

Research Report KTC-90-17

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**CORRELATION OF ASTM AND  
KENTUCKY CBR METHODS  
FOR FAYETTE COUNTY**

by

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## INTRODUCTION

There has been, in recent years, considerable discussion as to the most appropriate CBR test method for pavement designers to use in Fayette County. Present Fayette County street regulations apparently default to the Kentucky CBR method (KM-501) (1). However, it appears some geotechnical laboratories and design consultants prefer to use the ASTM method (ASTM D 1883) (2). A laboratory testing program was performed to determine a correlation between the two methods for three major soil types in Fayette County.

Kentucky CBR samples are molded near optimum moisture content by applying a static load up to 2,000 pounds per square inch gradually on the soil sample over a two-minute interval. When the maximum load is reached, it is held for approximately one minute. The amount of soil used and moisture content are determined from moisture-density tests. The sample is then soaked until swell measurements (taken 24 hours apart) do not vary by more than 0.003 inch. The minimum soaking period, regardless of swell, is 72 hours. No attempt is made to control density of the molded specimen.

ASTM CBR samples are molded by compacting soil in three equal layers to a specified density (95% of max. dry density for this study) and moisture content (near optimum). The sample is then soaked in water for a period of 96 hours.

The load bearing test is performed in the same manner for both methods. After the soaking period, the sample is penetrated with a piston (3.0 square inches) to a depth of 0.5 inch. A five-pound surcharge, with a hole in the center, is placed on the sample around the piston, to prevent upheaval of the soil. The load is applied so the rate of penetration of the piston is 0.05 inch per minute.

Load readings are obtained when the depth of penetration has reached 0.010, 0.025, 0.05, 0.075, 0.1, 0.2, 0.3, 0.4, and 0.5 inch. The bearing ratio is calculated by expressing the stress (load in psi), at the 0.1, 0.2, 0.3, 0.4, and 0.5 inch penetration depths as a percentage of the following respective standard reference stress values.

<u>Penetration (inches)</u>	<u>Standard Reference Stress(psi)</u>
0.1	1,000
0.2	1,500
0.3	1,900
0.4	2,300
0.5	2,600

The lowest bearing ratio is reported when using Kentucky specifications. The bearing ratio at 0.1 and/or 0.2 inch penetration is reported when using ASTM specifications.

## SAMPLING

Sampling sites were selected by personnel from the Lexington-Fayette Urban County Government, Engineering Division. The samples were obtained in areas of Fayette County currently being developed for residential use. Samples selected were a red clay from Copperfield Drive, a brown clay from Rockbridge Road, and a green clay from Kenesaw Drive. The samples were dug by hand from exposed soil cuts. These sites were selected for two reasons: 1) they were located in areas currently being developed, and 2) they were expected to have fairly low CBR values. Thus, the information obtained will be useful for future pavement designs in the areas sampled.

## TESTING PROCEDURES AND RESULTS

Atterberg limits (ASTM D 4318), grain size analysis (ASTM D 422) and specific gravity (ASTM D 854) were performed on the samples to determine the AASHTO and Unified soil classifications. Standard moisture-density tests (ASTM D 698) were performed to determine maximum dry density and optimum moisture content. Results of classification and moisture-density tests are listed in Appendix A.

Nine Kentucky CBR tests (KM-501) and nine ASTM CBR tests (ASTM D 1883) were performed on each soil type. Nine tests were performed for each set of test variables in an attempt to reduce statistical and random testing errors. Less than five tests lead to a wider band of error or scatter in the data. However, more than nine tests does not appear to significantly reduce the width of the error band. Standard deviation (an indication of error) as a function of the number of tests is shown in Figures 1 through 6. Standard deviations were higher for Kentucky CBR samples because the range of CBR values was wider.

Results of the CBR tests are listed in Tables 1 through 3. CBR values were lower when using ASTM procedures than those using Kentucky CBR procedures for all three samples. The red clay averaged 41.8% lower, brown clay 23.8% lower, and the green clay averaged 11.8% lower. These values were obtained from the lowest Kentucky CBR and the ASTM CBR at 0.2-inch penetration. Figures 7 through 9 are plots of ASTM CBR values as a function of Kentucky CBR values.

Dry density and moisture content, before and after swelling, for the three soils are listed in Tables 4 through 6. Dry densities, after compaction, for all Kentucky CBR tests are above the maximum dry density as determined from the standard moisture-density test. Dry densities of the ASTM CBR specimens after compaction were approximately 95 percent of the maximum dry density. The ASTM CBR specimens also absorbed more water during the swelling process than the Kentucky CBR specimens. This is due to less density and more voids in the ASTM specimens than in the Kentucky specimens. Table 7 summarizes the density and moisture conditions of the test specimens before and after swelling.

## ANALYSIS OF RESULTS

The 2,000 pounds per square inch of static compaction that is applied to the Kentucky CBR specimens produces a large increase in density and in the variability of density. This increased density results in decreased voids in the soil which, in turn, reduces the permeability of the specimen. Reduced permeability makes it more difficult for the soil to absorb water, thereby reducing swell. The greater variability in density results in a greater range of values for the Kentucky CBR specimens. This is evident in larger standard deviation values for the Kentucky CBR test specimens. Conversely, the ASTM specimens had less variation in standard deviation values because of more uniform density after compaction.

Figure 10 is a combined plot of ASTM CBR values as a function of Kentucky CBR values for all three soils. To develop a relationship between the two CBR test methods, an exponential regression analysis was performed on the data. From that analysis, the ASTM CBR value can be estimated, if the Kentucky CBR value is known. The following equation describes that relationship.

$$\text{ASTM CBR} = 0.17e^{0.364(\text{Kentucky CBR})} \quad (1)$$

where:  $e$  = natural logarithm.

If the ASTM CBR value is known, the Kentucky CBR value can be determined as follows:

$$\text{Kentucky CBR} = [\ln(\text{ASTM CBR}/0.17)]/[0.364] \quad (2)$$

It is apparent from Figure 10 the difference between ASTM CBR and Kentucky CBR decreases as CBR values increase. The two testing procedures yield the same value, at a CBR value of 11.6. It may be assumed the two methods continue to be equal at any CBR value greater than 11.6. For that reason, Equations 1 and 2 should not be used to estimate CBR for any value greater than 11.6.

The ratio of the two CBR testing methods approach equality because the more granular soils that have higher CBR values are not as susceptible to static compaction and moisture as are fine-grained clays.

## CONCLUSIONS AND RECOMMENDATIONS

CBR values were higher using Kentucky standards because the samples are compacted to a density greater than the density obtained from moisture-density tests. The ASTM samples were compacted around 95% of maximum dry density. The ASTM samples absorbed more water during the soaking period causing a reduction in bearing capacity.

The ASTM test procedures should be used for Fayette County soils because the CBR

values are more conservative and compaction specifications simulate field compaction specifications more closely.

CBR tests on granular soils (CBR greater than approximately 11) will most likely yield similar results regardless of the test method used to perform the test.

### References

1. "Method of Test for Determining the CBR of Soil and Soil-aggregate Mixtures", Transportation Cabinet, Commonwealth of Kentucky; Kentucky Methods, Guidance Manual, 1985
2. "CBR (California Bearing Ratio) of Laboratory-Compacted Soils", ASTM Annual Book of Standards, Vol 4.08, 1988, pp. 236-243.

