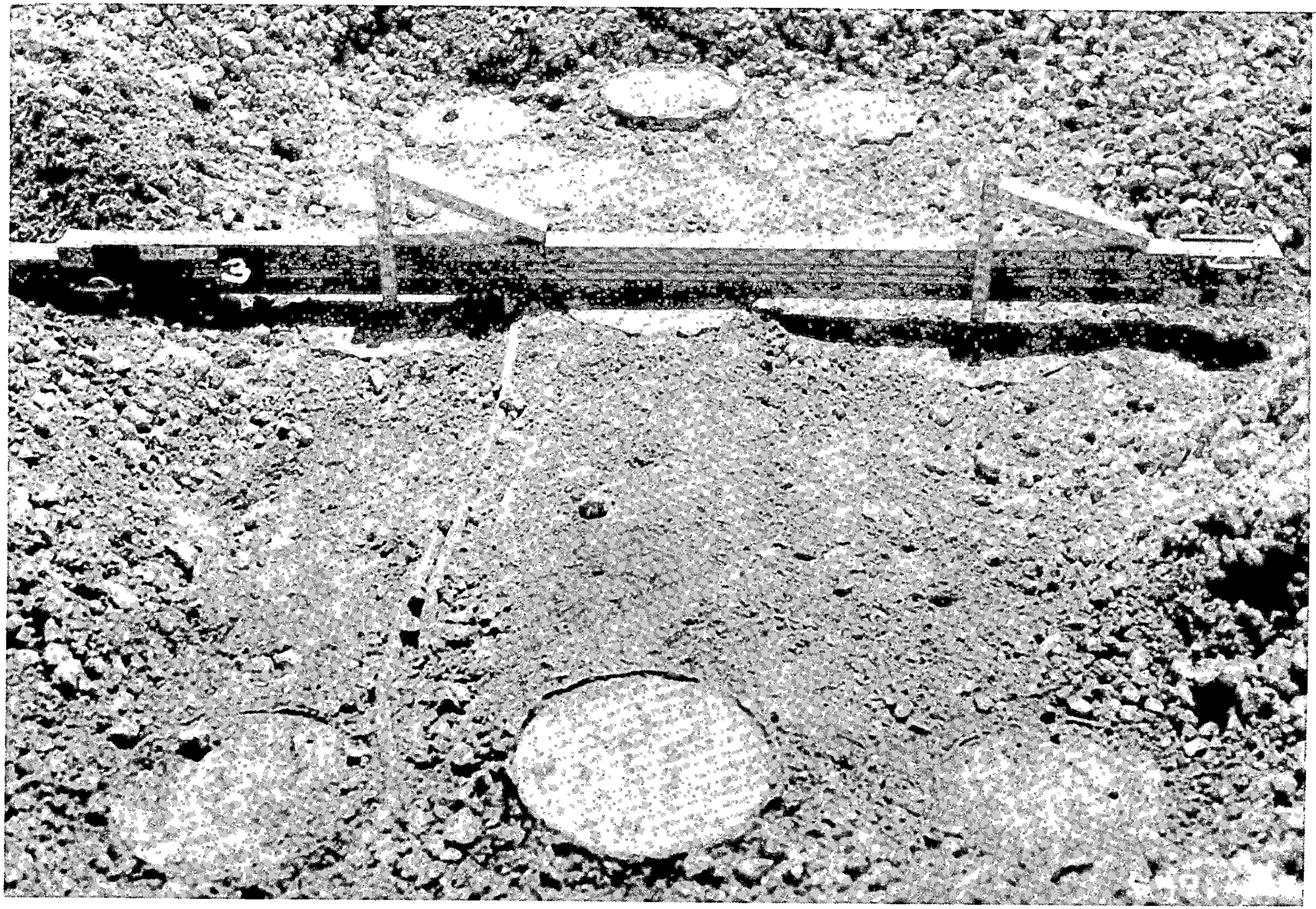


FIGURE E-34. DIFFERENTIAL SETTLEMENT IN PCA PRESSURE