Research Report
UKTRP-86-24

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Kentucky Transportation Research Program
College of Engineering
University of Kentucky
Lexington, Kentucky

in cooperation with
The Dravo Lime Company

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INTRODUCTION

The purposes of this study were to evaluate the effects of hydrated lime on the soils from Section AA-19 of the Alexandria-Ashland Highway and determine if the engineering properties of the soils from Section AA-19 could be improved by lime stabilization. Soil samples used in the study were obtained by the Kentucky Transportation Research Program on March 25, 1986. Three bag samples were collected from Section AA-19 (Lewis County, Kentucky) of the Alexandria-Ashland Highway, Stations 1630 (Sample A), 1495 (Sample B), and 1675+50 (Sample C), respectively. Based on a review of the geology of Section AA-19, the three sampling sites are directly underlain by the Crab Orchard Formation.

The study was authorized by contract dated April 4, 1986 (Purchase Order No. ML86-1248), between the Kentucky Transportation Research Program, College of Engineering, University of Kentucky, and the Dravo Lime Company of Maysville, Kentucky. Authorization to proceed with the work was given by Mr. Ward Blakefield of the Dravo Lime Company. The scope and specific engineering services to be performed are outlined in the purchase order contract. Preliminary test results (1) were submitted to the Dravo Lime Company on July 30, 1986.

TESTING PROGRAM

INDEX TESTS AND MOISTURE-DENSITY RELATIONSHIPS

The testing program consisted of determining some engineering properties of the soil samples in an untreated, or natural, state and in a state treated by hydrated lime. The hydrated lime (Black River) used for treatment was submitted by the Dravo Lime Company. The laboratory study consisted of performing liquid and plastic limit tests, specific gravity tests, particle-size analyses, classifications, visual descriptions, moisture-density relationships, California Bearing Ratio (CBR) tests and unconfined compression tests on untreated and treated specimens. Liquid and plastic limit tests were performed according to procedures of ASTM (American Society for Testing and Materials) D 423-66(72) and ASTM D 424-59(71). Particle-size analysis determinations were made according to procedures of ASTM D 421-58(78) and ASTM D 422-63(72). Specific gravity tests were performed according to ASTM D 854-58(79). The soil samples were classified using the Unified Soil Classification System, ASTM D 2487-69(75), and the AASHTO Classification System (M 145-82). Moisture-density relationships were determined according to ASTM D 698-78, Method A.

BEARING RATIO

California Bearing Ratio tests (CBR) were performed using two slightly different procedures. A few tests were performed following procedures of ASTM D 1883-73(1978). The second set of bearing ratio tests were performed following procedures (2) of the Kentucky Method (KM-64-501-76). In the

ASTM CBR procedure, specimens are compacted dynamically at maximum dry density and optimum moisture content, as determined from ASTM D 698-78. In the Kentucky method, CBR specimens were molded using the values of optimum moisture content and maximum dry density, as determined from ASTM D 698-78. However, static compaction was used to mold the specimens (according to KM-64-501-76). A static pressure of 2,000 pounds per square inch (psi) was maintained on the specimens for 2 minutes during the compaction stage. In the ASTM procedure, the CBR specimens are soaked (immersed) in a water tank for 96 hours. In the Kentucky method, the CBR specimens are placed (immersed) in a water tank and allowed to absorb water until consecutive swell deflection readings are equal to or less than 0.003 inch; however, specimens are soaked a minimum time of 72 hours. Hence, in the Kentucky method, the CBR specimens are allowed to soak until swell ceases. In the ASTM method, swell of the specimen may still be in progress when the specimen is removed from the water tank after 96 hours. Generally, based on past studies (3, 4), the final dry densities and moisture contents of the Kentucky CBR specimens after soaking and the completion of swell are slightly higher and lower, respectively, than maximum dry densities and optimum moisture contents as determined by ASTM D 698-78. In both bearing tests, penetration values, as recorded in the test, are 0.100, 0.200, 0.300, 0.400, and 0.500 inches. In the ASTM bearing ratio test, the CBR-value normally reported is the one occurring at 0.100-inch penetration. In the Kentucky method, the minimum CBR-value occurring at one of the five penetration values is normally reported.

PERCENTAGE OF LIME

The percentage of lime to be added to the soil samples was provided by personnel of the Dravo Company. This was determined from pH tests performed on the three samples by the Dravo Company. These test data are summarized in Table 1. Dravo personnel recommended a value of six percent. Accordingly, all treated specimens were mixed with six percent hydrated lime. The treated lime-soil specimens were prepared following procedures of ASTM D 3551-76 (Laboratory Preparation of Soil-Lime Mixtures Using a Mechanical Mixer). For treated specimens, a one-hour mellowing period was used.

UNCONFINED COMPRESSIONS

Unconfined compression tests were performed on treated and untreated remolded specimens following procedures in ASTM D 2166-66 (1972). Six tests were performed on treated specimens after various curing times. One test was performed on an untreated specimen about 1 day after molding. Another test was performed on an untreated specimen 14 days after molding. All specimens were sealed tightly to prevent the loss of water during curing periods.

TEST RESULTS AND ANALYSIS

INDEX PROPERTIES AND MOISTURE-DENSITY RELATIONSHIPS

Index test data and classifications of the untreated and treated soils are summarized in Table 2 and Appendix A. The three untreated bag samples, A (station 1630+00), B (station 1495+00), and C (station 1675+50), obtained from Section 19 of the AA-highway classified as MH-CH, CH, and MH-CH, respectively, according to the Unified Soil Classification System. Based on the AASHTO System, the samples classified as A-7-5(40), A-7-5(44), and A-7-5(32), respectively. The soils had relatively high plasticity indices. The plasticity indices ranged from 29 to 37 percent as shown in Table 3. Liquid limits of the soils ranged from 61 to 71 percent. Specific gravities ranged from 2.80 to 2.97. The percentage of soil passing the No. 200 sieve ranged from 92.8 to 94.4 percent. The soils are brown to greenish gray in color and are fat (slightly silty) clays. The clays are alkaline, as shown in Table 1.

The treated specimens (A, B, and C) classified as SM and ML and A-4 and A-2-4 as shown in Table 2 and Appendix A. Treatment with six percent lime transformed the natural, fine-grained, silty clays into silty sands. The percent passing the No. 200 sieve and the percent finer than the 0.002mm-size are reduced considerably after treatment with lime. Particle-size curves of treated and untreated soils are compared in Appendix A. In all cases, the liquid and plastic limits of the natural clays are reduced significantly after treatment. The notable change occurs in the plasticity indices. The plasticity indices of the treated specimens are only about 5 to 16 percent of the plasticity indices of the untreated specimens. Hence, treatment with lime improves the engineering characteristics of the clayey soils.

Moisture-density relationships of treated and untreated specimens (A, B, and C) are compared in Table 3. Moisture-density curves of the treated and untreated samples are shown in Appendix B. Treatment of the natural clays with lime yielded optimum moisture contents and maximum dry densities that were higher and lower, respectively, than optimum moisture contents and dry densities of the untreated soils.

BEARING RATIOS

Based on the ASTM bearing ratio test, the soaked CBR-values of untreated specimens A, B, and C were 3.3, 2.7, and 0.8, respectively, as shown in Table 4. Soaked ASTM bearing ratio values of specimens A, B, and C, which had been treated with six percent hydrated lime, were 38.0, 30.3, and 8.0, respectively. Bearing ratio values of the lime-treated clays were some 10 to 11 times higher. Kentucky CBR tests were performed only on Sample A from station 1630+00. The soaked minimum Kentucky CBR-value of Specimen A without lime treatment was 2.6. This value occurred at 0.5-inch penetration. At 0.1-inch penetration, the soaked Kentucky CBR was 3.7 for the untreated soil. Minimum soaked KYCBR-values of specimens of Sample A treated with six percent hydrated lime ranged from 7.1 to 42.4, as shown in Table 4. These values occurred at 0.5-inch penetration. Curing times at room temperature (before immersion in

the water tank) varied from zero to 14 days. At 0.1-inch penetration, the KYCBR-values were 32.3, 58.0, 59.5, and 137.3 percent, which corresponded to curing times of 0, 3, 7, and 14 days, respectively. Generally, the treated specimens of Sample A had soaked CBR values (0.1-inch penetration) that were some 9 to 37 times greater than the KYCBR value obtained from an untreated specimen of Sample A. In each case where the soils had been treated, the KYCBR value occurred at 0.5-inch penetration. However, the maximum CBR-value occurred at 0.1-inch penetration. The CBR-value decreased with increasing stress. A bearing capacity failure had occurred after 0.1-inch penetration. For brittle soils, such as lime-treated soils, peak failure loads will occur at small strains. Hence, the CBR-value at peak failure load is the more valid value than the CBR value at 0.5-inch penetration, which occurs after the peak stress has been reached.