Table 1. CBR Results for Red Clay

Red clay	Ky. CBR	ASTM CBR
1	6.67	3.57
2	7.95	3.57
3	9.13	3.91
4	8.64	3.57
5	7.36	3.57
6	8.83	1.53
7	9.52	3.91
8	8.74	3.91
9	8.15	3.74
Average	8.33	3.48
Std. deviation	0.897465	0.746409

Table 2. CBR Results for Green Clay

Green clay	Ky. CBR	ASTM CBR
1	2.82	0.43
2	3.44	0.55
3	3.63	0.26
4	3.00	0.34
5	3.53	0.38
6	3.04	0.30
7	3.44	0.34
8	3.04	0.51
9	3.04	0.34
Average	3.22	0.38
Std. deviation	0.288660	0.096046

Table 3. CBR Results for Brown Clay

Brown clay	Ky. CBR	ASTM CBR
1	3.83	1.02
2	3.48	0.77
3	2.44	0.68
4	3.77	0.68
5	3.22	0.94
6	4.42	0.85
7	3.73	0.68
8	3.53	0.85
9	2.26	0.85
Average	3.41	0.81
Std. deviation	0.684405	0.121449

Table 4. Summary of Moisture Content and Dry Density for Red Clay

Test No.	Ky. CBR				ASTM CBR			
	At Compaction		After Swell		At Compaction		After Swell	
	M.C. (%)	Dens. (pcf)	M.C. (%)	Dens. (pcf)	M.C. (%)	Dens. (pcf)	M.C. (%)	Dens. (pcf)
1	23.95	103.10	25.43	102.04	24.36	90.91	31.23	89.52
2	24.06	105.16	24.99	104.24	23.23	91.64	29.14	90.66
3	22.85	105.25	23.65	104.50	23.17	91.14	28.83	90.22
4	21.82	104.85	22.48	103.82	22.28	92.35	28.08	91.63
5	22.04	105.85	23.08	104.40	19.07	94.84	28.91	90.88
6	23.49	104.82	24.56	103.50	19.30	94.43	29.61	90.50
7	23.26	105.22	24.19	104.02	18.45	95.22	29.18	90.89
8	23.31	105.84	24.36	104.72	22.38	92.39	30.86	87.55
9	24.11	103.16	25.18	102.35	22.60	91.89	30.90	88.95

Table 5. Summary of Moisture Content and Dry Density for Green Clay

Test No.	Ky. CBR				ASTM CBR			
	At Compaction		After Swell		At Compaction		After Swell	
	M.C. (%)	Dens. (pcf)	M.C. (%)	Dens. (pcf)	M.C. (%)	Dens. (pcf)	M.C. (%)	Dens. (pcf)
1	17.72	117.02	22.40	108.34	17.96	98.44	29.97	91.85
2	17.29	117.90	22.20	108.95	16.33	99.59	28.37	97.98
3	16.99	115.98	21.88	107.27	16.96	99.17	28.95	97.67
4	16.29	117.76	21.18	108.70	16.32	99.49	28.44	97.81
5	17.15	118.43	21.40	109.26	16.26	99.19	29.08	97.28
6	16.54	117.77	21.21	109.06	15.98	99.78	28.32	97.73
7	16.36	119.35	21.45	109.82	16.59	99.49	29.43	92.57
8	16.53	117.53	21.40	108.65	17.22	98.95	28.46	92.67
9	18.51	115.12	22.01	106.66	17.27	98.46	29.08	92.02

Table 6. Summary of Moisture Content and Dry Density for Brown Clay

Test No.	Ky. CBR				ASTM CBR			
	At Compaction		After Swell		At Compaction		After Swell	
	M.C. (%)	Dens. (pcf)	M.C. (%)	Dens. (pcf)	M.C. (%)	Dens. (pcf)	M.C. (%)	Dens. (pcf)
1	20.89	110.82	25.27	103.12	22.34	93.94	30.41	90.70
2	21.42	109.98	26.16	102.04	22.72	93.76	31.33	90.23
3	21.33	108.77	25.52	101.97	22.96	93.46	30.98	90.02
4	22.03	108.59	26.06	102.02	22.66	93.58	30.88	89.93
5	22.34	109.05	26.12	102.99	22.30	94.19	30.47	90.66
6	22.65	106.96	26.17	101.67	20.54	95.57	27.18	92.45
7	22.66	107.01	25.73	99.64	23.04	93.62	30.57	90.16
8	21.86	108.49	25.30	103.20	22.43	94.08	30.01	90.72
9	18.30	111.61	26.40	101.57	22.71	93.76	29.88	90.51

Table 7. Density Ratios and Moisture Conditions Before and After Swell

Sample ID	Average Ratio of Compaction Dry Density KY/ASTM	Average Ratio of Swell Dry Density KY/ASTM	Average Percent Increase in Moist. Content	
			KY	ASTM
Red Clay	1.130155	1.151597	1.09	7.99
Green Clay	1.184067	1.139787	4.64	12.14
Brown clay	1.160045	1.126183	4.36	7.78



