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EFFECT OF STORAGE TIME AND TEMPERATURE ON CLAY SAMPLES

by
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PREFACE

When samples of clay are removed from the ground they are subjected to changes in both stress and temperature environment. This report describes an attempt to assess the effect of such changes in temperature environment over a five-month period on the strength of Leda clay from one site. Complementary studies are proceeding on the time-temperature effects on the physico-chemical properties of the same clay. Although this report cannot be considered to present conclusive evidence that such effects are negligible, it is hoped that the test information given will be useful to others concerned with storage effects on clay samples.

The work described was conducted in the Soil Mechanics Section of the Division and the report was prepared by a research officer in that Section.

Ottawa
January 1965

R. F. Legget
Director

EFFECT OF STORAGE TIME AND TEMPERATURE ON CLAY SAMPLES

by

W. J. Eden

In geotechnical investigations, it is sometimes necessary to store clay samples for a period of months at temperatures higher than the normal ground temperature. It has been noted that sealed samples stored for a year or more undergo changes in colour indicating that some physico-chemical activity is in process. Apart from some reference to the physico-chemical effects, the literature reveals little information on the effects of storage on the strength of clays. Thus it was decided to assess the storage effects by unconfined compression tests on undisturbed samples. Unconfined compression tests were conducted at storage times varying from zero to five months. This report presents the results obtained.

THE SAMPLES

It was possible to obtain four block samples from a tunnel face in Leda clay, 52 ft below the surface (Elevation 165 ft). Special precautions were taken to ensure that the temperature history of the samples was known.

The temperature of the clay face was 44°F, approximately 4° below the mean ground temperature for the Ottawa area. The blocks were obtained from two benches cut in the tunnel face, one immediately above the other. Two samples were taken from each bench with approximately 4 in. between each sample. The two samples from the upper bench were designated 136-3 and from the lower bench, 136-4. The clay at this site had a stiff consistency and behaved as a brittle material in spite of its extreme sensitivity. The geotechnical information for the samples is presented in Table I.

The blocks were taken during the noonhour break of the tunnelling crew on 18 December 1963. At the time, the outside air temperature was about 10°F. As soon as the samples were cut, they were wrapped in a mineral wool insulation blanket, hoisted to the surface and transported about 2 miles by truck to the laboratory.

They were immediately brought into a humid room with the temperature controlled at 55°F where they were cut into 2-in. by 2-in. by 6-in. prisms as indicated on the test schedule shown in Figure 1.

Samples to be tested immediately or at one day were wrapped in plastic film to prevent moisture changes. Those to be stored for longer periods were wrapped in film and dipped in petroleum wax. Two thirds of the samples remained in the humid room, and the remaining third were further wrapped in a polythene bag and stored in a water tank with the temperature controlled at 85°F until they were trimmed and tested in the laboratory. One third of the samples were stored in the humid room where they were tested at 55°F. One third were stored in the humid room but were trimmed and tested in the laboratory at 70 to 75°F. Thus, one third of the samples had the following temperature history: 48°F → 44°F → 55°F; the second third, 48°F → 44°F → 55°F → 75°F; and the final third 48°F → 44°F → 55°F → 85°F → 75°F.

Before conducting the unconfined compression tests, each prism was trimmed to a standard size of 1.4 in. by 3 in. long. Densities and water contents were determined on the specimens, and classification tests were conducted on the trimmings. The unconfined compression tests were conducted on a gear-driven constant rate of strain apparatus, the rate of strain being $\frac{1}{2}$ %/min.

TEST RESULTS

Seventy-five tests were made on the two samples. The result of each test specimen is tabulated in Appendix A, and the average results at the end of each storage period are presented in Tables II, III and IV. It was found that all of the test specimens failed at less than one per cent strain. The usual failure pattern was one of vertical splitting rather than a clearly defined single shear plane.

To find statistical averages all the results from sample 136-3 and 136-4 were assembled, and averages and standard deviations were determined. The process was repeated for the two samples combined. These results are presented in Table V.

The results were then assembled according to their storage temperature and test temperature without regard to time. These results are presented in Table VI.

It will be noted that the samples stored at 85°F yielded a slightly higher strength but their water contents were slightly lower. The results of time studies are presented in Figures 2, 3 and 4 and show no indication of change in strength with time. Tables II, III and IV do not indicate any change in water content with time.

In Figure 5, the results of density and water content determinations are plotted. Lines of regression have been established between the

density and water content. This figure demonstrates the variability which occurs within samples of a clay of uniform appearance.

