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TRIAXIAL TESTS ON LEDA CLAY

by

C. B. Crawford

Internal Report No. 269

of the

Division of Building Research

OTTAWA

April 1963

PREFACE

It has not been possible in papers published by the Division on its shear research on Leda clay to include a complete record of all tests. Several workers who wanted to make a detailed study of the tests have asked for more complete information. This report provides supplementary information on the more important tests and should therefore be used together with the quoted references. The author, a civil engineer, is Head of the Soil Mechanics Section, DBR/NRC.

Ottawa
April 1963

R. F. Legget
Director

TRIAXIAL TESTS ON LEDA CLAY

by

C. B. Crawford

General engineering properties of Leda clay have been recorded (1) but this record is far from complete. Detailed studies of shear strength have been confined to samples from the Ottawa area. Earlier tests on tube samples indicated the need for fundamental studies on good undisturbed block samples. At every opportunity, therefore, block samples have been obtained from deep excavations.

To date it has been possible to carry out comprehensive tests on specimens cut from relatively uniform layers of undisturbed block samples obtained from three locations. The average properties of the soil in these blocks are given in Table I. All specimens were saturated and undisturbed.

TESTS AND TEST RESULTS

The first series of consolidated undrained (CU) tests, designed to investigate the influence of rate of strain on test results, has been published (2). Detailed supplementary information on each test is given in Table II of this present report. Consolidated drained (CD) tests with increasing axial stress resulted in such distortion of the soil that the tests were judged to be unsatisfactory. Detailed information for each consolidated drained test specimen is given in Table III and the stress-strain curves are shown in Figure 10 of Reference (2).

The second series of consolidated undrained tests, designed to investigate the influence of axial strain on test results and interpretation, has been published (3). Further detailed information on each test is given in Tables IV and V. The consolidated drained tests on this soil have not been published and are reported in Table VI and Figures 1 to 8.

These consolidated drained tests were considered to confirm the earlier interpretation that the ordinary consolidated drained test with axial loading is an unsatisfactory test method. Figures 1 to 4 show the normal trend of continuing increase in deviator stress at strains in excess of 20 per cent. This may prove to be a test of the remoulded soil but cannot be considered to represent the performance of the undisturbed soil. Figures 5 and 6 illustrate similar performance of specimens from an adjacent block.

Consolidated drained tests with axial stress decreasing may be better suited to this material; Figures 7 and 8 show results of such tests. Each specimen was first consolidated and then the lateral stress was decreased in stages while the axial stress remained constant. In these cases, it was possible to apply about 3/4 of the ultimate shear stress under fully drained conditions while axially straining the specimen by only 1 per cent. Further increases in the shearing stress would cause much greater axial strain until the last increment causes failure (probably under only partially drained conditions).

The volume changes noted on Figures 7 and 8 are probably unreliable. Due to the long duration of the test the independently estimated magnitude of membrane leakage is of the same order as the measured volume change. Assessment of membrane leakage is difficult but in the average stress range of these tests it may amount to about 0.1 cm^3 per day or 1.5 cm^3 during the period of shear. Membrane leakage may in fact account for most of the measured volume change during the long shearing period of tests 96-3-3 and 96-3-4. Since volume change during the consolidation stage is computed by subtracting volume change during the period of shear from total volume change this may account for the lower than average ΔV_c recorded for these two tests.

A third series of tests, designed to investigate shear at low effective stress levels, has been completed and is in process of publication (4). This series, primarily on block sample 94-21, includes unconfined compression, consolidated undrained tests, and consolidated drained tests at constant volume.

This report was intended to supplement published information by giving detailed test results. It includes the results of a number of consolidated drained tests which have not been published. These tests round out the test series but are not considered to be sufficient for a general assessment of shear strength of Leda clay.

REFERENCES

1. Crawford, C. B. Engineering studies of Leda clay. Soils in Canada, Roy. Soc. Can., Special Publications No. 3, 1961, p. 200-217.

2. Crawford, C. B. The influence of rate of strain on effective stresses in sensitive clay. Papers on Soils - 1959 Meetings, ASTM STP No. 254, Am. Soc. Testing Mats., 1960, p. 36-61. NRC 5529.

3. Crawford, C. B. The influence of strain on shearing resistance of sensitive clay. Proceedings, ASTM, Vol. 61, 1961, p. 1250-1276. NRC 6662.