# STANDARD DEVIATION vs. TEST NUMBER KENTUCKY CBR - RED CLAY

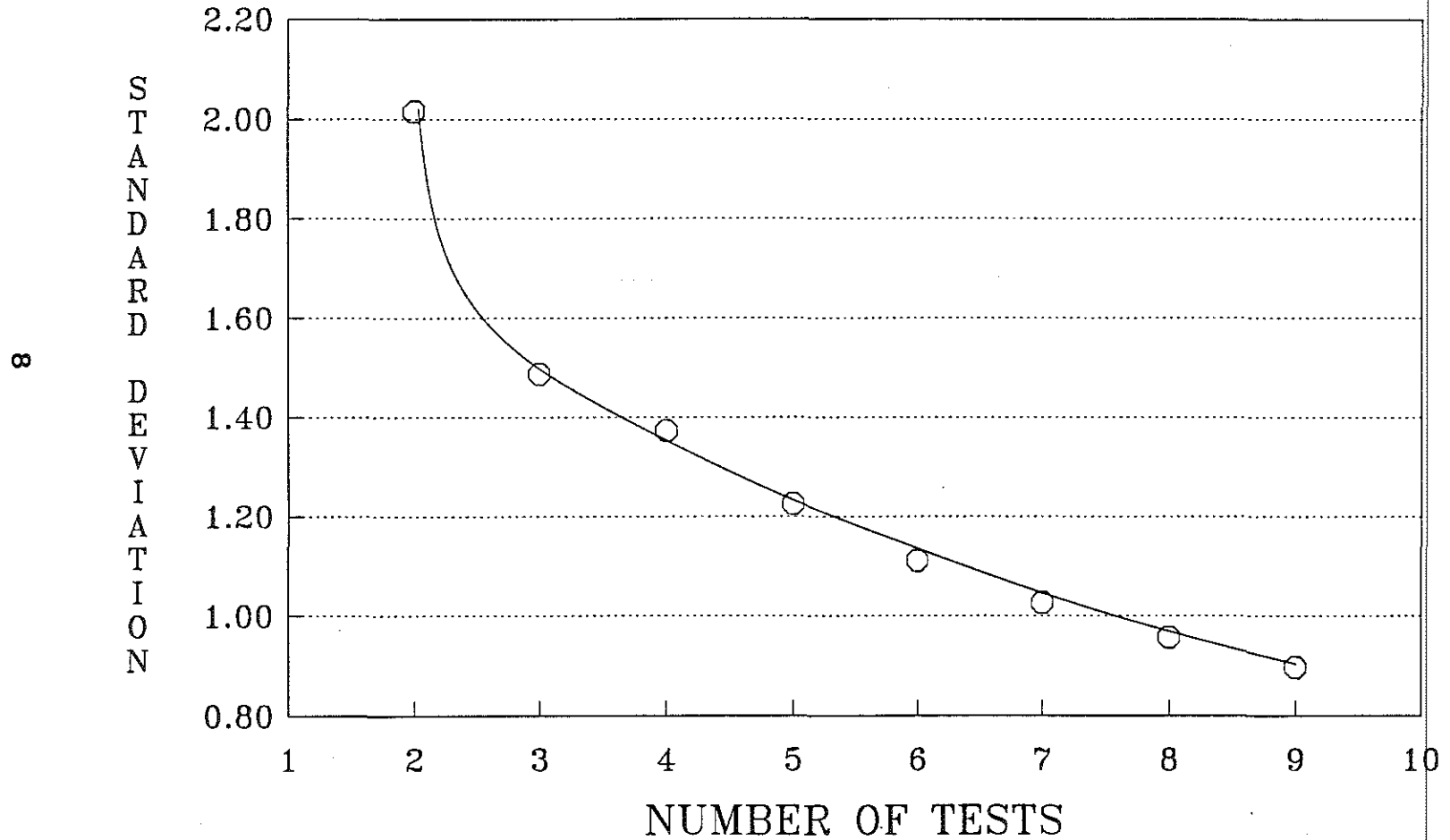


Figure 1.

# STANDARD DEVIATION vs. TEST NUMBER ASTM CBR - RED CLAY

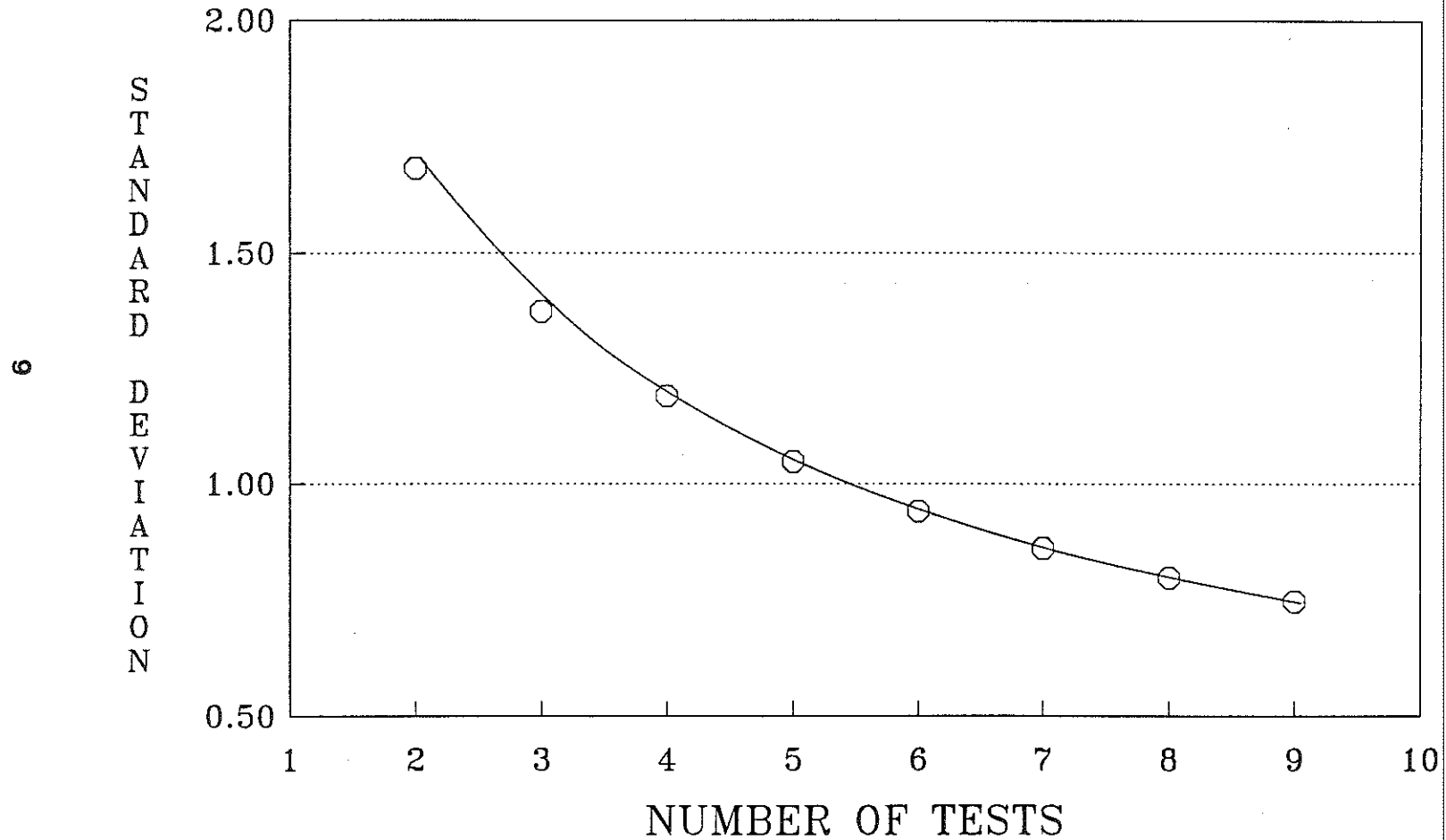


Figure 2.