Comparisons of values of total volumetric strain (swell) of the CBR specimens in an untreated state and treated state are made in Table 5. Strains obtained from both ASTM and KYCBR tests are compared. Strains obtained from the ASTM bearing ratio tests for the untreated soils (A, B, and C) ranged from 2.1 to 5.0 percent. After treatment with six percent hydrated lime, the strains observed in the ASTM bearing ratio tests decreased significantly and ranged from 0.2 to 2.4 percent. Strains from ASTM tests of treated soils were some 6 to 52 percent lower than strains observed for the untreated soils. However, in the treated ASTM bearing ratio no curing time was used. As shown in Table 6, strains obtained from the KYCBR test were reduced significantly, based on comparisons between untreated and treated specimens. For the untreated soil (A), the strain was 4.4 percent. For four specimens allowed to cure at zero, 3, 7, and 14 days, the strains were 0.5, 0.2, 0.1, and 0.04 percent, respectively. The swell strains decreased with increasing time. The strains from the treated tests were only some 1 to 12 percent (depending on the curing time allowed) of the strain obtained from the untreated specimen. In the Kentucky CBR test, the specimens are allowed to swell or absorb water until swell essentially ceases.

UNCONFINED COMPRESSIVE STRENGTHS

Results of unconfined compressive tests performed on remolded, untreated, specimens and remolded specimens treated with six percent hydrated lime are summarized and compared in Table 6. Stress-strain curves obtained from the treated and untreated, remolded specimens are compared in Figure 1. All unconfined compressive tests were performed on bag sample A from station 1630+00. The specimens were remolded to optimum moisture content and maximum dry density. Treated specimens identified as A-4, A-1, A-2, A-3, and A-5 were cured for 0.1, 1.1, 5, 8, and 14 days, respectively. Peak failure stresses of the treated specimens were 6450, 6000, 11000, 12160, and 15800 psf, respectively. Peak failure stresses of the three untreated specimens (A-8, A-6, and A-7) were 1965, 3100 and 4490 psf, respectively. Peak failure stresses of the treated and untreated specimens as a function of time are plotted and compared in Figure 2. The 0.1-day and 1.1-day peak failure stress of the treated specimens was about two times the peak failure stress of the 1-day peak failure stress of the untreated specimen. Specimen A-8 (untreated)

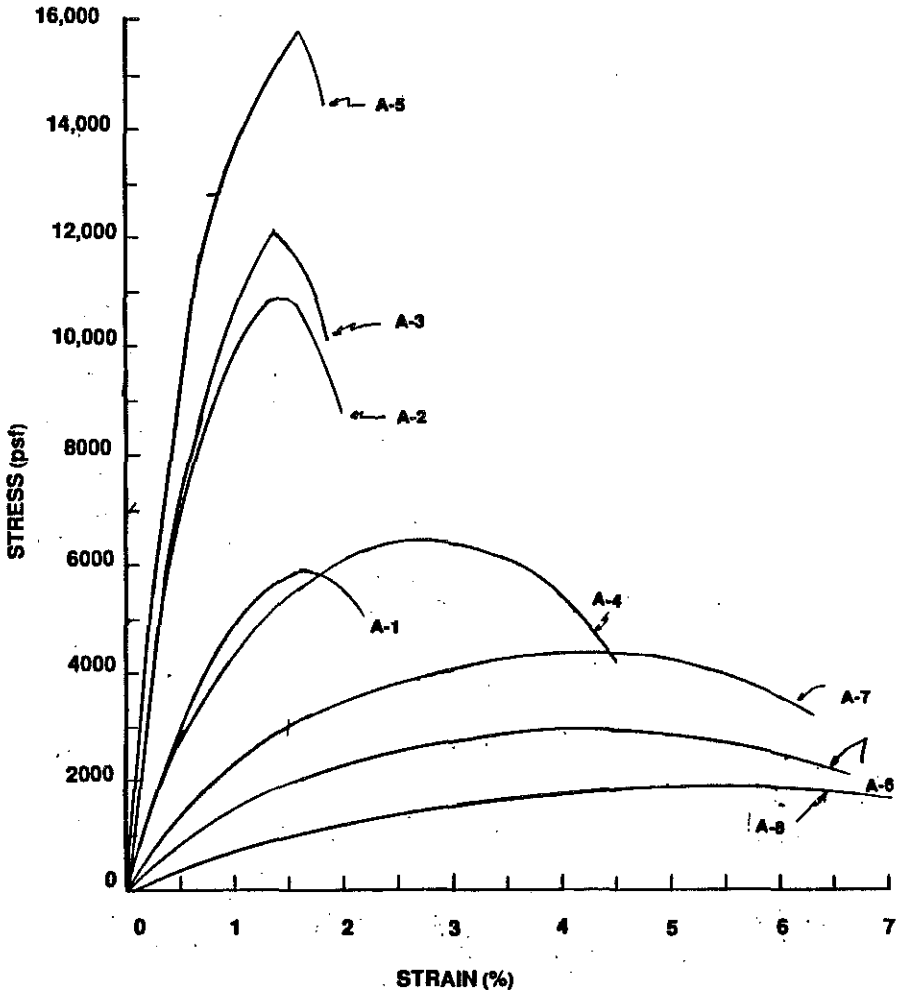

Figure 1. Stress-Strain Curves of Treated and Untreated Specimens.

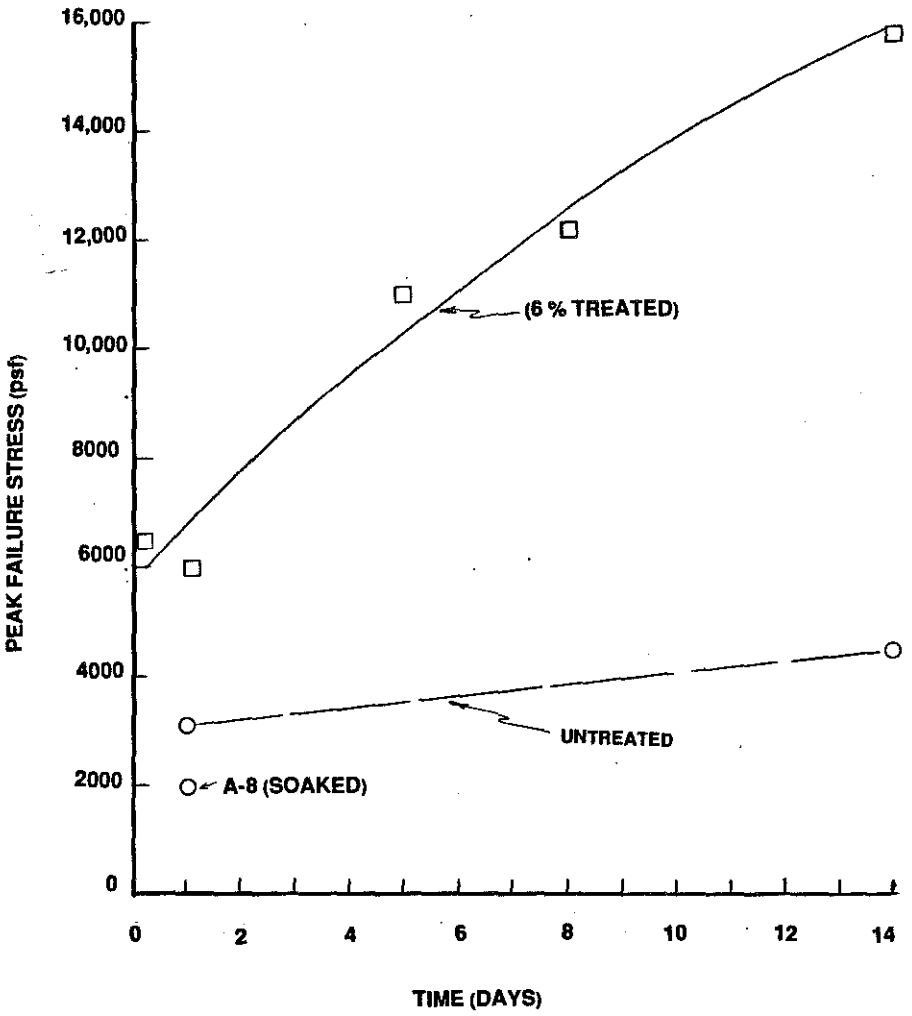

Figure 2. Peak Failure Stresses as a Function of Time.

was prepared by molding sample A in a CBR mold at optimum moisture and maximum dry density. The specimen was allowed to soak and absorb water until vertical swell ceased. A specimen of the molded soil was obtained using a shelby tube. Unconfined compressive strength of specimen A-8 was 1965 pounds per square foot.