CONCLUSIONS

1. The experiments described show no significant effect of storage temperature over the 5-month test period. Variations found for the various storage times and temperatures appear to fall within the variations which might be expected in a sample.

2. High storage temperatures show slightly higher strengths than average, but this may be attributed to a slightly lower water content than the average. It cannot be determined whether this trend in water contents was due to the higher temperatures or to the random distribution of water contents.

TABLE I

GEOTECHNICAL PROPERTIES

Sample No.	136-3	136-4
W_N, %	70.0 ± 3	69.0 ± 2
W_L, %	50.0	45.0
W_p, %	27.0	27.0
I_p, %	23.0	18.0
I_L, %	1.9	2.3
% Clay Size	80.0	79.0
Specific Gravity	2.84	2.83
Pore Water Salt Concentration, gm/l	0.1	0.3
γ, lb/cu ft	99.6 ± 1.3	100.2 ± 1.0
Preconsolidation Pressure - kg/cm^2	-	3.4

NOTE:

W_N = natural water content.

W_L = liquid limit.

W_p = plastic limit.

I_p = plasticity index.

I_L = liquidity index.

γ = wet density.

TABLE II

SUMMARY OF TEST RESULTS ON SAMPLES STORED AND TESTED AT 55°F

Storage Time, Days	Sample	No. of Tests	Av. W_N, %	Av. γ, lb/cu ft	Av. q_u, kg/cm^2	Av. ϵ_f, %
1	136-3	3	70.3	100.3	2.44	0.80
1	136-4	4	68.8	101.0	2.48	0.85
1	Combined	7	69.5	100.7	2.46	0.83
2	136-3	3	72.3	100.1	2.34	0.80
2	136-4	3	66.8	101.6	2.24	0.80
2	Combined	6	69.6	100.8	2.29	0.80
9	136-3	3	72.6	98.9	1.93	0.63
9	136-4	3	68.6	100.5	2.16	0.73
9	Combined	6	70.2	99.7	2.03	0.68
32	136-3	3	65.3	101.4	2.20	0.77
32	136-4	3	70.2	98.7	2.19	0.70
32	Combined	6	67.8	100.1	2.20	0.73
145	136-3	3	72.6	98.2	2.26	0.77
145	136-4	3	68.9	89.6	2.02	0.69
145	Combined	6	70.7	98.9	2.14	0.73

NOTE: q_u = compressive strength.

ϵ_f = unit strain at failure.

TABLE III

SUMMARY OF TEST RESULTS ON SAMPLES STORED AT 55°F AND TESTED AT 75°F

Storage Time, Days	Sample	No. of Tests	Av. W_N, %	Av. γ, lb/cu ft	Av. q_u, kg/cm^2	Av. ϵ_f, %
1	136-3	3	72.5	97.9	2.13	0.73
1	136-4	3	70.4	99.3	1.92	0.77
1	Combined	6	71.4	98.6	2.03	0.75
2	136-3	2	70.2	100.7	2.47	0.85
2	136-4	3	66.8	101.0	2.48	0.80
2	Combined	5	69.4	100.9	2.48	0.82
9	136-3	2	73.0	98.7	1.76	0.50
9	136-4	3	67.9	100.5	1.94	0.77
9	Combined	5	69.9	99.8	1.87	0.66
32	136-3	2	66.0	100.5	3.00	0.85
32	136-4	3	71.1	98.9	2.03	0.80
32	Combined	5	69.1	99.6	2.42	0.82
145	136-3	2	71.1	99.0	1.42	0.76
145	136-4	3	68.0	100.3	2.18	0.79
145	Combined	5	69.2	99.8	1.87	0.78

TABLE IV

SUMMARY OF TEST RESULTS ON SAMPLES STORED AT 85°F AND TESTED AT 75°F

Storage Time, Days	Sample	No. of Tests	Av. W_N, %	Av. γ, lb/cu ft	Av. q_u, kg/cm^2	Av. ϵ_f, %
9	136-3	3	68.9	99.6	2.62	0.72
9	136-4	3	66.1	100.8	2.15	0.72
9	Combined	6	67.5	100.2	2.38	0.72
32	136-3	3	64.9	100.9	2.79	0.83
32	136-4	3	70.2	100.1	2.23	0.80
32	Combined	6	67.5	100.5	2.61	0.82
145	136-3	3	72.3	98.3	2.61	0.83
145	136-4	3	67.8	99.9	2.21	0.80
145	Combined	6	69.9	99.1	2.41	0.82