# STANDARD DEVIATION vs. TEST NUMBER KENTUCKY CBR - GREEN CLAY

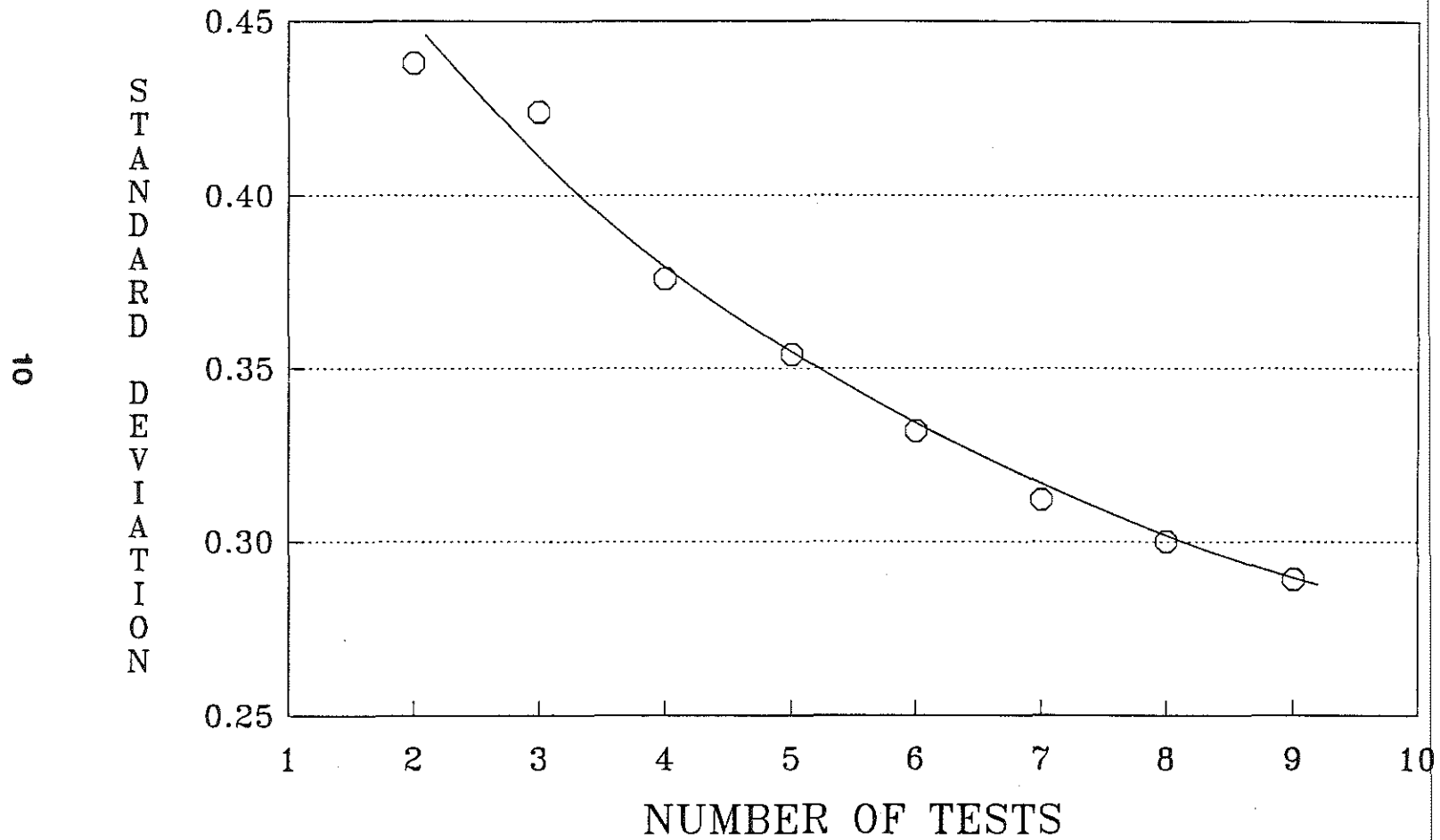
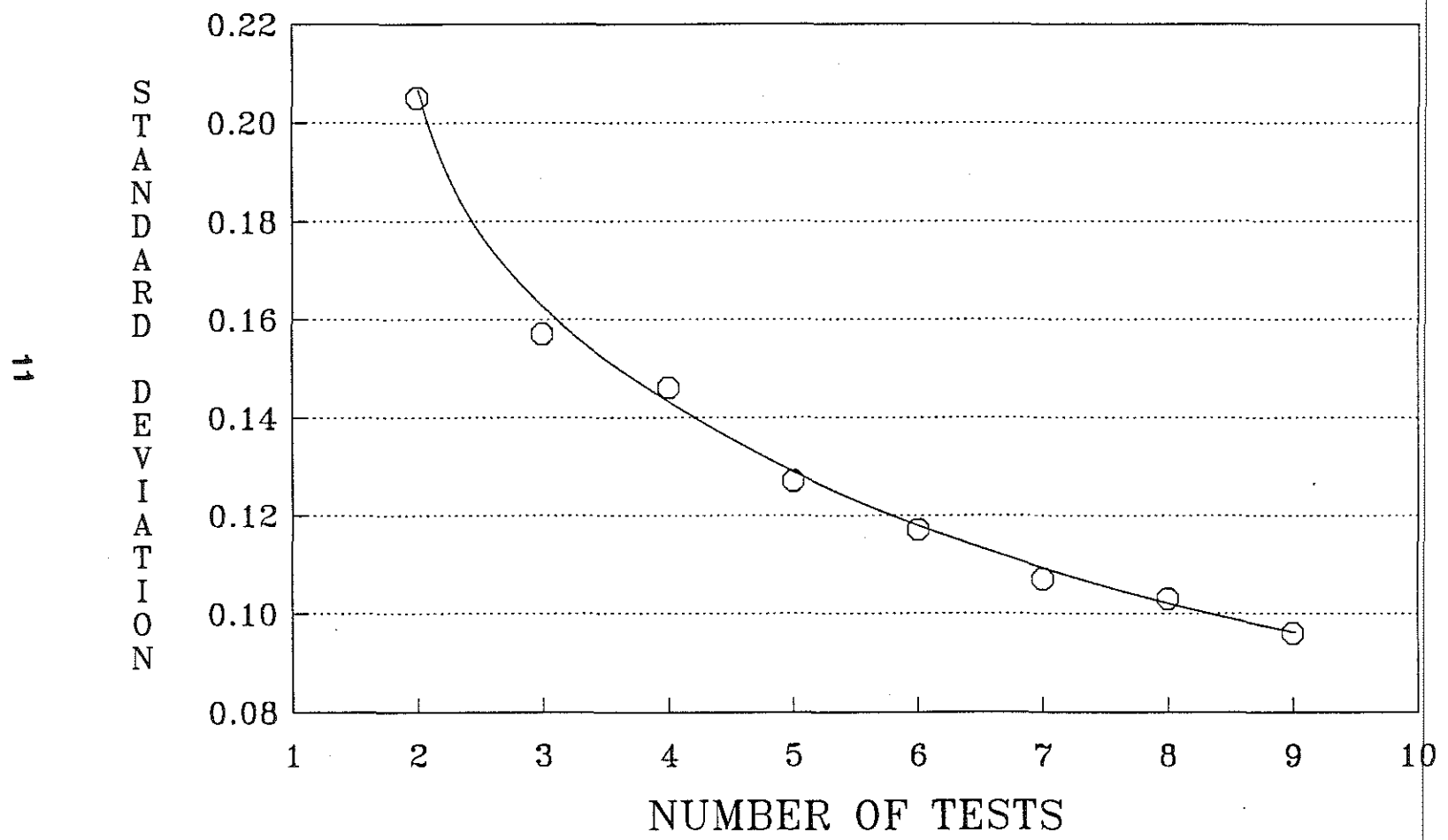


Figure 3.

# STANDARD DEVIATION vs. TEST NUMBER ASTM CBR - GREEN CLAY



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Figure 4.