The peak failure stress of the treated specimen cured for 14 days was about 3.5 times larger then the peak failure stress of the untreated specimen "cured" for 14 days and about 5 times larger than the untreated specimen "cured" for 1 day. As shown in Figure 2, the strength of the treated soil continued to increase significantly with time while that of untreated specimens did not increase with increasing curing time. Based on the trend of the peak failure stresses as a function of time, the shear strength of the treated specimens could be expected to increase after the 14-day curing period. Failure strains of the untreated specimens averaged about 4 percent. Excluding specimen A-4, the failure strains of the treated specimens averaged about 1.5 percent. Hence, treatment of the soils with six percent lime produced a subgrade material having failure strains that were only some 38 percent of the failure strain of the untreated soil. Additionally, the failure mode of the treated material was a brittle type whereas the untreated clay specimens exhibited a plastic type of failure mode.

CONCLUSIONS

Based on the preliminary results presented above, the following conclusions are made:

1. Treatment of soils obtained from Section 19 of the AA highway with six percent hydrated lime significantly increased the bearing ratio value when compared to bearing ratio values obtained from the untreated soils. The bearing ratio values of untreated soils ranged from 0.8 to 3.3 percent. The bearing ratio values of treated specimens (six percent hydrated lime) ranged from 7 to 57 percent, depending on test method and curing time. For a treated sample of soil A, and using a 7-day curing time, the bearing ratio value was 57 (at 0.1-inch penetration).

2. Treatment of the soils with six percent hydrated lime decreases the maximum dry density and increases optimum moisture contents when compared to the maximum dry density and optimum moisture content of untreated specimens.

3. Swell strain due to absorption of water is significantly less for specimens treated with six percent hydrated lime than values observed for the untreated soils.

4. Unconfined compressive strengths of specimens treated with six percent lime were significantly larger than the strengths of untreated specimens.

5. The engineering properties of the soils from Section AA-19 were largely improved with the addition of six percent hydrated lime.

REFERENCES

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2. Kentucky Methods, Division of Materials, Department of Highways, Kentucky Transportation Cabinet, Commonwealth of Kentucky, Frankfort, Kentucky, 1976.

3. Hopkins, T. C.; Relationship between Kentucky CBR and Slake-Durability Index, UKTRP-84-24, University of Kentucky Transportation Research Program, College of Engineering, August 1984.

4. Hopkins, T. C. and Deen, R. C.; Identification of Shales, ASTM Geotechnical Testing Journal, Vol. 7, March-December 1983.

TABLE 1. pH-VALUES AS A FUNCTION OF PERCENT OF LIME

SAMPLE NUMBER AND LOCATION	pH-VALUES*					
PERCENT OF LIME	0	3	4	5	6	7
AA-A STA 1630+00	775	1209	1231	1231	1236	1241
AA-B STA 1495+00	794	1226	1236	1242	1248	1251
AA-C STA 1675+50	860	1231	1245	1247	1248	1250
SHOOK HARD AND LET SETTLE FOR 10 MINUTES						
AA-A STA 1630+00	781	1208	1226	1235	1231	1239
AA-B STA 1495+00	792	1197	1215	1225	1229	1232
AA-C STA 1675+50	860	1220	1232	1235	1235	1236

* As reported by the Dravo Lime Company.

TABLE 2. SUMMARY OF INDEX TEST DATA AND SOIL CLASSIFICATION OF UNTREATED SOIL SPECIMENS, SECTION AA-19

SAMPLE NUMBER AND LOCATION	NATURAL WATER CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	SPECFIC GRAVITY	PARTICLE-SIZE ANALYSIS PERCENT FINER THAN: NO. 10 (%)	NO. 200 (%)	0.002mm (%)	CLASSIFICATION: AASHTO	CLASSIFICATION: UNIFIED
UNTREATED SPECIMENS										
A STA 1630+00		71	34	37	2.97	99.2	90.0	57.5	A-7-5(40)	MH-CH
B STA 1495+00		71	30	41	2.80	98.9	92.8	57.5	A-7-5(44)	CH
C STA 1675+50		61	32	29	2.80	99.5	94.4	66.0	A-7-5(32)	MH-CH
SPECIMENS TREATED WITH 6% LIME										
A STA 1630+00		53	47	6	2.94	97.2	39.4	21.0	A-4(0)	SM
B STA 1495+00		45	43	2	2.80	98.2	34.7	21.5	A-2-4(0)	SM
C STA 1675+50		41	37	4	2.81	98.9	65.4	38.0	A-4(0)	ML

TABLE 3. SUMMARY OF MOISTURE-DENSITY TEST DATA FOR UNTREATED SOIL SPECIMENS AND SOIL SPECIMENS TREATED WITH 6 PERCENT HYDRATED LIME

	UNTREATED		TREATED*	
SAMPLE NUMBER	OPTIMUM MOISTURE CONTENT (%)	MAXIMUM DRY DENSITY (pcf)	OPTIMUM MOISTURE CONTENT (%)	MAXIMUM DRY DENSITY (pcf)
A STA 1630+00	31.0	90.1	31.3	86.8
B STA 1495+00	24.5	96.3	27.7	89.8
C STA 1675+50	14.3	98.6	20.8	91.4

*Specimens were allowed to mellow 1 hour after mixing with 6 percent hydrated lime.

TABLE 4. SUMMARY OF BEARING RATIO DATA OF UNTREATED SOIL SPECIMENS AND SOIL SPECIMENS TREATED WITH 6 PERCENT HYDRATED LIME

	UNTREATED SPECIMENS			TREATED SPECIMENS (6% HYDRATED LIME)			
	SOAKED ASTM CBR	SOAKED KENTUCKY CBR		SOAKED ASTM CBR	SOAKED KENTUCKY CBR		
SAMPLE NUMBER AND LOCATION	0.1-INCH PENETRATION** (%)	MINIMUM VALUE (%)	0.1-INCH PENETRATION (%)	0.1-INCH PENETRATION (%)	MINIMUM VALUE (%)	0.1-INCH PENETRATION (%)	CURING TIME (days)
A STA 1630+00	3.3	2.6	3.7	38.0	7.1* 39.7* 21.9* 42.4*	32.3 58.0 59.5 137.3	0 3 7 14
B STA 1495+00	2.7			30.3			
C STA 1675+50	0.8			8.0			

*Values occurred at 0.5-inch Penetration.
**According to ASTM bearing ratio test (ASTM D 1883-73(1978)), the bearing ratio value occurring at 0.1-inch penetration is normally reported.

TABLE 5. COMPARISIONS OF TOTAL VOLUMETRIC STRAINS OBSERVED FROM BEARING RATIO TESTS OF TREATED AND UNTREATED SOILS

SOIL SAMPLE AND SPECIMEN NUMBER	UNTREATED SOILS		SOILS TREATED WITH 6% HYDRATED LIME	
	ASTM BEARING RATIO TEST TOTAL VOLUMETRIC STRAIN (%)	KYCBR TEST TOTAL VOLUMETRIC STRAIN (%)	ASTM BEARING RATIO TEST TOTAL VOLUMETRIC STRAIN (%)	KYCBR TEST TOTAL VOLUMETRIC STRAIN (%)
SOIL A:				
A(ASTM-U)	2.10	--		
A(KY-U)	--	4.37		
A(ASTM-6-0-T)			1.09	
A(KY-6-0-T)				0.51 (No Curing Time)
A(KY-6-3-T)				0.17 (3-Day Curing Time)
A(KY-6-7-T)				0.15 (7-Day Curing Time)
A(KY-6-14-T)				0.04 (14-Day Curing Time)
SOIL B:				
B(ASTM-U)	3.84			
B(ASTM-6-0-T)			0.22	
SOIL C:				
C(ASTM-U)	5.00			
C(ASTM-6-0-T)			2.40	