TABLE V

AVERAGE RESULTS OF ALL TESTS ON SAMPLES

Sample	No. of Tests	W_N, %	σ (Standard deviation)	γ lb/cu ft	σ	q_u, kg/cm^2	σ
136-3	35	70.1	± 3.4	99.6	± 1.3	2.32	± 0.62
136-4	40	68.7	± 1.8	100.2	± 1.0	2.19	± 0.28
Combined	75	69.3	± 2.7	99.9	± 1.2	2.25	± 0.46

TABLE VI

RESULTS OF TESTS AT VARIOUS STORAGE AND TEST CONDITIONS

Sample	Storage Temp., °F	Test Temp., °F	No. of Tests	Av. W_N, %	Av. q_u, kg/cm^2
136-3	55	55	15	70.6	2.23
136-4	55	55	16	68.7	2.23
Combined	55	55	31	69.6	2.23
136-3	55	75	11	70.7	2.15
136-4	55	75	15	68.8	2.11
Combined	55	75	26	69.6	2.13
136-3	85	75	9	68.7	2.67
136-4	85	75	9	68.0	2.20
Combined	85	75	18	68.4	2.43

APPENDIX A

RESULTS OF INDIVIDUAL TESTS

Test No.	Storage Time, Days	Storage Temp., °F	Test Temp., °F	W_N, %	γ, lb/cu ft	q_u, kg/cm^2	ϵ_f, %	Type of Failure
136-3-A4	1	55	55	68.0	101.4	3.09	0.9	Split
-C4	1	55	55	71.9	99.5	1.15	0.6	"
-D5	1	55	55	71.0	100.1	3.09	0.9	"
136-4-A5	1	55	55	69.5	101.0	2.73	0.9	"
-A9	1	55	55	65.8	102.7	2.28	0.7	"
-D5	1	55	55	70.6	100.2	2.42	0.9	"
-D9	1	55	55	69.4	100.2	2.47	0.9	Shear
136-3-B2	1	55	75	71.5	98.4	2.51	0.7	Split
-E2	1	55	75	75.2	96.6	1.53	0.8	"
-C7	1	55	75	71.2	98.6	2.35	0.7	"
136-4-C6	1	55	75	69.3	98.8	1.58	0.7	"
-C3	1	55	75	70.7	99.5	2.08	0.9	"
-B7	1	55	75	70.2	99.5	2.11	0.7	"
136-3-B5	2	55	55	74.2	100.0	2.95	0.8	"
-C1	2	55	55	72.2	99.6	2.47	1.0	"
-D7	2	55	55	70.6	100.6	1.60	0.6	Shear
136-4-A6	2	55	55	66.8	101.7	2.31	0.8	Split
-B2	2	55	55	67.0	101.4	1.92	0.8	"
-B10	2	55	55	66.6	101.6	2.49	0.8	"
136-3-A6	2	55	75	72.6	99.7	2.93	0.9	"
-E4	2	55	75	67.8	101.7	2.00	0.8	"
136-4-A3	2	55	75	69.1	100.9	2.57	0.8	Shear
-C1	2	55	75	67.0	101.6	2.46	0.8	Combined
-D7	2	55	75	70.3	100.4	2.42	0.8	Split
136-3-A2	9	55	55	—	99.3	2.58	0.7	"
-C3	9	55	55	72.6	98.1	2.08	0.7	"
-D4	9	55	55	72.5	99.3	1.14	0.5	Shear