# STANDARD DEVIATION vs. TEST NUMBER KENTUCKY CBR - BROWN CLAY

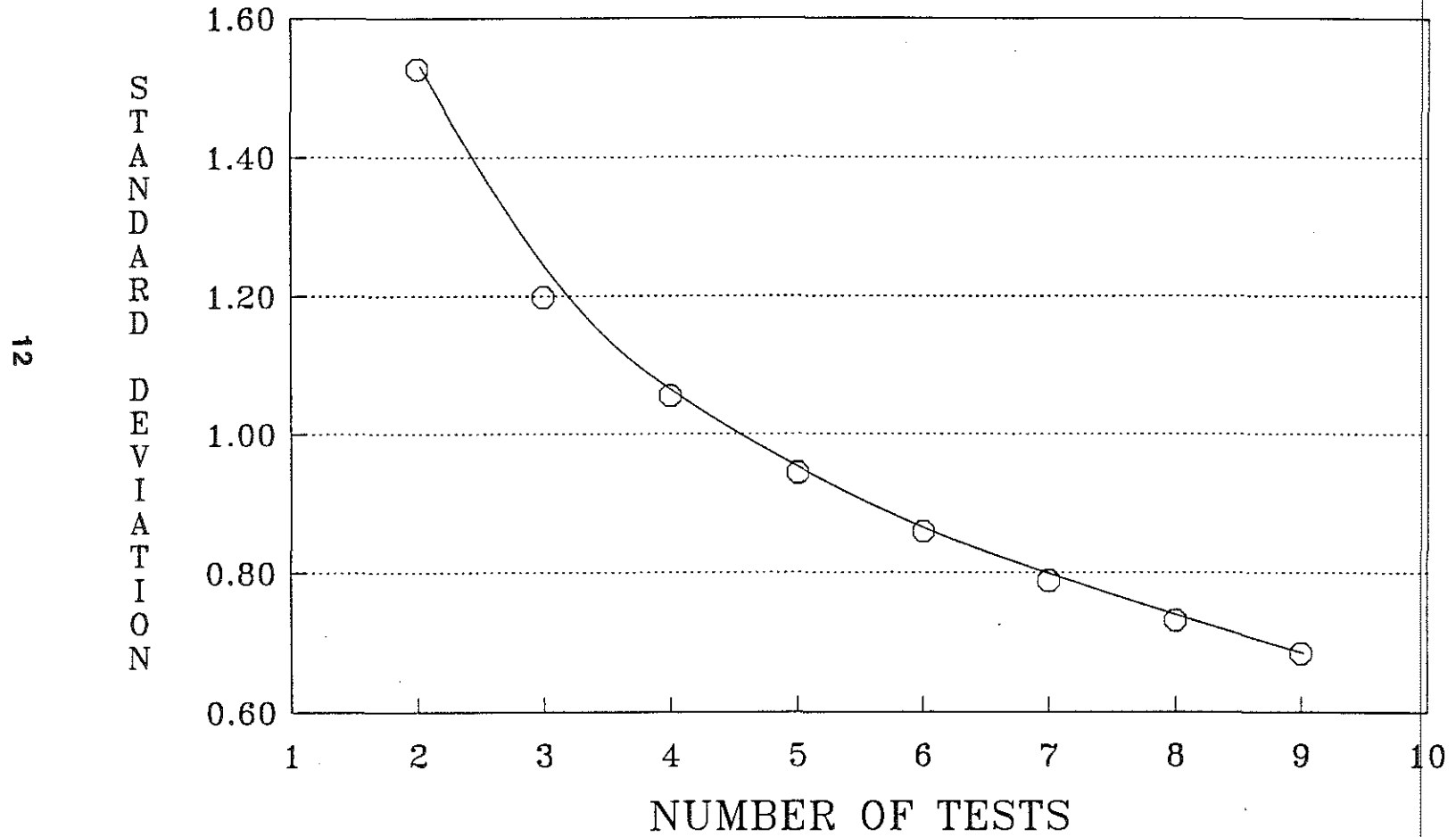


Figure 5.

# STANDARD DEVIATION vs. TEST NUMBER ASTM CBR - BROWN CLAY

13

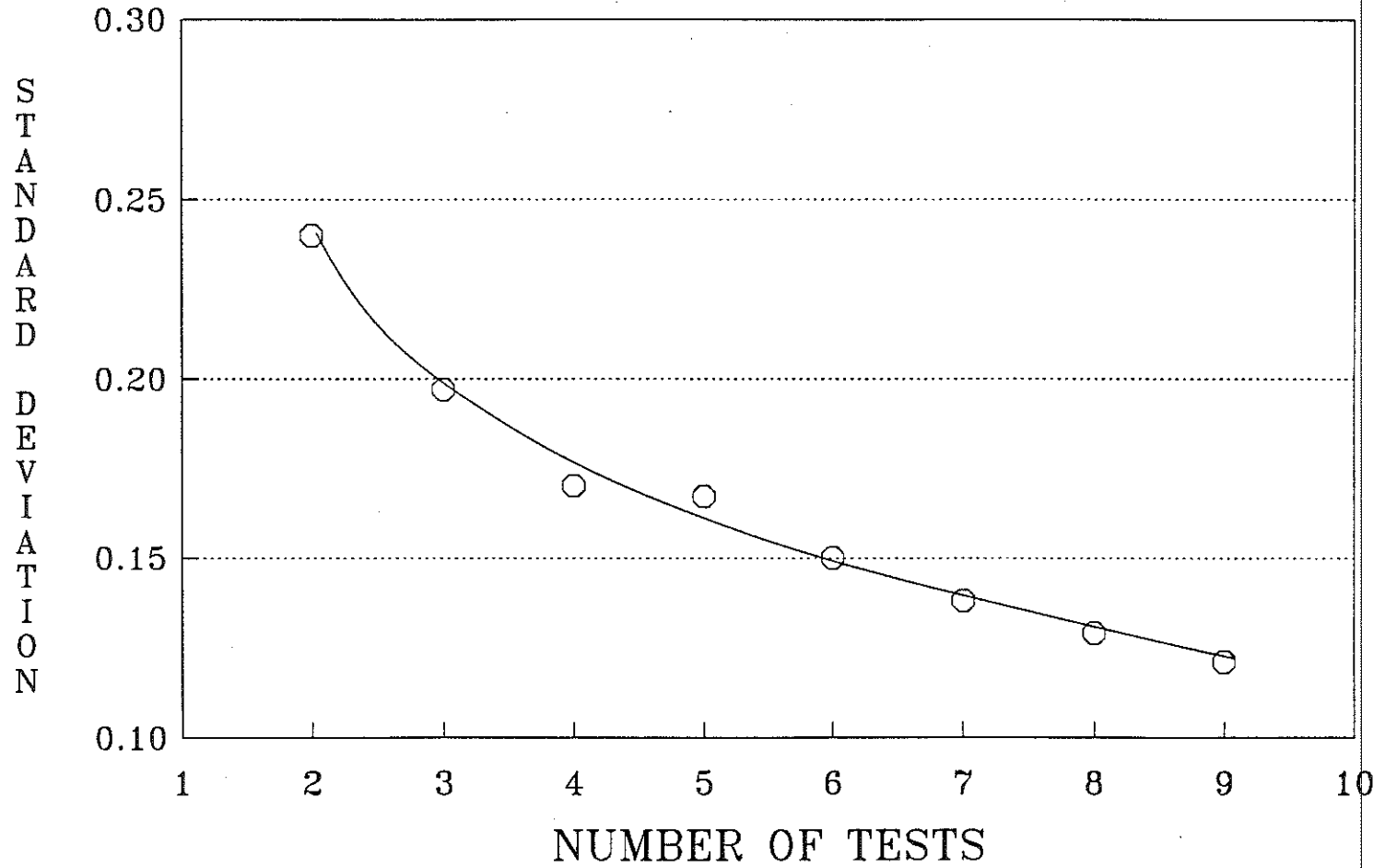


Figure 6.