NOTE: 1. All specimens allowed one hour mellowing time when prepared.
2. ASTM - ASTM bearing ratio test (ASTM D 1883-73(1978)); 6 - refers to percent lime; U - untreated soil; 0, 3, 7, and 14 - refers to curing time in days at room temperature before specimen immersed in water tank; T - treated with 6 percent hydrated lime; and KY - KYCBR test (KM-64-501-76)

TABLE 6. RESULTS OF UNCONFINED COMPRESSION TESTS PERFORMED ON REMOLDED, UNTREATED SPECIMENS AND SPECIMENS TREATED WITH 6 PERCENT LIME (BAG SAMPLE A, STATION 1630+00)

SPECIMEN NUMBER	UNCONFINED COMPRESSIVE STRENGTH (PSF)	FAILURE STRAIN (PERCENT)	MOLDING CONDITIONS* WATER CONTENT (PERCENT)	MOLDING CONDITIONS* DRY DENSITY (PCF)	STANDARD COMPACTION** OPTIMUM WATER CONTENT (PERCENT)	STANDARD COMPACTION** MAXIMUM DRY DENSITY (PCF)	CURING TIME (DAYS)
			UNTREATED SPECIMENS				
A-6	3100	4.0	30.3	87.1	31.0	90.1	1
A-7	4490	4.0	27.9	90.8	31.0	90.1	14
A-8(soaked)	1965	4.9	31.9	89.9	31.0	90.1	0
			TREATED SPECIMENS (6% LIME)				
A-1	6450	2.7	35.9	83.9	31.3	86.8	0.1
A-4	6000	1.7	35.0	85.6	31.3	86.8	1.1
A-2	11000	1.4	35.9	84.7	31.3	86.8	5
A-3	12160	1.3	34.0	86.5	31.3	86.8	8
A-5	15800	1.6	32.3	87.2	31.3	86.8	14

* Water contents and dry densities of all specimens were determined at the time of testing.
** ASTM D 698.

APPENDIX A

SUMMARY OF INDEX PROPERTIES AND PARTICLE-SIZE DISTRIBUTION CURVES OF UNTREATED AND TREATED SOILS

LABORATORY RECORD OF SOIL TEST DATA

SAMPLE NUMBER	LL	PL	PI	SPGR	AASHTO	GI	USC
DRAVO A	71.0	33.9	37.1	2.97	A-7-5	(40)	MH-CH

HYDROMETER SIEVE ANALYSIS

SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
PERCENT PASSING NO. 10 = 99.20(SUPPLIED VALUE)		
NO. 20	0.50	98.07
NO. 40	0.86	96.12
NO. 60	0.75	94.42
NO. 200	1.92	90.07

HYDROMETER ANALYSIS

TIME (MIN)	TEMP	HYD READING	PERCENT FINER	PARTICLE DIAMETER-M/M
1.00	63.00	48.00	96.22304	0.03714
2.00	63.00	46.00	91.98038	0.02678
5.00	63.55	44.00	87.73773	0.01726
15.00	65.00	40.00	79.76585	0.01018
30.00	66.00	39.00	77.90128	0.00721
60.00	68.00	35.00	69.92941	0.00519
240.00	73.00	30.00	60.73601	0.00261
1440.00	74.00	25.00	50.49464	0.00110

LABORATORY RECORD OF SOIL TEST DATA

SAMPLE NUMBER	LL	PL	PI	SPGR	AASHTO	GI	USC
DRAVO B	71.2	30.2	41.0	2.80	A-7-5	(44)	CH

HYDROMETER SIEVE ANALYSIS

SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
PERCENT PASSING NO. 10 = 98.90(SUPPLIED VALUE)		
NO. 20	0.80	97.14
NO. 40	0.55	95.93
NO. 60	0.42	95.00
NO. 200	1.00	92.80

HYDROMETER ANALYSIS

TIME (MIN)	TEMP	HYD READING	PERCENT FINER	PARTICLE DIAMETER-M/M
1.00	65.00	47.00	95.29535	0.03869
2.00	65.00	46.50	94.22702	0.02749
5.00	65.00	45.00	91.02214	0.01764
15.00	66.00	42.00	84.87105	0.01039
30.00	67.50	39.00	78.71988	0.00749
60.00	69.00	36.00	72.82726	0.00535
240.00	73.50	30.00	61.17261	0.00273
1440.00	74.00	25.00	50.85760	0.00115

LABORATORY RECORD OF SOIL TEST DATA

SAMPLE NUMBER	LL	PL	PI	SPGR	AASHTO GI	USC
DRAVO C	60.9	32.2	28.7	2.80	A-7-5 (32)	MH-CH

HYDROMETER SIEVE ANALYSIS

SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
PERCENT PASSING NO. 10 = 99.50(SUPPLIED VALUE)		
NO. 20	0.36	98.73
NO. 40	0.40	97.87
NO. 60	0.33	97.16
NO. 200	1.28	94.41

HYDROMETER ANALYSIS

TIME (MIN)	TEMP	HYD READING	PERCENT FINER	PARTICLE DIAMETER-M/M
5.00	65.00	49.00	97.16460	0.01696
15.00	65.50	46.50	91.95206	0.01004
30.00	67.00	44.00	87.24432	0.00717
60.00	69.00	42.00	83.57901	0.00509
240.00	74.00	35.00	70.47984	0.00261
1440.00	74.00	28.00	55.88472	0.00112

LABORATORY RECORD OF SOIL TEST DATA

SAMPLE NUMBER	LL	PL	PI	SPGR	AASHTO	GI	USC
TREATED 6% LIME A	0.0	0.0	0.0	2.94	A-4	(0)	SM

MECHANICAL SIEVE ANALYSIS

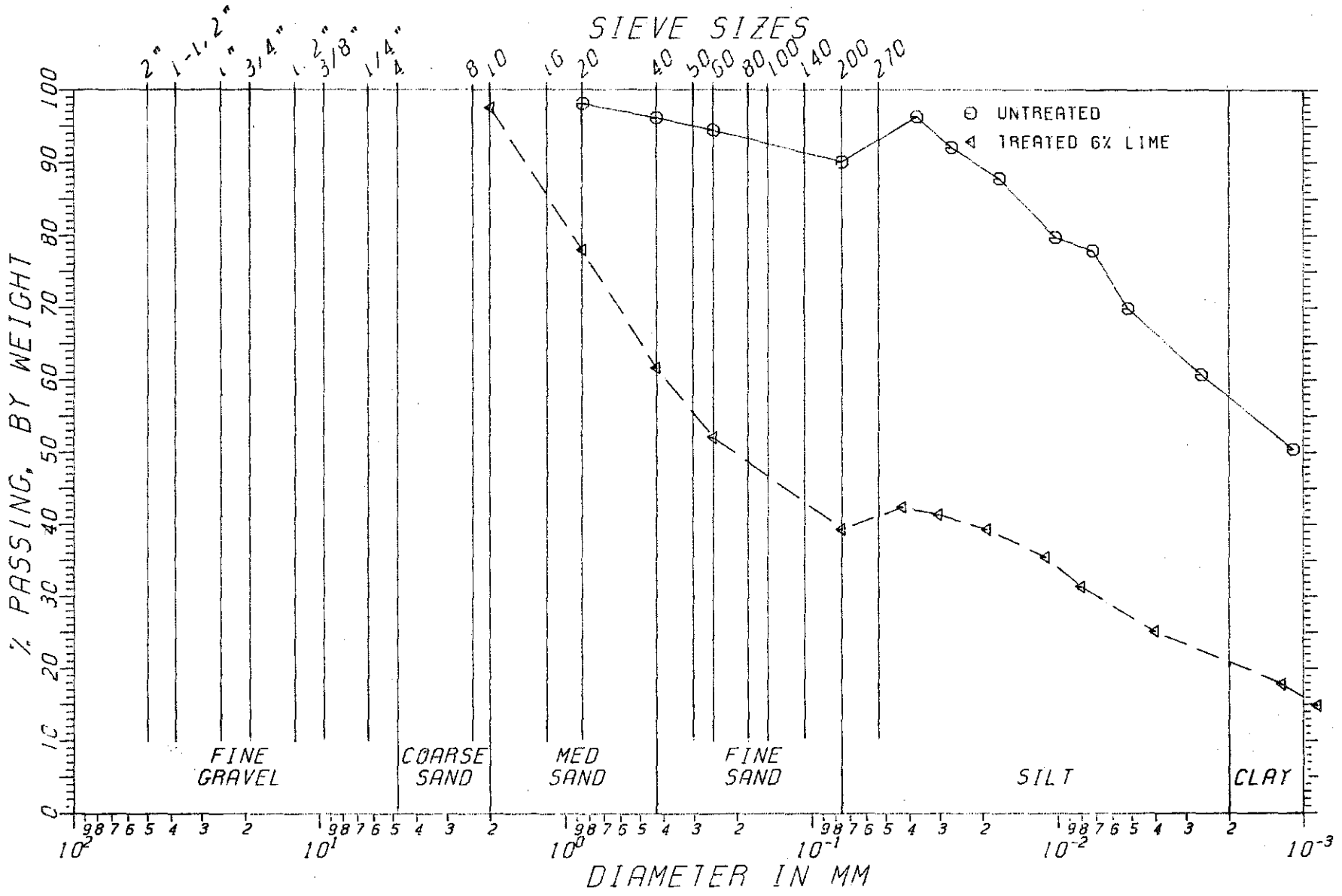
SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
NO. 4	0.0	100.00
NO. 10	18.70	97.52