CELL ARRAY, TEST SECTION 3

FIGURE E-35. PCA PRESSURE CELL IN CLOSE PROXIMITY TO REINFORCING BAR, TEST SECTION 7

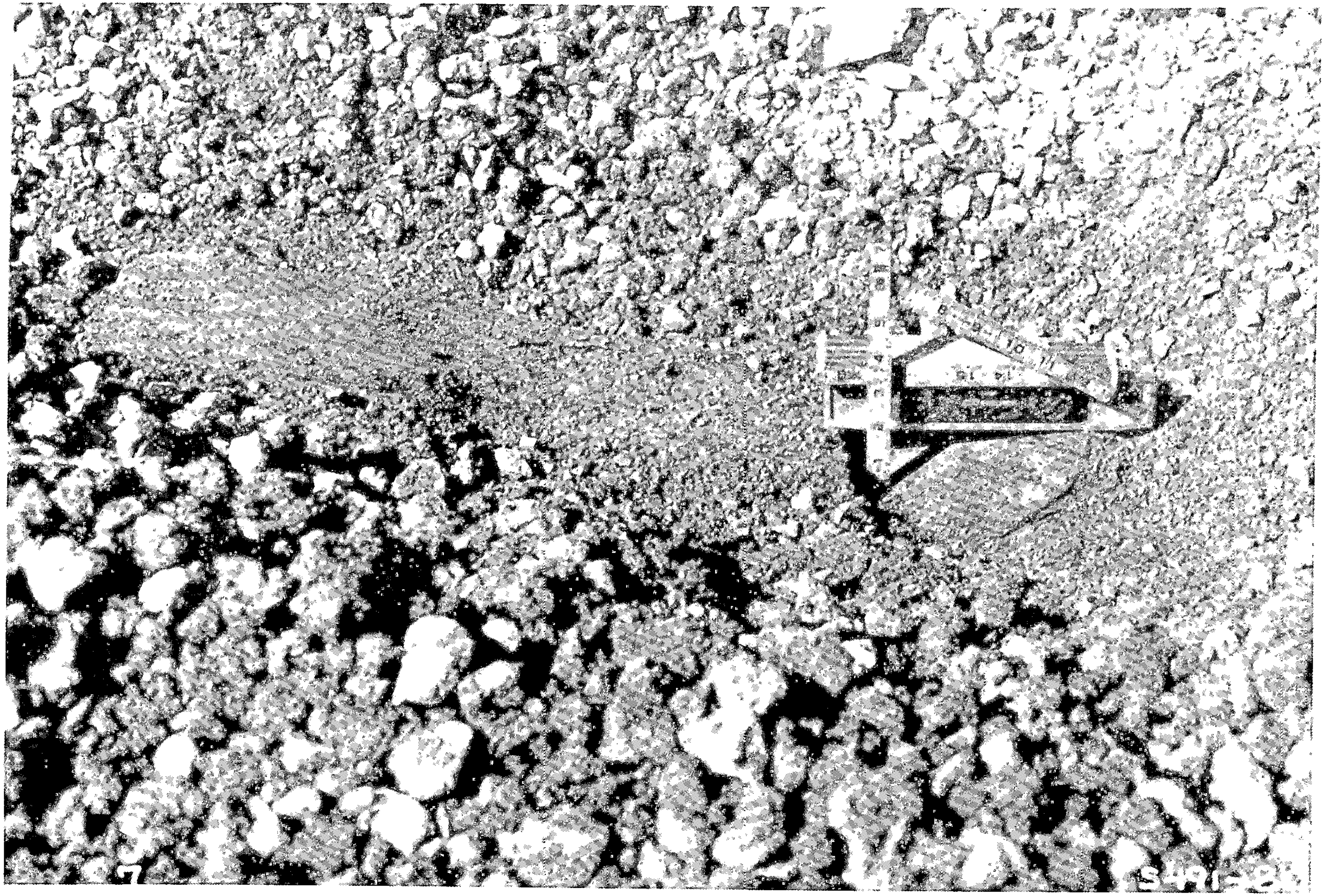
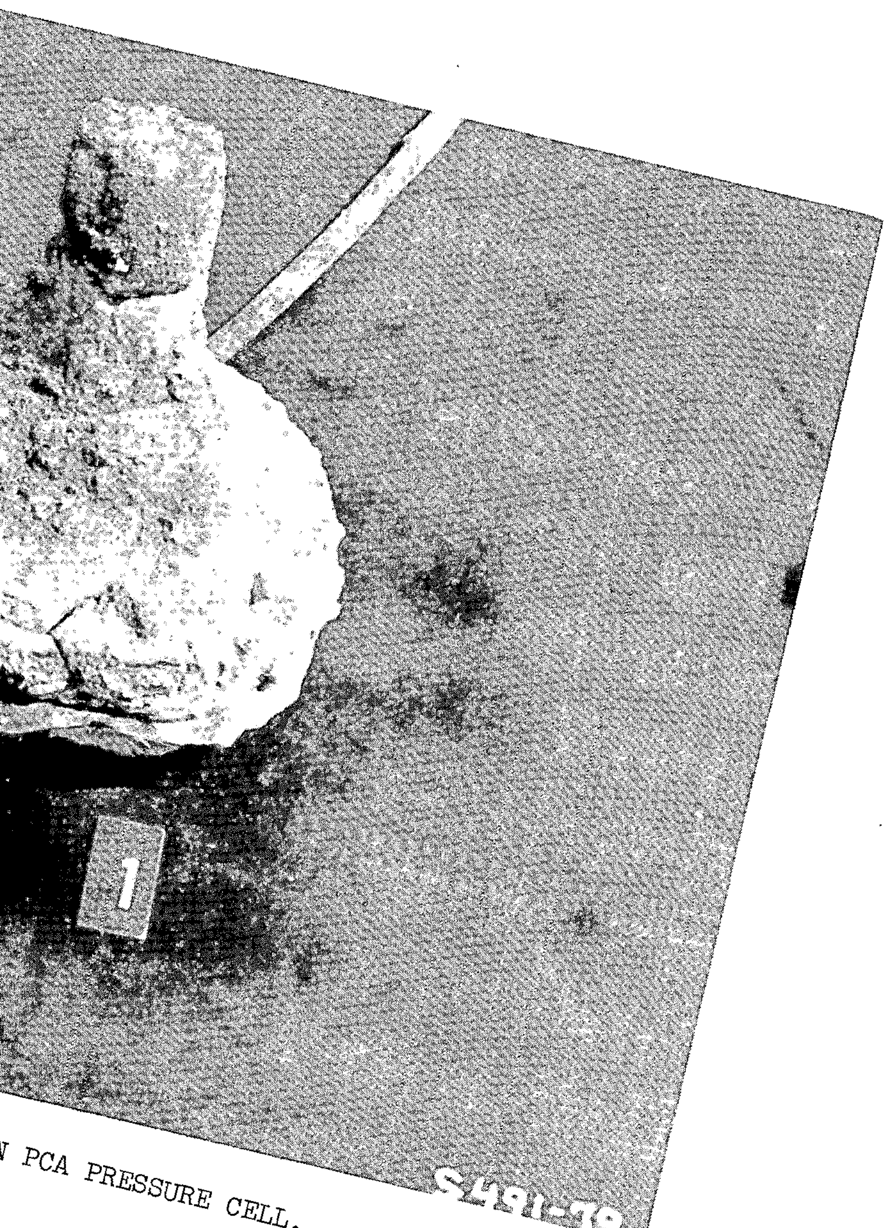