# RED CLAY

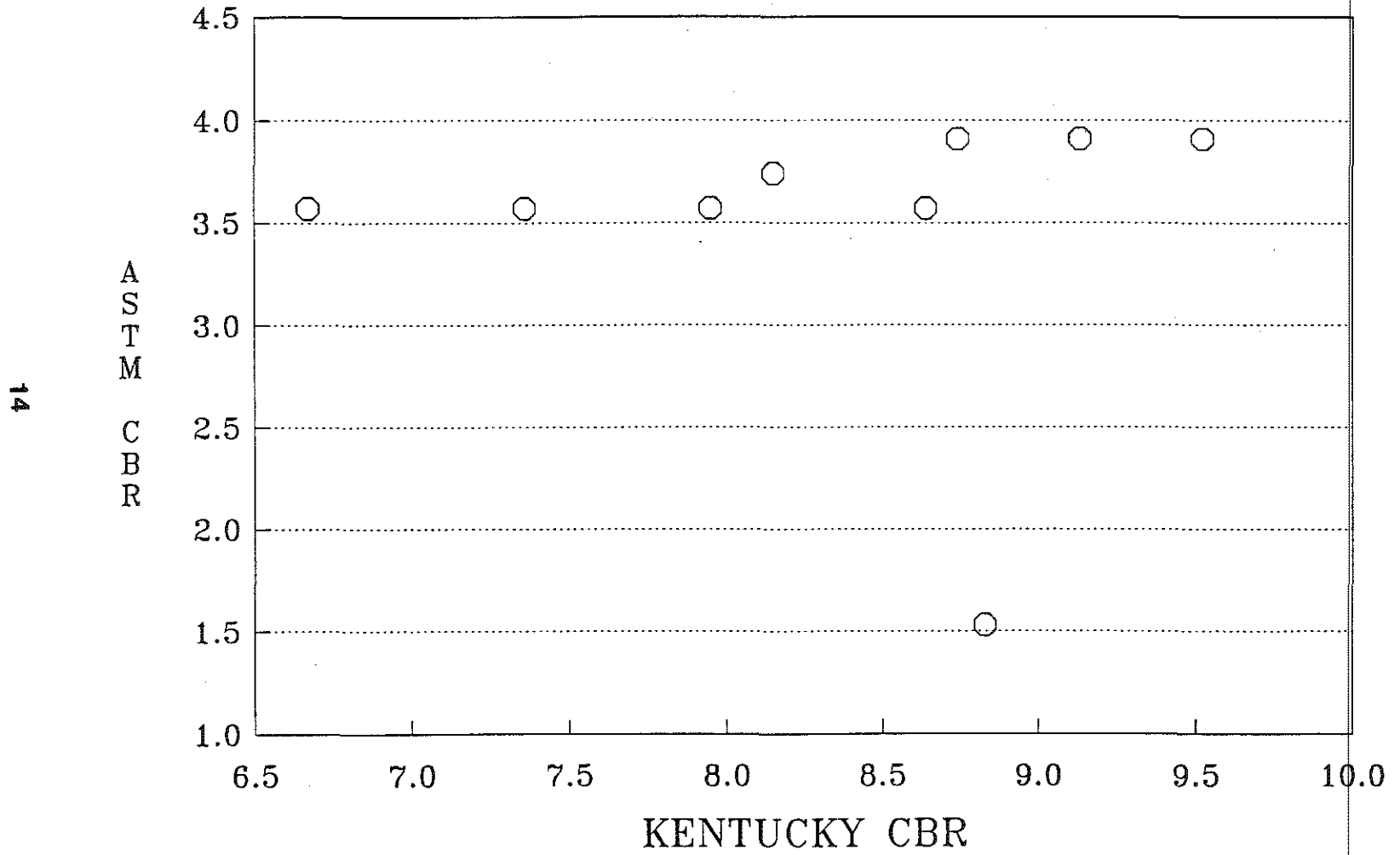


Figure 7.

# GREEN CLAY

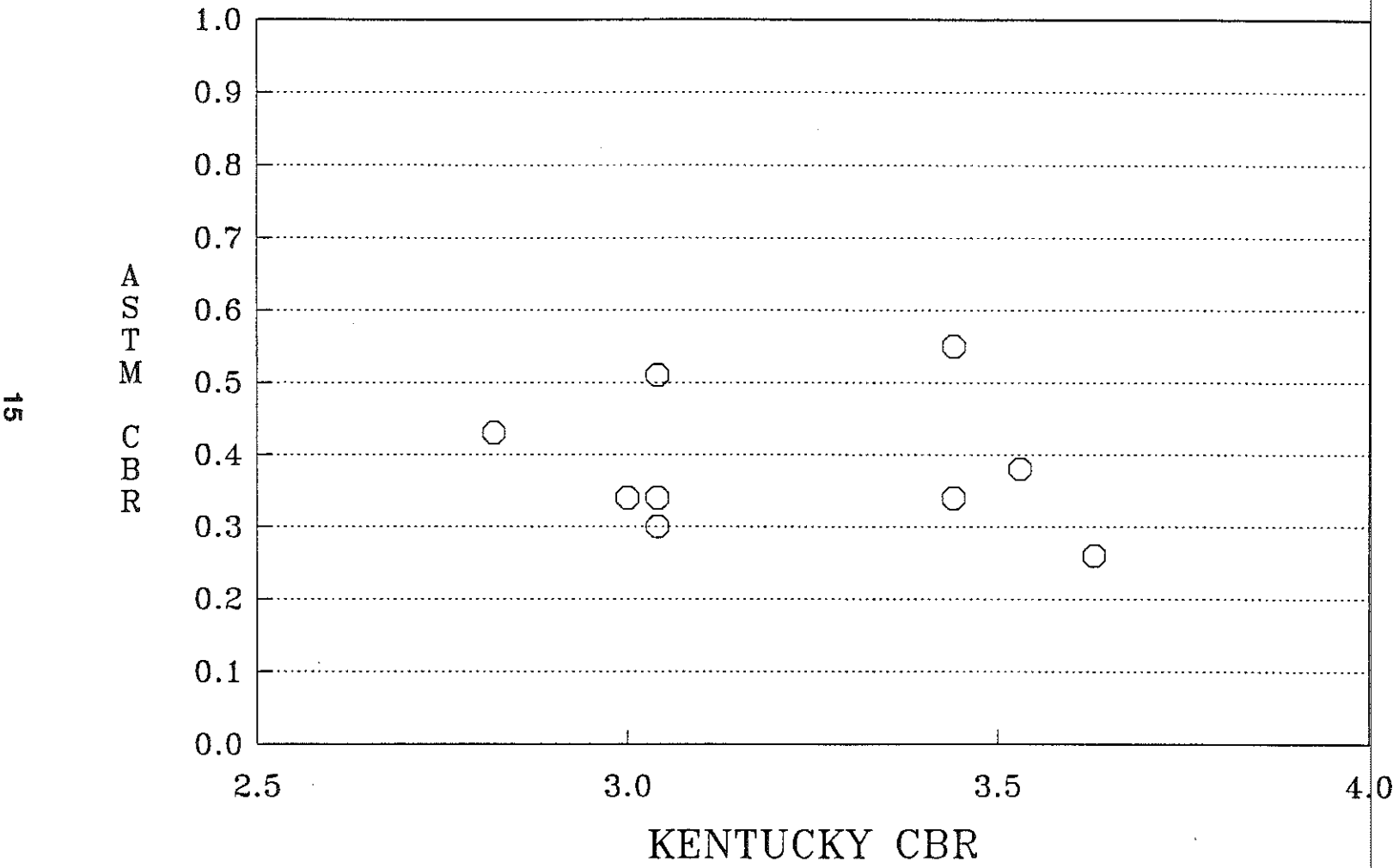


Figure 8.