HYDROMETER SIEVE ANALYSIS

SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
NO. 20	8.91	77.94
NO. 40	7.42	61.64
NO. 60	4.33	52.12
NO. 200	5.81	39.36

HYDROMETER ANALYSIS

TIME (MIN)	TEMP	HYD READING	PERCENT FINER	PARTICLE DIAMETER-M/M
1.00	75.00	21.50	42.38339	0.04263
2.00	75.00	21.00	41.34843	0.03024
5.00	75.00	20.00	39.27844	0.01925
15.00	76.00	18.00	35.49500	0.01118
30.00	76.00	16.00	31.35509	0.00800
124.00	76.00	13.00	25.14517	0.00401
1440.00	73.00	10.00	17.86580	0.00122
2755.00	76.00	8.00	14.79534	0.00087


SIEVE SIZES
2" 1-1/2" 1" 3/4" 1/2" 3/8" 1/4" 4 8 10 16 20 40 50 60 80 100 140 200 270
% PASSING, BY WEIGHT
0 10 20 30 40 50 60 70 80 90 100
UNTREATED
TREATED 6% LIME
FINE GRAVEL
COARSE SAND
MED SAND
FINE SAND
SILT
CLAY
10^2 10^1 10^0 10^{-1} 10^{-2} 10^{-3}
DIAMETER IN MM

DRAVO A

LABORATORY RECORD OF SOIL TEST DATA

SAMPLE NUMBER	LL	PL	PI	SPGR	AASHTO	GI	USC
TREATED 6% LIME B	0.0	0.0	0.0	2.80	A-2-4	(0)	SM

MECHANICAL SIEVE ANALYSIS

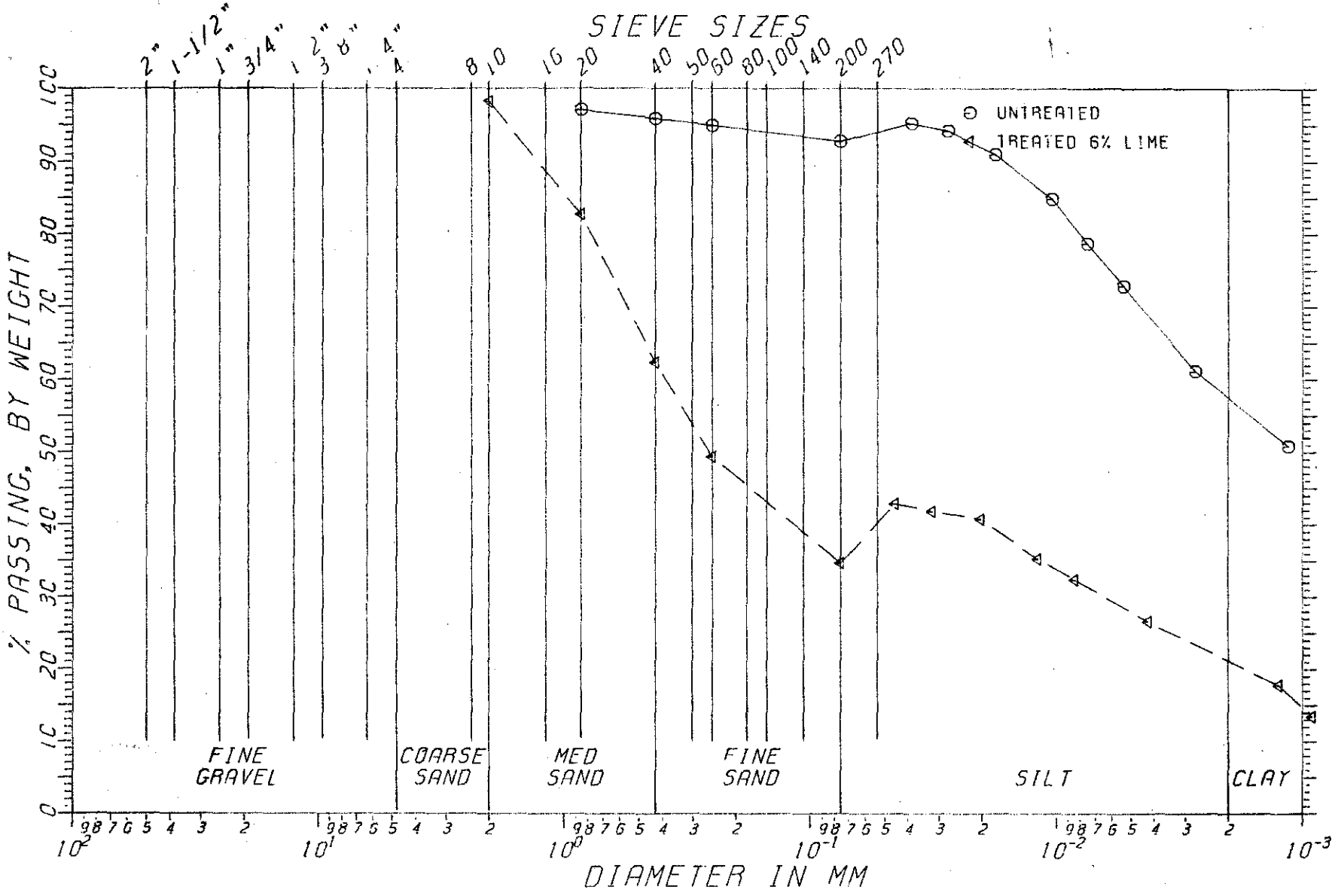
SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
NO. 4	0.0	100.00
NO. 10	28.91	98.22

HYDROMETER SIEVE ANALYSIS

SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
NO. 20	6.88	82.72
NO. 40	9.05	62.33
NO. 60	5.77	49.34
NO. 200	6.50	34.69

HYDROMETER ANALYSIS

TIME (MIN)	TEMP	HYD READING	PERCENT FINER	PARTICLE DIAMETER-M/M
1.00	73.00	21.00	42.89699	0.04498
2.00	73.00	20.50	41.80444	0.03191
5.00	73.00	20.00	40.71185	0.02024
15.00	73.00	17.50	35.24893	0.01187
30.00	74.00	16.00	32.34752	0.00842
120.00	76.00	13.00	26.54465	0.00423
1440.00	76.00	9.00	17.80394	0.00125
2780.00	76.00	7.00	13.43360	0.00091


SIEVE SIZES
2" 1-1/2" 1" 3/4" 1/2" 3/8" 4" 4
8 10 16 20 40 50 60 80 100 140 200 270
UNTREATED
TREATED 6% LIME
% PASSING, BY WEIGHT
0 10 20 30 40 50 60 70 80 90 100
FINE GRAVEL
COARSE SAND
MED SAND
FINE SAND
SILT
CLAY
10^{2} 10^{1} 10^{0} 10^{-1} 10^{-2} 10^{-3}
DIAMETER IN MM