Test No.	Storage Time, Days	Storage Temp., °F	Test Temp., °F	W_N, %	γ, lb/cu ft	q_u, kg/cm^2	ϵ_f, %	Type of Failure
136-4-A2	9	55	55	66.8	100.7	1.84	0.7	Split
-B8	9	55	55	69.4	100.7	2.20	0.7	"
-C7	9	55	55	69.7	100.0	2.44	0.8	"
136-3-A7	9	55	75	72.7	99.2	2.26	0.6	"
-D1	9	55	75	73.2	98.2	1.26	0.4	"
136-4-B3	9	55	75	67.4	101.3	1.72	0.7	"
-C4	9	55	75	68.5	99.8	2.27	0.8	"
-C10	9	55	75	67.7	100.5	1.84	0.8	"
136-3-B4	9	85	75	64.1	99.4	2.49	0.85	"
-C6	9	85	75	71.1	100.0	3.13	0.8	"
-E6	9	85	75	71.4	99.3	2.25	0.5	Shear
136-4-A7	9	85	75	65.5	101.2	2.40	0.7	Split
-B1	9	85	75	66.0	101.0	2.24	0.7	Shear
-D2	9	85	75	66.9	100.3	1.80	0.75	Split
136-3-B6	32	55	55	64.8	102.3	2.04	0.8	"
-C2	32	55	55	66.2	100.7	2.45	0.75	"
-E7	32	55	55	64.8	101.2	2.11	0.75	"
136-4-B5	32	55	55	71.4	98.7	2.26	0.7	"
-B9	32	55	55	70.5	99.1	2.10	0.7	"
-B4	32	55	55	68.8	98.4	2.21	0.7	"
136-3-A1	32	55	75	65.4	100.7	3.10	0.9	"
-E1	32	55	75	66.7	100.3	2.91	0.8	"
136-4-D3	32	55	75	70.9	98.2	1.96	0.7	"
-D10	32	55	75	71.6	98.6	1.98	0.8	"
-A1	32	55	75	70.9	100.0	2.14	0.9	"
136-3-A5	32	85	75	64.8	100.8	2.78	0.8	Combined
-B3	32	85	75	64.8	101.5	2.79	0.8	Split
-D3	32	85	75	65.1	100.3	2.79	0.9	"

Test No.	Storage Time, Days	Storage Temp., °F	Test Temp., °F	W_N, %	γ, lb/cu ft	q_u, kg/cm^2	ϵ_f, %	Type of Failure
136-4-AB	32	85	75	69.6	100.2	2.57	0.9	Split
-C2	32	85	75	70.3	99.5	2.28	0.8	Shear
-C8	32	85	75	70.6	100.7	2.45	0.7	Split
136-3-C5	145	55	55	71.3	98.3	2.15	0.7	"
-D2	145	55	55	75.8	97.6	1.44	0.7	"
-D6	145	55	55	70.6	98.6	3.18	0.9	"
136-4-B6	145	55	55	67.7	99.6	1.42	0.6	"
-C5	145	55	55	70.2	99.8	2.54	0.8	"
-C9	145	55	55	68.7	99.4	2.10	0.65	"
136-3-A3	145	55	75	70.2	99.2	1.41	0.8	Combined
-E5	145	55	75	72.0	98.9	1.42	0.7	Shear
136-4-D4	145	55	75	68.0	99.6	2.12	0.8	Combined
-D1	145	55	75	66.0	101.3	1.98	0.7	Split
-D6	145	55	75	70.0	100.1	2.43	0.7	Combined
136-3-B1	145	85	75	70.5	98.8	2.38	0.6	Split
-B7	145	85	75	71.4	98.4	2.98	0.9	"
-E3	145	85	75	75.1	97.7	2.48	1.0	Combined
136-4-A4	145	85	75	68.3	100.0	2.22	0.8	Split
-A10	145	85	75	65.4	101.0	2.13	0.8	"
-D8	145	85	75	69.0	98.7	2.29	0.8	Combined