# ASTM CBR vs. KENTUCKY CBR

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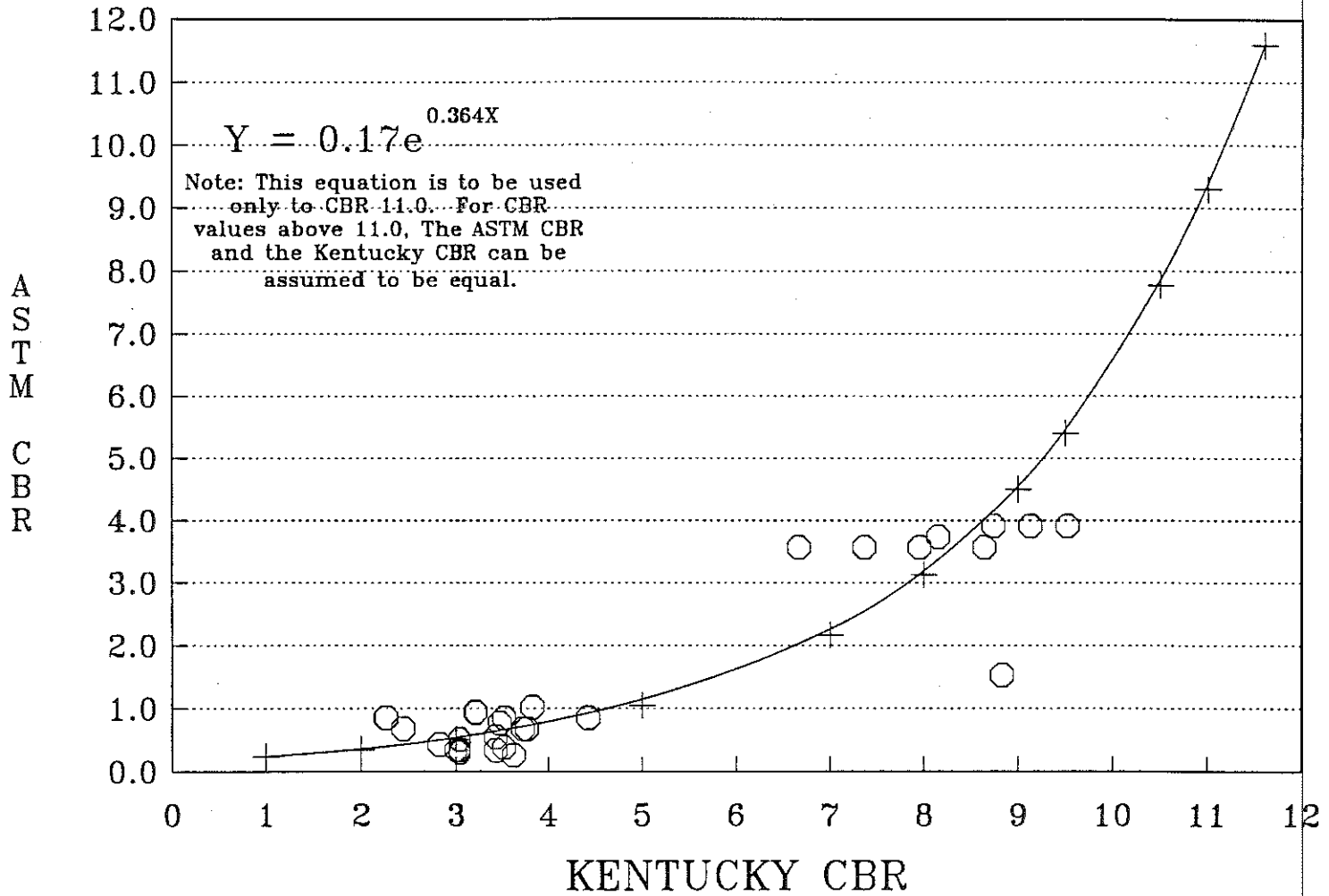


Figure 10.

LABORATORY RECORD OF SOIL TEST DATA

SAMPLE NUMBER	LL	PL	PI	SPGR	AASHTO	GI	USC
RED CLAY	63.0	25.7	37.3	2.75	A-7-6	(36)	CH

MECHANICAL SIEVE ANALYSIS

SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
1 IN	0.00	100.00
3/4 IN	0.00	100.00
1/2 IN	0.00	100.00
3/8 IN	0.00	100.00
NO. 4	0.00	100.00
NO. 10	12.12	98.60

HYDROMETER SIEVE ANALYSIS

SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
NO. 20	2.24	94.85
NO. 40	2.08	91.36
NO. 60	0.94	89.78
NO. 200	1.35	87.52

HYDROMETER ANALYSIS

TIME (MIN)	TEMP (°F)	HYD READING	PERCENT FINER	PARTICLE DIAMETER (MM)
1.00	67.00	54.00	83.52637	0.03597
2.00	67.00	53.00	81.88354	0.02572
5.00	68.00	49.00	75.51120	0.01685
15.00	69.00	44.00	67.49597	0.01014
30.00	69.00	40.00	60.92476	0.00743
60.00	71.00	37.00	56.32613	0.00531
240.00	73.00	33.00	50.32074	0.00271
1655.00	72.00	28.00	41.82378	0.00108

LABORATORY RECORD OF SOIL TEST DATA

SAMPLE NUMBER	LL	PL	PI	SPGR	AASHTO	GI	USC
GREEN CLAY	48.6	22.5	26.1	2.75	A-7-6	(24)	CL

MECHANICAL SIEVE ANALYSIS

SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
1 IN	0.00	100.00
3/4 IN	0.00	100.00
1/2 IN	0.00	100.00
3/8 IN	0.00	100.00
NO. 4	0.00	100.00
NO. 10	21.82	97.61

HYDROMETER SIEVE ANALYSIS

SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
NO. 20	2.02	94.15
NO. 40	1.50	91.58
NO. 60	0.91	90.02
NO. 200	2.33	86.03

HYDROMETER ANALYSIS

TIME (MIN)	TEMP (°F)	HYD READING	PERCENT FINER	PARTICLE DIAMETER (MM)
1.00	67.00	53.00	83.66284	0.03637
2.00	66.00	52.00	81.78120	0.02618
5.00	66.00	48.00	75.06721	0.01726
15.00	67.00	44.00	68.55632	0.01028
30.00	68.00	40.00	62.04546	0.00748
60.00	69.00	36.00	55.53461	0.00543
240.00	73.00	31.00	48.05717	0.00275
1639.00	73.00	25.00	37.98613	0.00110

LABORATORY RECORD OF SOIL TEST DATA

SAMPLE NUMBER	LL	PL	PI	SPGR	AASHTO	GI	USC
BROWN CLAY	42.1	32.1	10.0	2.75	A-5	(11)	CL

MECHANICAL SIEVE ANALYSIS

SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
1 IN	0.00	100.00
3/4 IN	0.00	100.00
1/2 IN	0.00	100.00
3/8 IN	0.00	100.00
NO. 4	0.00	100.00
NO. 10	2.34	99.72

HYDROMETER SIEVE ANALYSIS

SIEVE SIZE	WEIGHT RETAINED	TOTAL PERCENT PASSING
NO. 20	0.43	98.96
NO. 40	1.08	97.06
NO. 60	1.55	94.33
NO. 200	3.27	88.58