DRAVO B

LABORATORY RECORD OF SOIL TEST DATA

SAMPLE NUMBER	LL	PL	PI	SPGR	AASHTO	GI	USC
TREATED 6% LIME C	0.0	0.0	0.0	2.80	A-4	(0)	ML

MECHANICAL SIEVE ANALYSIS

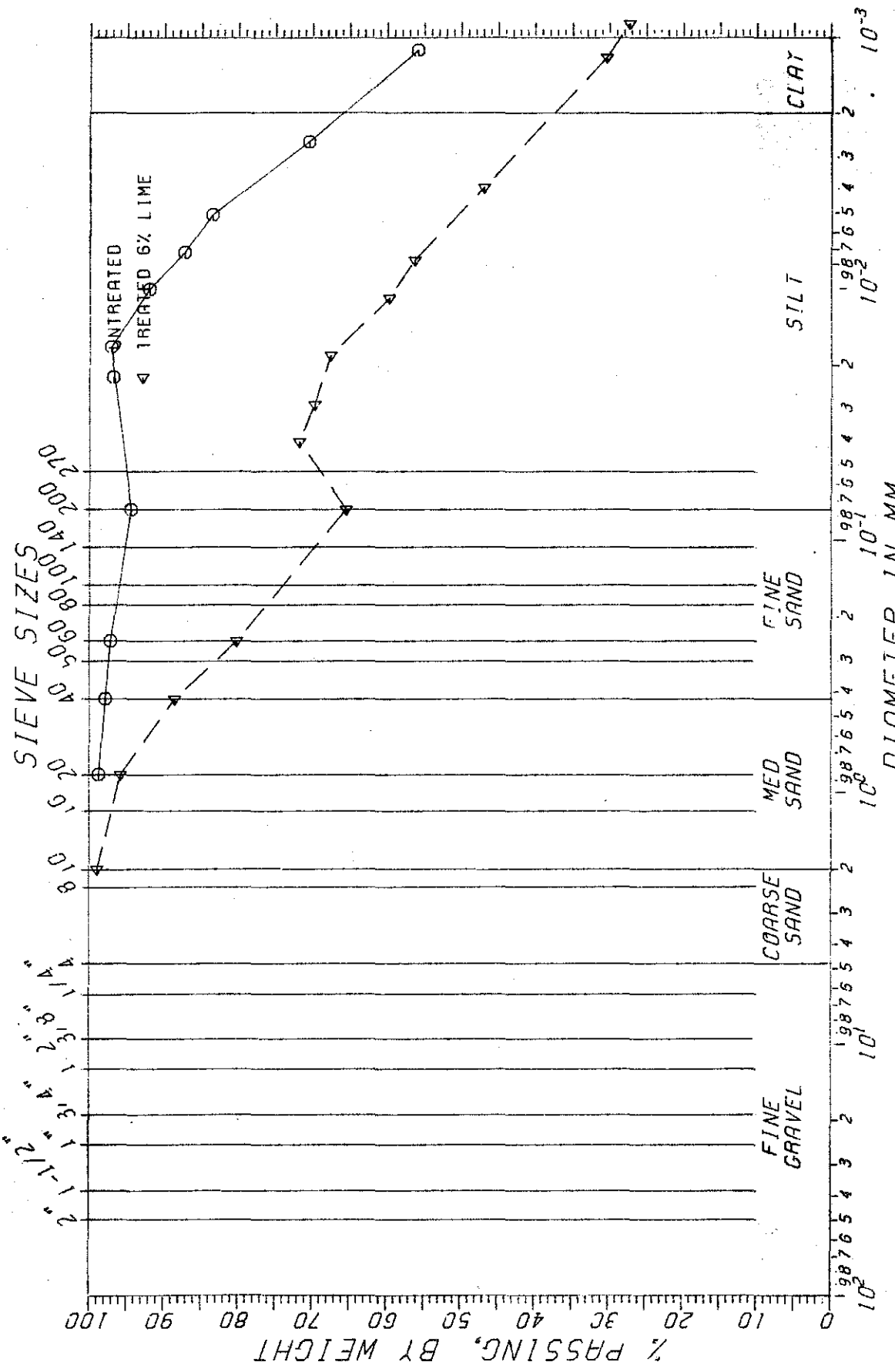
SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
NO. 4	0.0	100.00
NO. 10	15.31	98.87

HYDROMETER SIEVE ANALYSIS

SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
NO. 20	1.43	95.82
NO. 40	3.40	88.55
NO. 60	3.93	80.16
NO. 200	6.91	65.40

HYDROMETER ANALYSIS

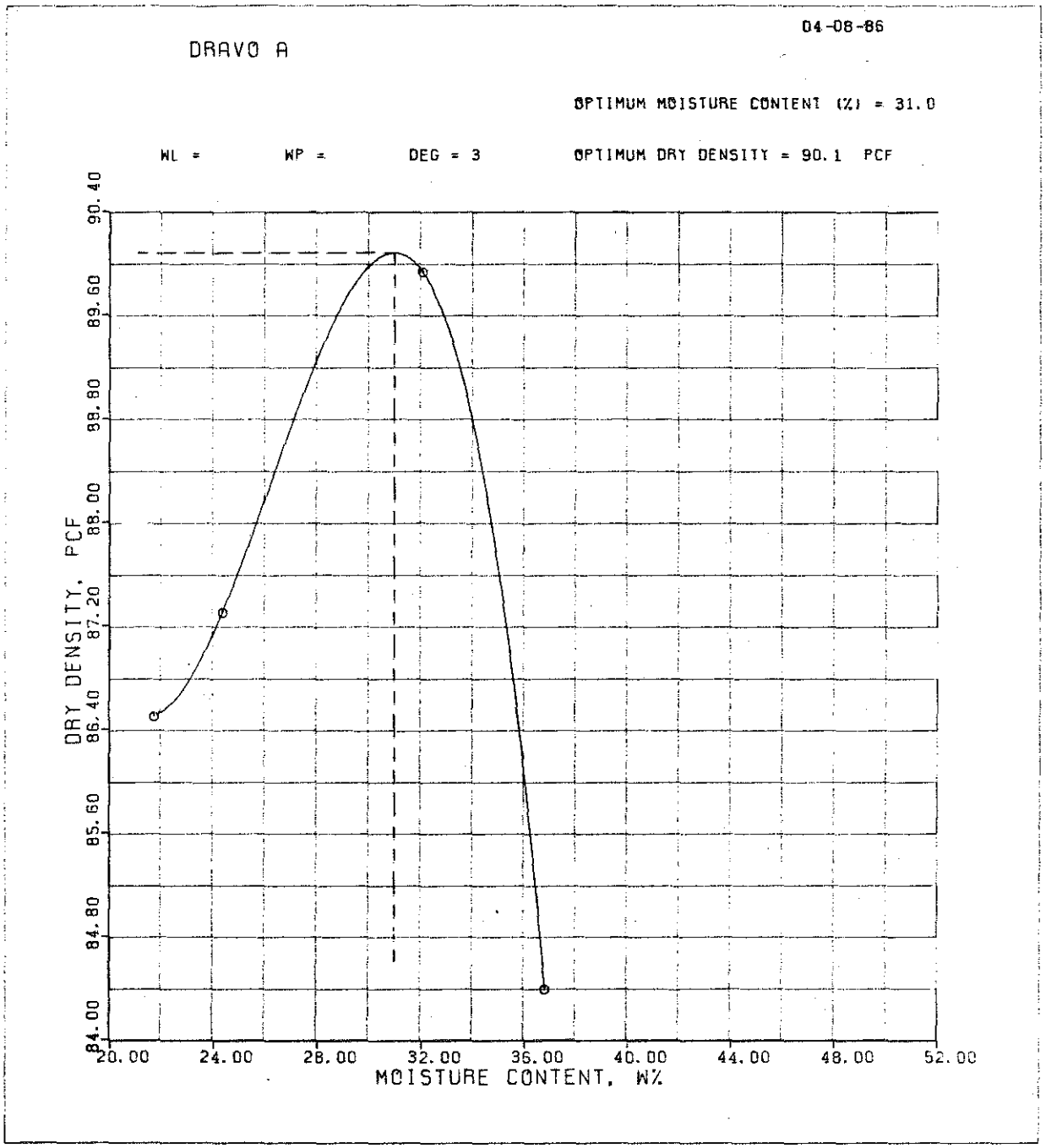
TIME (MIN)	TEMP	HYD READING	PERCENT FINER	PARTICLE DIAMETER-M/M
1.00	73.00	36.00	71.74805	0.04038
2.00	73.00	35.00	69.67624	0.02878
5.00	73.00	34.00	67.60449	0.01835
15.00	74.00	30.00	59.67413	0.01085
30.00	76.00	28.00	56.24414	0.00768
120.00	76.00	23.50	46.92108	0.00396
1440.00	76.00	15.50	30.34679	0.00120
2755.00	76.00	14.00	27.23911	0.00088


% PASSING, BY WEIGHT
SIEVE SIZES
DIAMETER IN MM
UNTREATED
TREATED 6% LIME
CLAY
SILT
FINE SAND
MED SAND
COARSE SAND
FINE GRAVEL