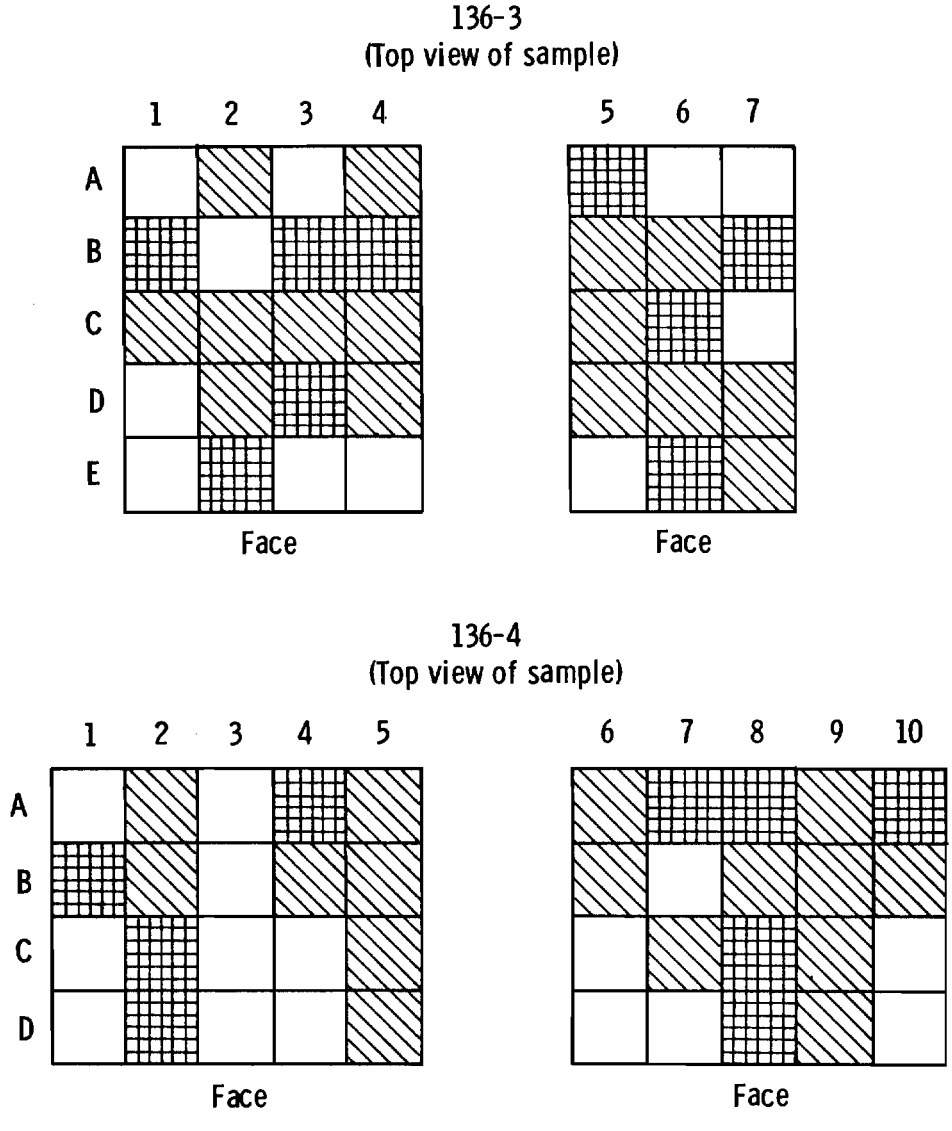

FIGURE 1 TEST SCHEDULE

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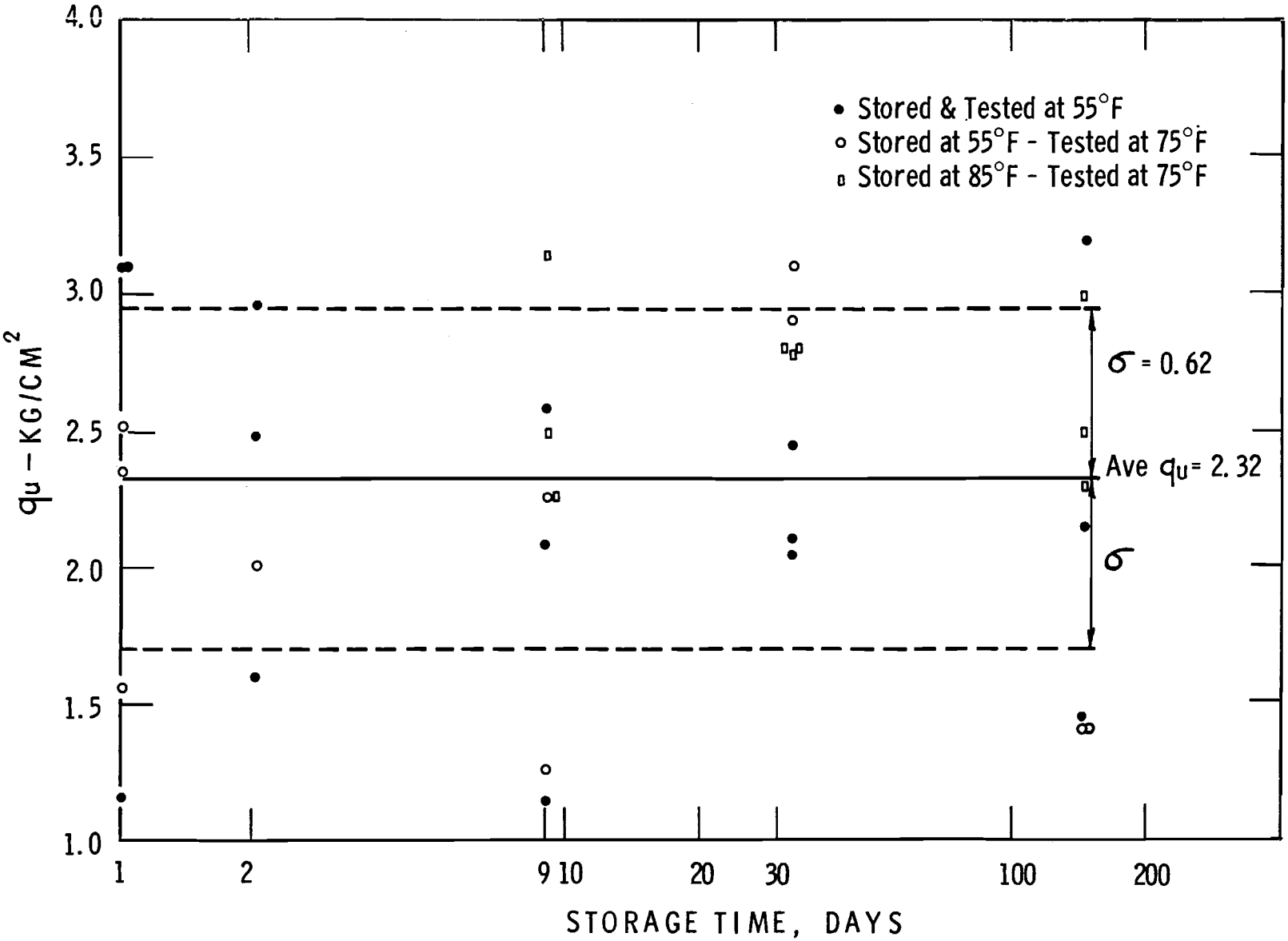