HYDROMETER ANALYSIS

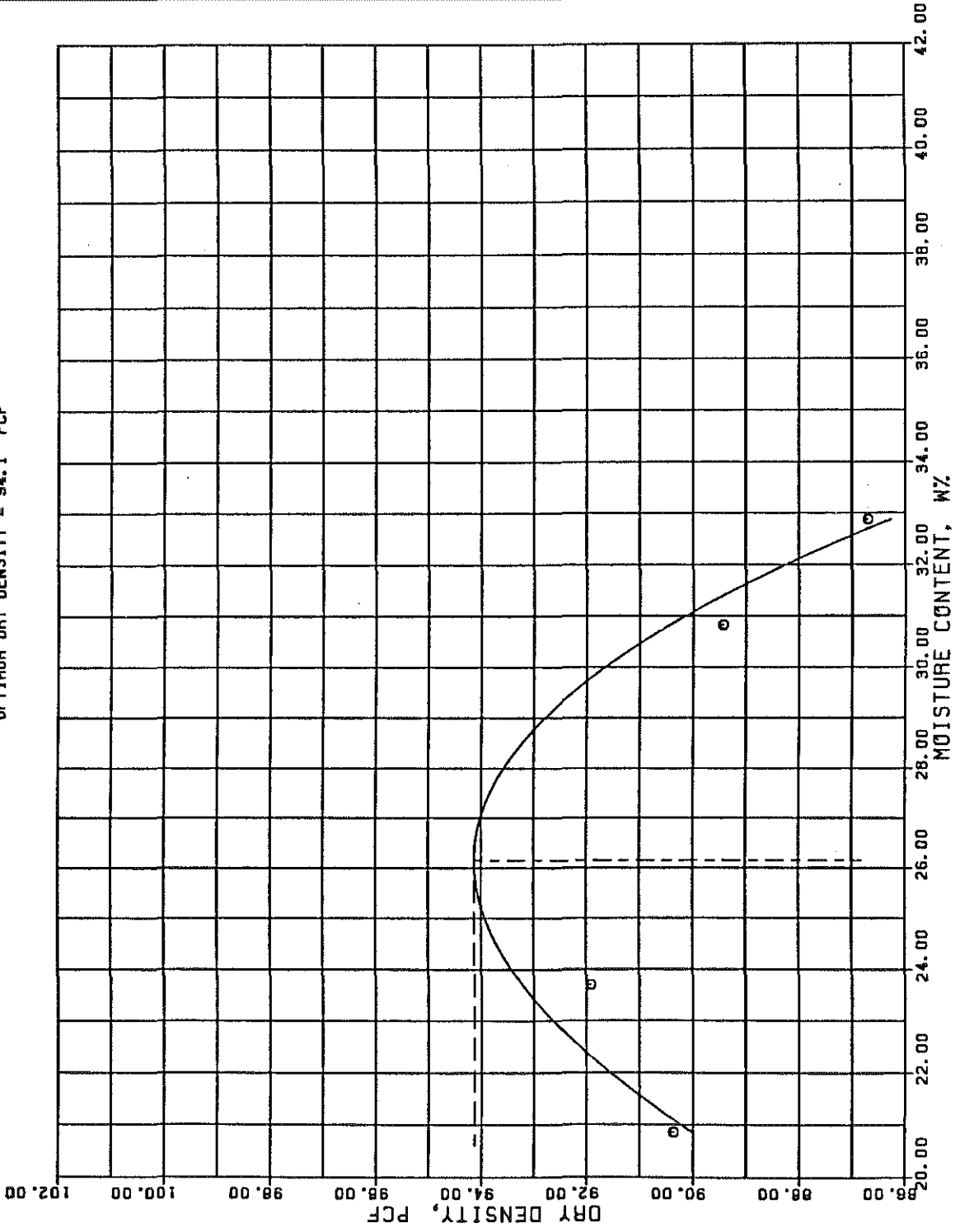
TIME (MIN)	TEMP (°F)	HYD READING	PERCENT FINER	PARTICLE DIAMETER (MM)
1.00	67.00	54.00	87.70959	0.03597
2.00	67.00	53.00	85.98453	0.02572
5.00	67.00	50.00	80.80930	0.01679
15.00	68.00	47.00	75.84285	0.00992
30.00	69.00	43.00	69.15132	0.00724
60.00	71.00	40.00	64.32237	0.00518
240.00	73.00	35.00	56.29112	0.00266
1696.00	71.00	31.00	48.79660	0.00105

01-16-90

RED CLAY

OPTIMUM MOISTURE CONTENT (%) = 26.2

OPTIMUM DRY DENSITY = 94.1 PCF

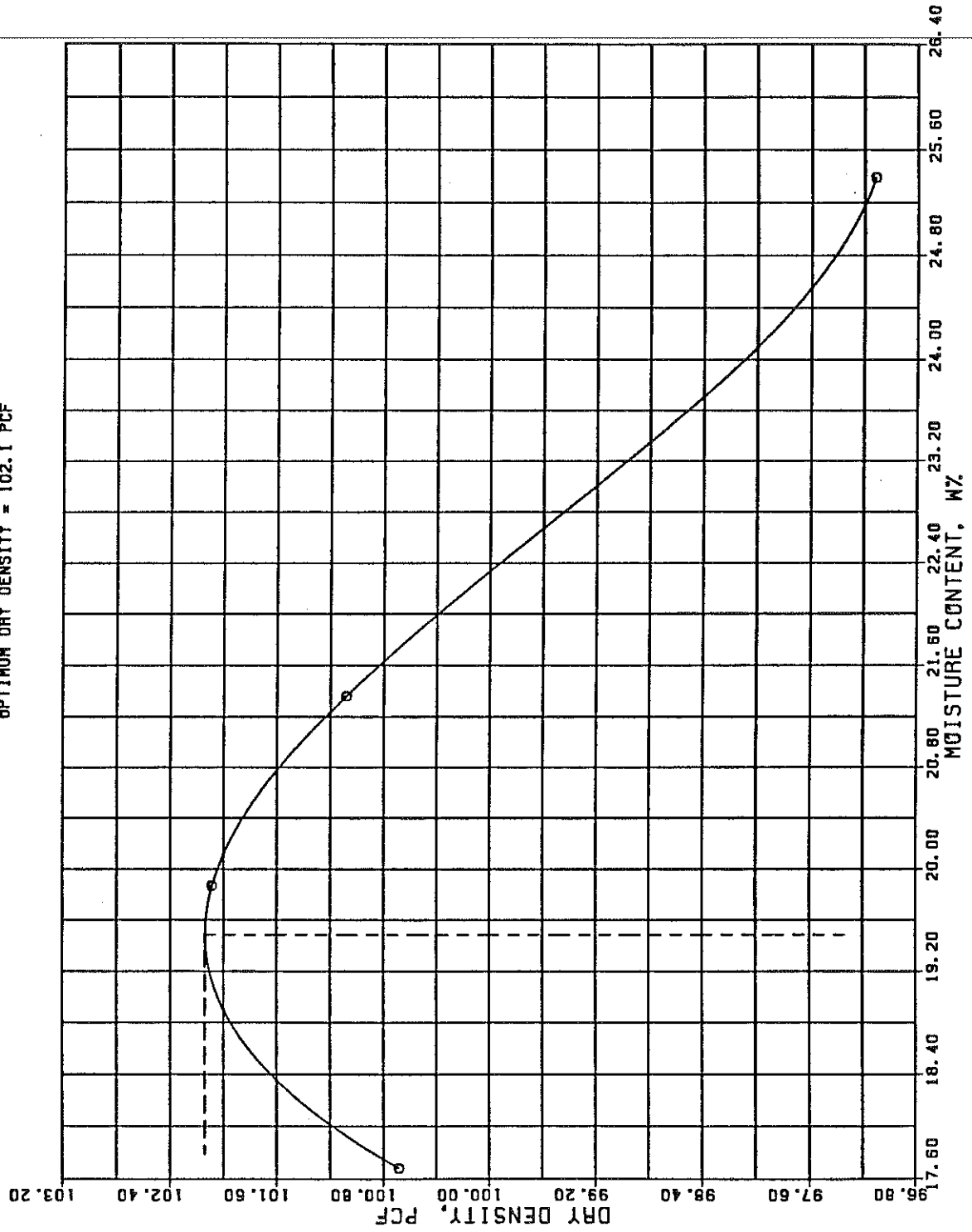


01-24-90

GREEN CLAY

OPTIMUM MOISTURE CONTENT (%) = 19.5

OPTIMUM DRY DENSITY = 102.1 PCF



01-26-90

BROWN CLAY

OPTIMUM MOISTURE CONTENT (%) = 25.9

OPTIMUM DRY DENSITY = 96.5 PCF