DRAVO C

APPENDIX B

MOISTURE-DENSITY CURVES OF LIME-TREATED AND UNTREATED SPECIMENS

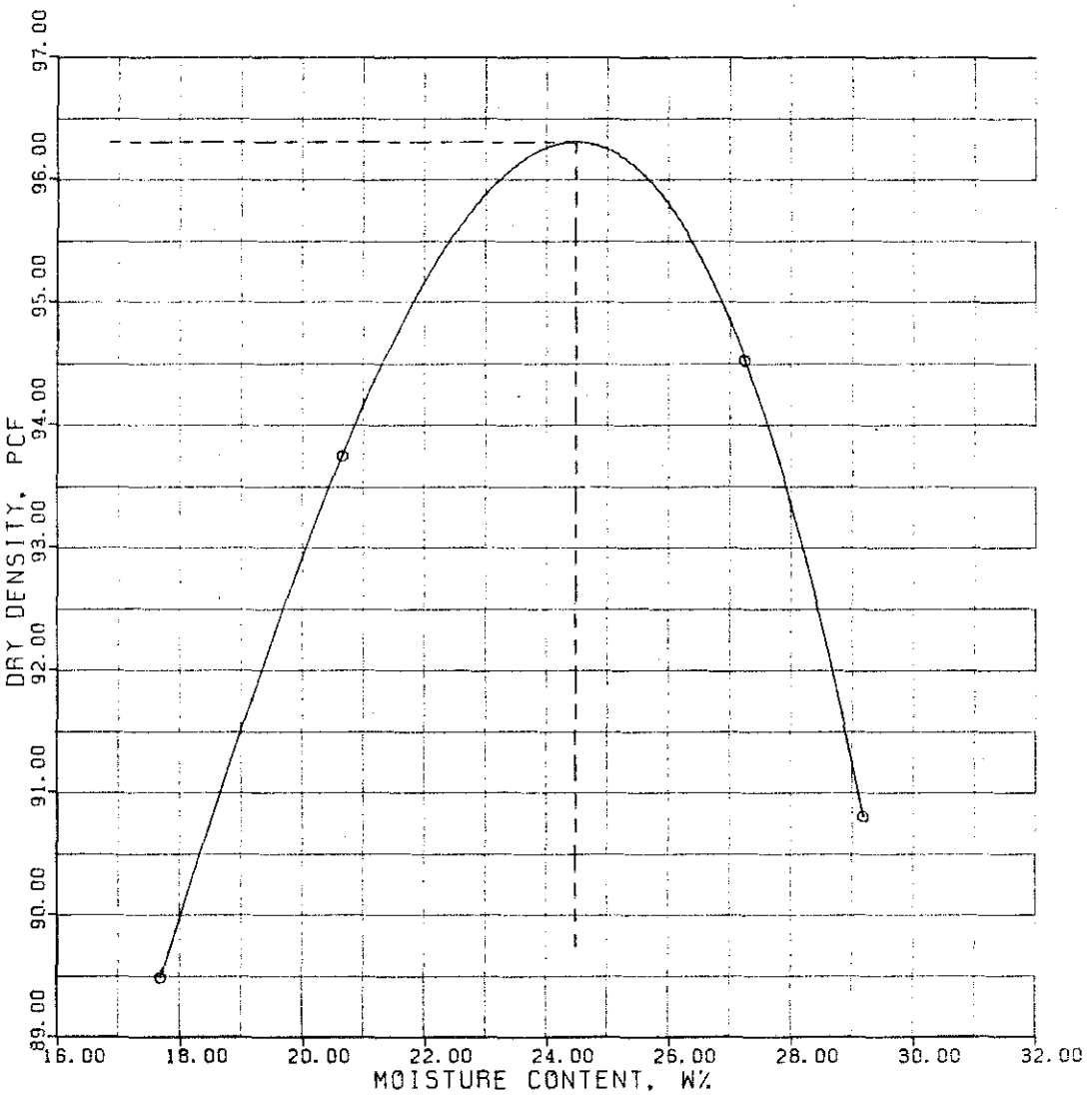

04-08-86
DRAVO A
OPTIMUM MOISTURE CONTENT (%) = 31.0
WL =
WP =
DEG = 3
OPTIMUM DRY DENSITY = 90.1 PCF
DRY DENSITY, PCF
90.40
89.60
88.80
88.00
87.20
86.40
85.60
84.80
84.00
20.00
24.00
28.00
32.00
36.00
40.00
44.00
48.00
52.00
MOISTURE CONTENT, W%