FIGURE 2

UNCONFINED COMPRESSION TESTS - 136-3

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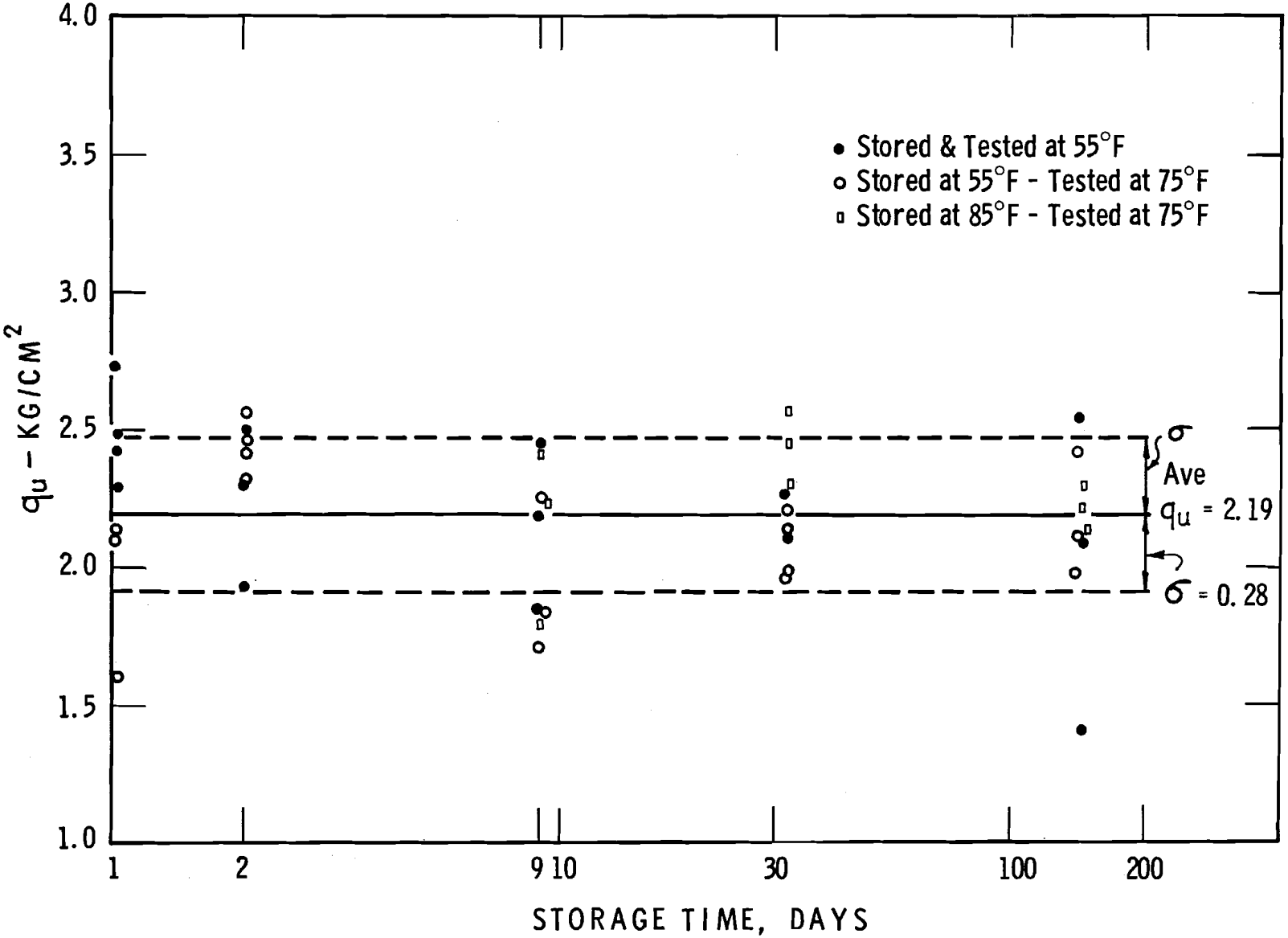