FIGURE E-36. WOODEN WEDGE DRIVEN AGAINST PCA PRESSURE CELL, TEST SECTION 7



N PCA PRESSURE CELL,

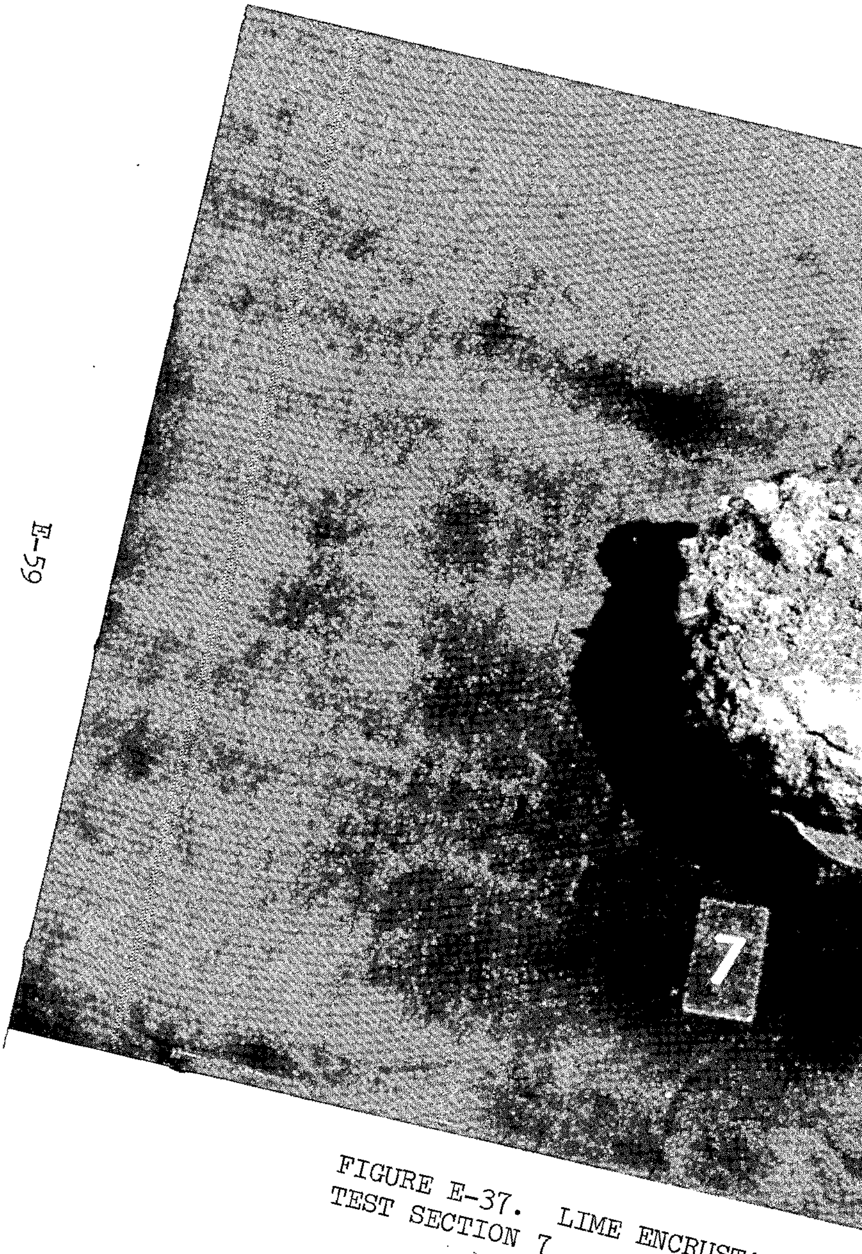


FIGURE E-37. LIME ENCRUSTATION ON
TEST SECTION 7

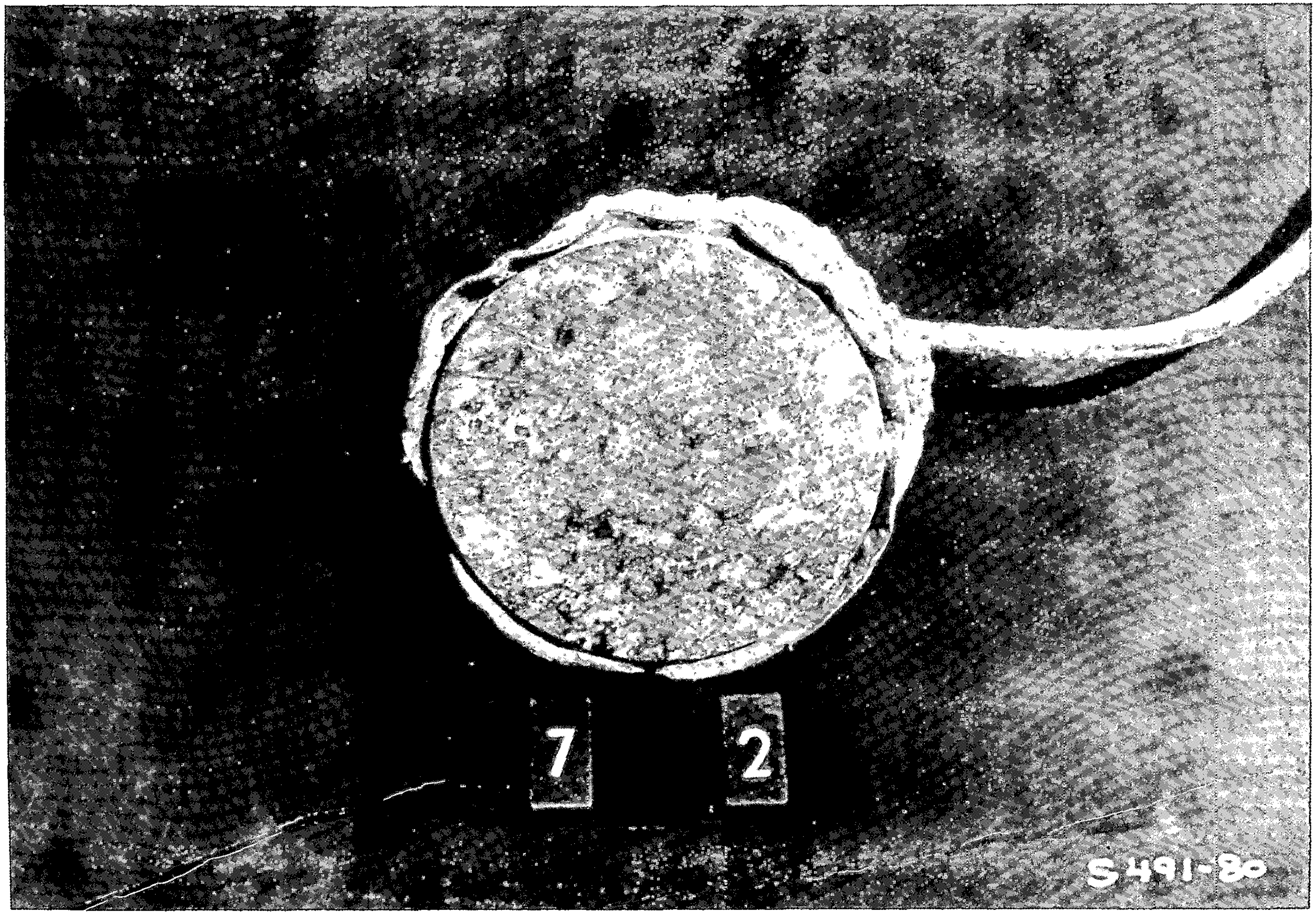


FIGURE E-38. DAMAGE TO CORK LINER AROUND SIDES OF PCA PRESSURE CELL, TEST SECTION 7

*U.S. GOVERNMENT PRINTING OFFICE: 1979 633-819/479 1-3

Post Mortem Investigation of the Kansas Test Track, Part II, 1979
US DOT, FRA

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FEDERAL RAILROAD ADMINISTRATION
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