04-08-86

DRAVO B

OPTIMUM MOISTURE CONTENT (%) = 24.5

WL = WP = DEG = 3 OPTIMUM DRY DENSITY = 96.3 PCF

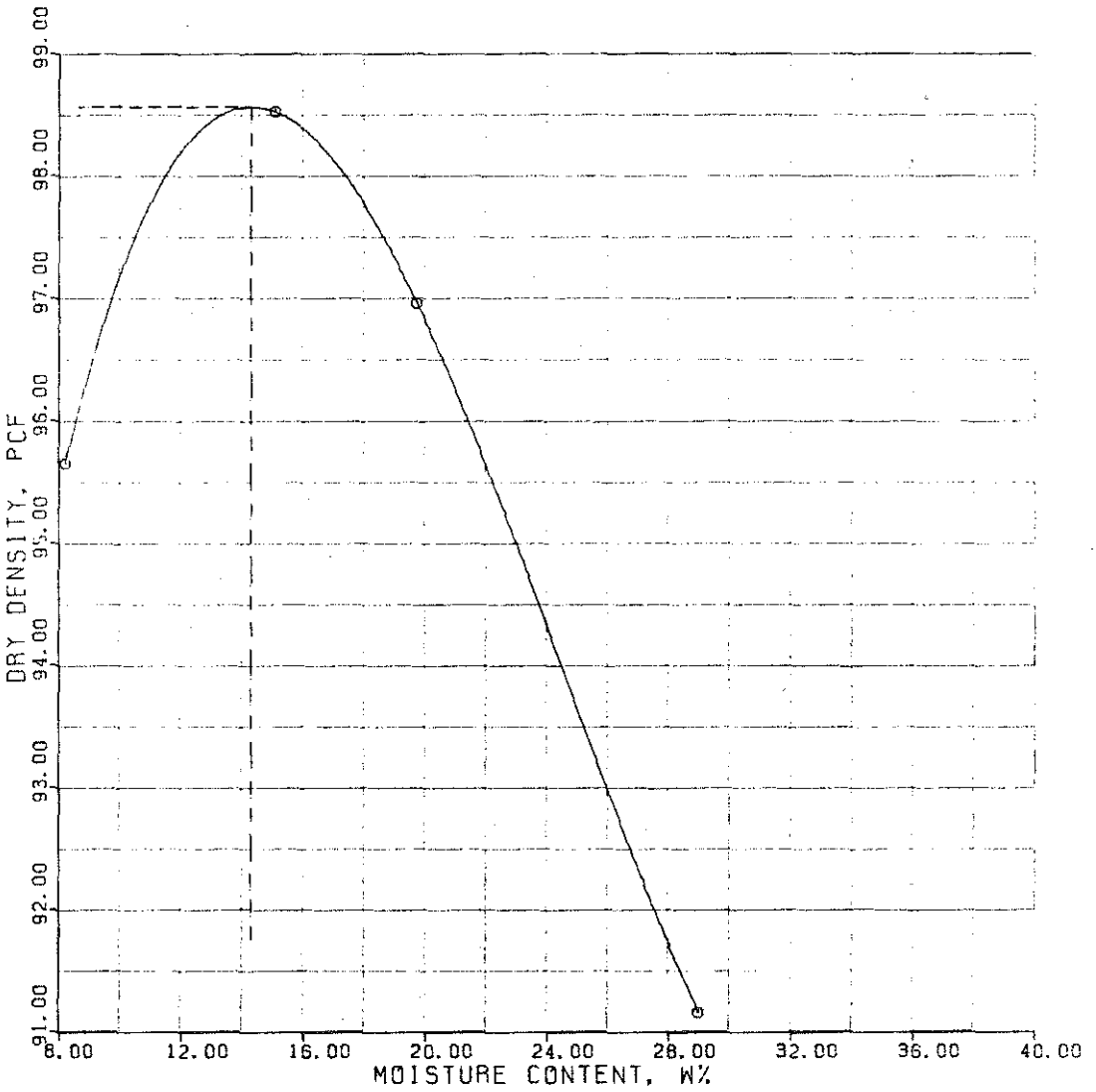


04-08-86

DRAVO C

OPTIMUM MOISTURE CONTENT (%) = 14.3

WL = WP = DEG = 3 OPTIMUM DRY DENSITY = 98.6 PCF

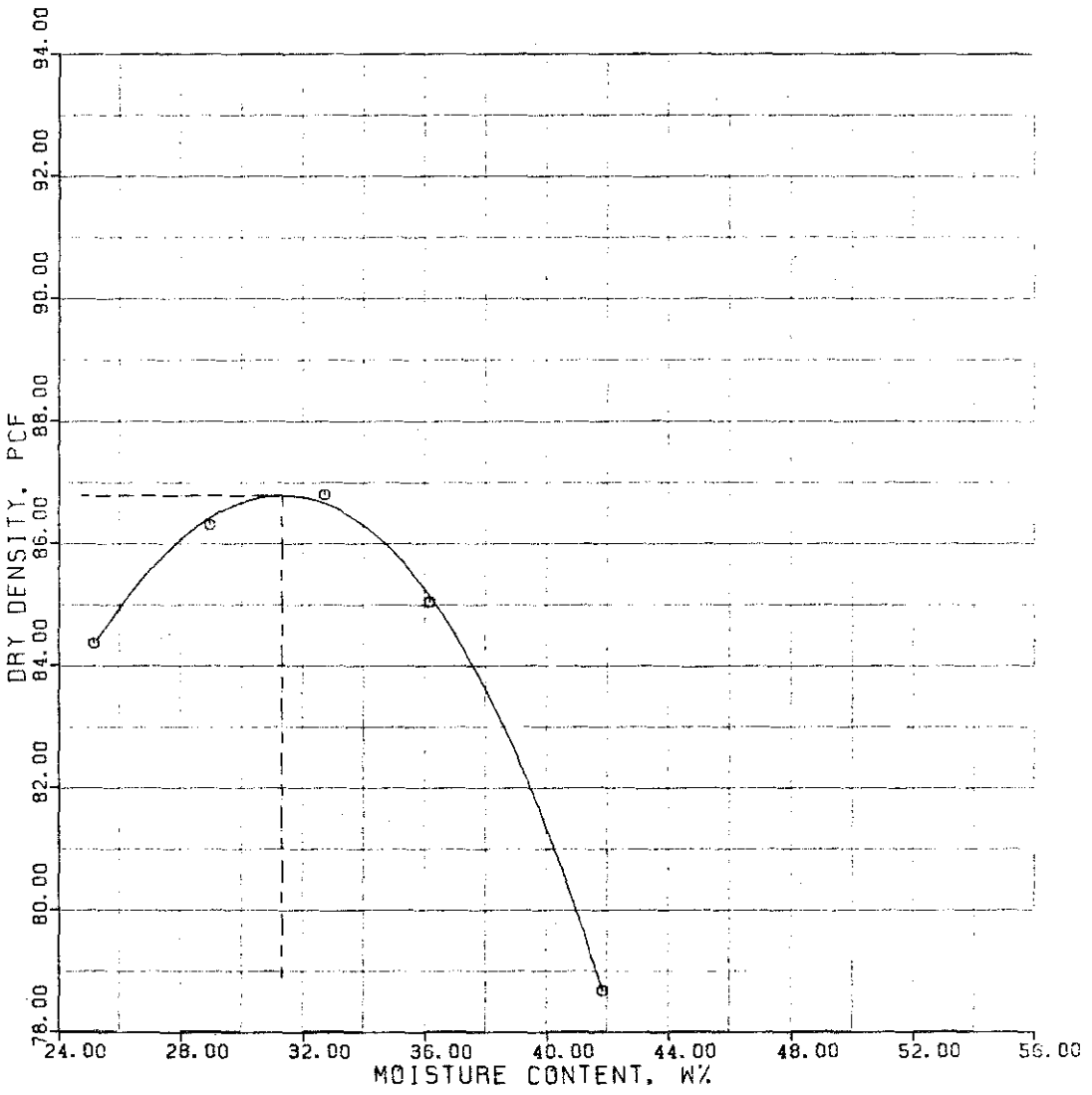


04-09-86

DRAVO A 6% LIME

OPTIMUM MOISTURE CONTENT (%) = 31.3

WL = WP = DEG = 3 OPTIMUM DRY DENSITY = 86.8 PCF

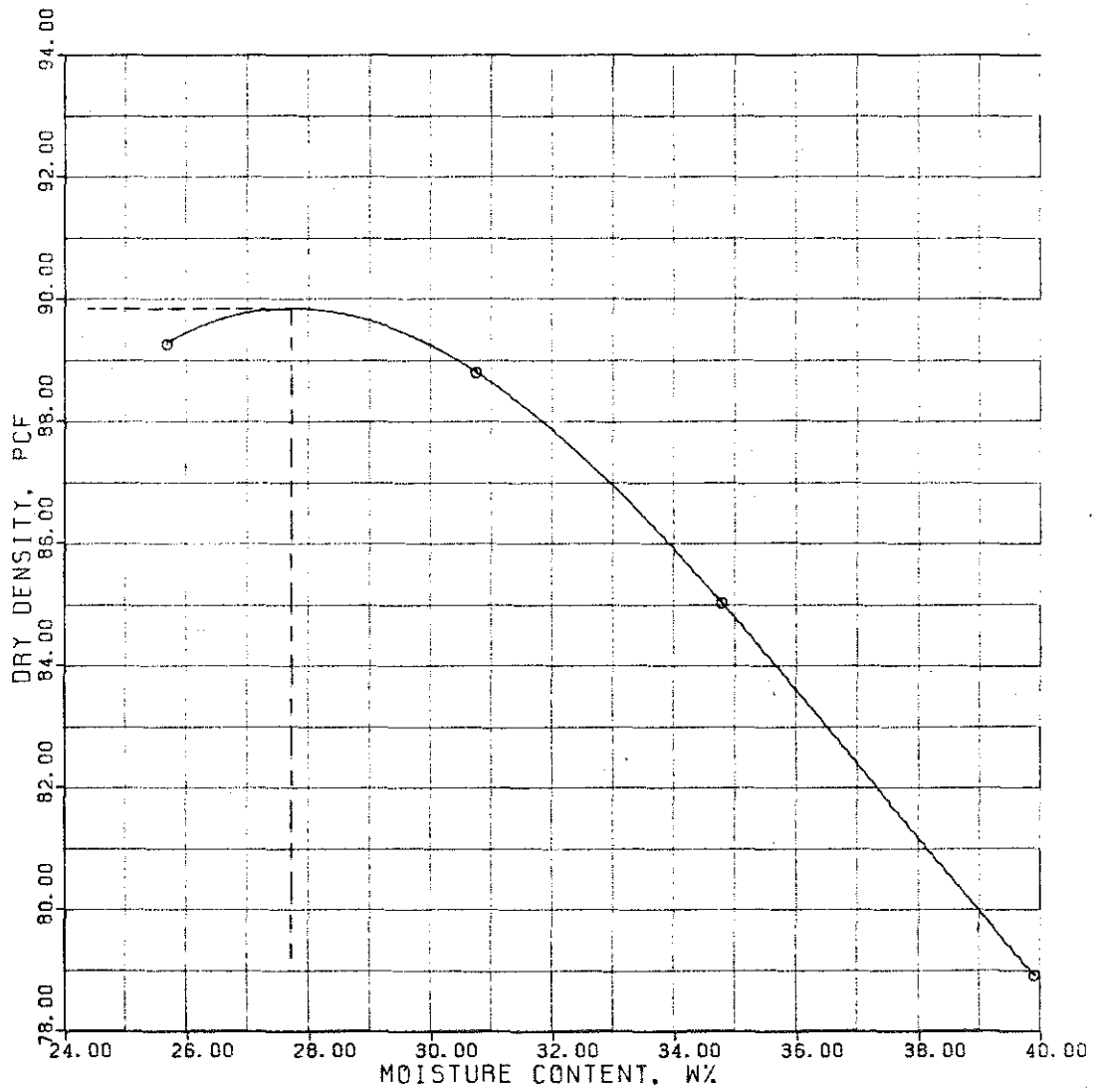


04-09-86

BRAVO B 6% LIME

OPTIMUM MOISTURE CONTENT (%) = 27.7

WL = WP = DEG = 3 OPTIMUM DRY DENSITY = 89.8 PCF



04-09-86

DRAVO C 6% LIME

OPTIMUM MOISTURE CONTENT (%) = 20.8

WL = WP = DEG = 3 OPTIMUM DRY DENSITY = 91.4 PCF