FIGURE 3

UNCONFINED COMPRESSION TESTS - 136-4

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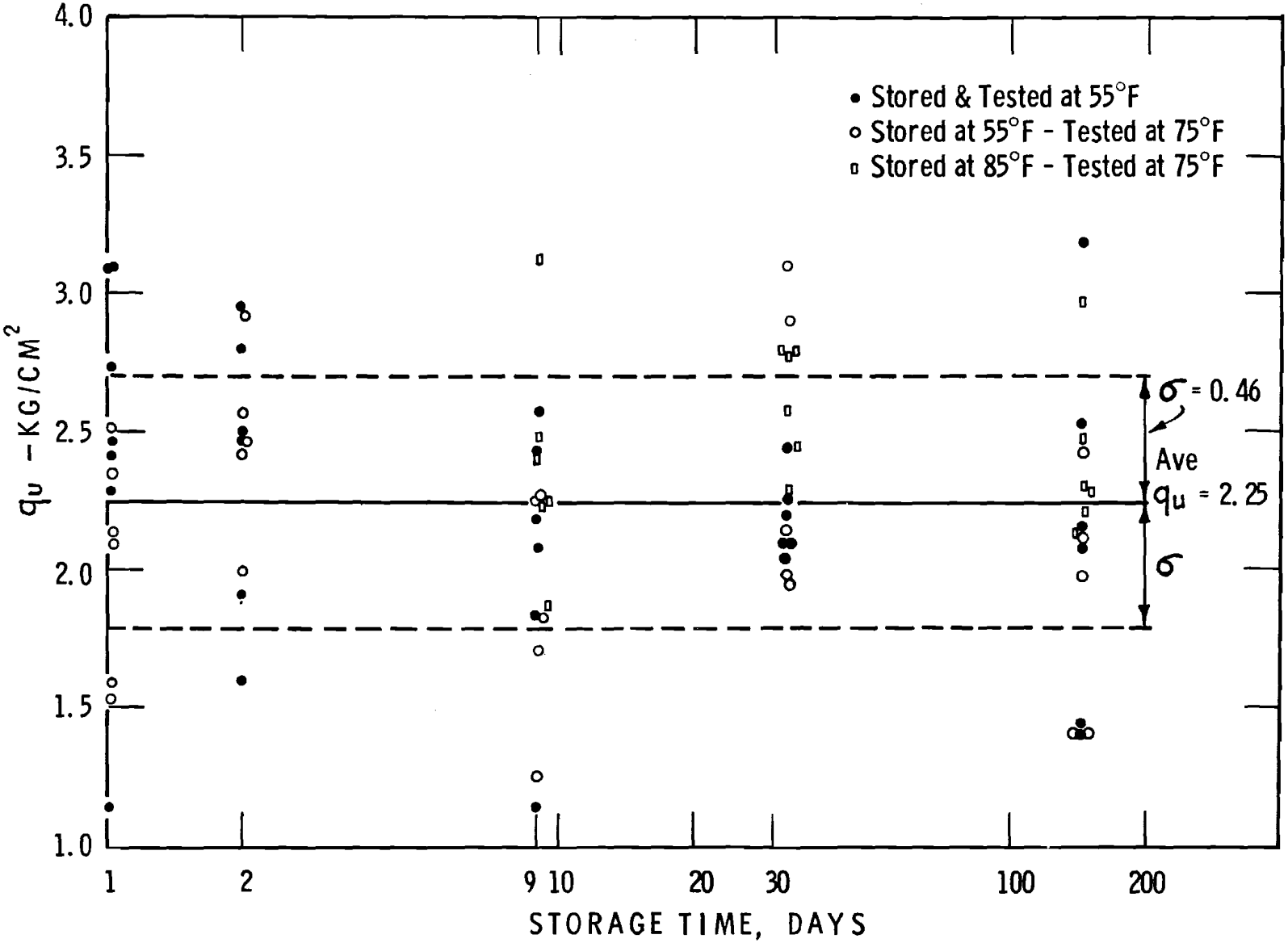

FIGURE 4

UNCONFINED COMPRESSION TESTS, COMBINED SAMPLES

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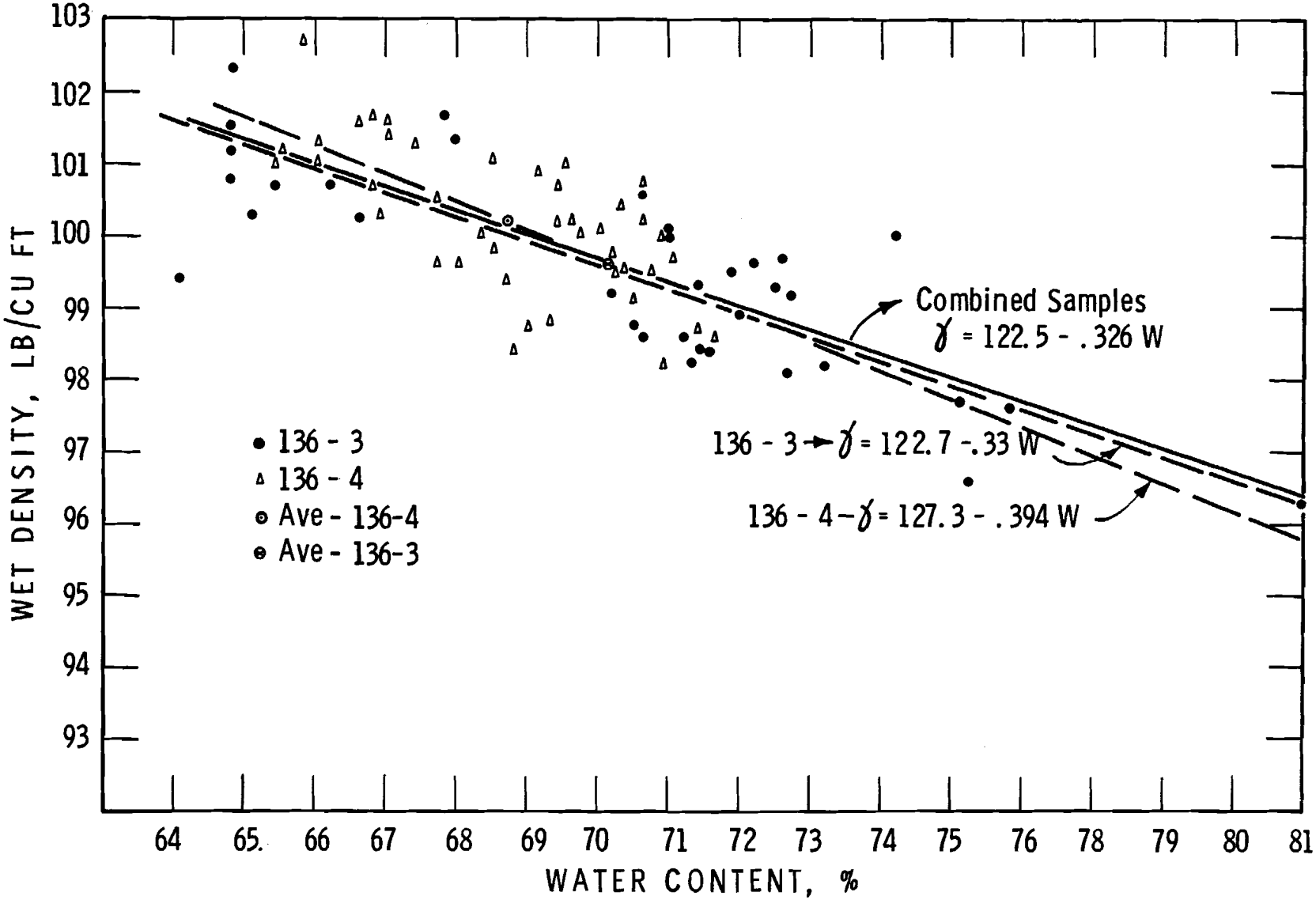

FIGURE 5

RELATION BETWEEN WATER CONTENT & WET DENSITY FOR TWO BLOCK SAMPLES

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