4. Crawford, C. B. Cohesion in an undisturbed sensitive clay. To be published in Géotechnique, June 1963.

TABLE I

PROPERTIES OF SOILS TESTED

Sample	83-27 83-28	96-3 96-4	94-21
Depth, ft	16	33	53
Elevation, ft	234	222	117
Preconsolidation press, kg/cm^2	2.2	2.0	4.5
Water content, %	67	58	53
Liquid limit, %	65	53	31
Plastic limit, %	26	25	23
Liquidity index	1.0	1.2	3.7
Clay content, %	60	62	65
Specific gravity	-	2.80	2.83
Activity	0.65	0.45	0.12
Salt content, grams/litre	0.5	1.7	0.03

TABLE II

CONSOLIDATED UNDRAINED TESTS ON SAMPLE 83-27

(see also Reference (2))

Specimen No.	Strain, %													
	0.25		0.50		0.75		1.0		1.5		2.0		3.0	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
83-27-8	0.60	0.28	1.09	0.51	1.35	0.70	1.48	0.83	1.51	1.04	1.50	1.18	1.46	1.33
11	0.81	0.32	1.28	0.55	1.58	0.71	1.73	0.83	1.80	1.03	1.76	1.15	1.64	1.32
10	0.87	0.27	1.38	0.54	1.72	0.74	1.88	0.91	1.97	1.14	1.91	1.28	1.72	1.44
3	0.82	0.55	1.29	0.97	1.51	1.26	1.63	1.47	1.72	1.75	1.72	1.87	1.69	2.02
2	0.84	0.50	1.32	0.91	1.53	1.16	1.64	1.33	1.74	1.55	1.73	1.70	1.70	1.97
1	0.85	0.46	1.27	0.78	1.51	1.02	1.63	1.17	1.72	1.34	1.73	1.53	1.72	1.68
6	0.78	0.33	1.32	0.64	1.60	0.87	1.75	1.03	1.88	1.26	1.91	1.43	1.88	1.62
7	0.85	0.23	1.41	0.50	1.74	0.75	1.89	0.98	2.00	1.30	1.98	1.45	1.97	1.64
9	0.95	0.62	1.40	1.12	1.65	1.43	1.80	1.69	1.99	2.08	2.06	2.38	2.06	-
5	1.20	0.72	1.75	1.29	1.98	1.65	2.11	1.92	2.22	2.27	2.25	2.50	-	-
4	1.20	0.52	1.78	1.01	2.07	1.38	2.23	1.60	2.36	1.89	2.39	2.06	2.38	2.33
13	1.65	0.56	2.45	1.27	2.85	1.88	3.07	2.37	3.27	3.00	3.34	3.39	3.31	3.98
12	1.90	0.82	2.76	1.62	3.18	2.13	3.37	2.52	3.46	3.01	3.47	3.39	3.42	3.77

A = deviator stress, kg/sq cm

B = pore pressure, kg/sq cm

TABLE III

CONSOLIDATED DRAINED TESTS ON SAMPLE 83-28

(see also Reference (2))

Specimen No.	Water Content, %		σ_c^1, kg/cm^2	T_c, min	ΔV_c, %	ΔV_T, %	Rate of strain, %/hr
	Initial	Final					
83-28-1	66.7	46.7	2.0	2900	3.5	20.5	0.17
83-28-2	67.3	41.5	2.8	4300	12.8	24.8	0.17
83-28-3	67.4	36.8	4.0	7000	19.4	29.3	0.17

σ_c^1 = Effective consolidation stress

T_c = Time of consolidation

ΔV_c = Volume change during consolidation stage

ΔV_t = Total volume change during test

TABLE IV

CONSOLIDATED UNDRAINED TESTS ON SAMPLE 96-4

(see also Reference (3))

Specimen No.	Strain, %															
	0.25		0.50		0.75		1.0		1.5		2.0		3.0		5.0	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
96-4-1	0.66	0.46	0.93	0.74	1.07	0.93	1.14	1.07	1.23	1.25	1.25	1.36	1.25	1.51	1.20	1.65
2	0.99	0.60	1.32	0.95	1.50	1.20	1.60	1.40	1.72	1.67	1.78	1.85	1.80	2.02	1.78	2.30
3	1.46	0.52	1.91	0.96	2.15	1.33	2.29	1.61	2.44	1.98	2.50	2.18	2.55	2.51	2.51	2.85
4	2.20	0.83	2.93	1.53	3.30	2.06	3.49	2.44	3.70	2.92	3.79	3.27	3.83	3.72	3.77	4.16
5	0.65	0.31	0.93	0.60	1.07	0.85	1.18	1.01	1.27	1.24	1.29	1.40	1.27	1.56	1.20	1.65
6	0.96	0.44	1.30	0.77	1.50	1.09	1.63	1.28	1.76	1.58	1.82	1.75	1.84	2.00	1.82	2.24
7	1.22	0.20	1.72	0.39	1.94	0.58	2.07	0.75	2.23	1.07	2.30	1.33	2.33	1.68	2.30	2.06
8	1.83	0.35	2.56	0.84	2.98	1.36	3.26	1.82	3.56	2.52	3.70	2.97	3.81	3.56	3.80	4.14
9	0.43*	0.47*	0.88	0.77	1.04	0.96	1.13	1.07	1.19	1.24	1.22	1.36	1.21	1.52		
10	0.85*	0.32*	0.85	0.74	1.51	1.08	1.68	1.30	1.81	1.59	1.86	1.78	1.87	2.01		
11	0.89*	0.73*	1.73	1.21	2.05	1.55	2.18	1.78	2.31	2.11	2.37	2.33	2.40	2.62		
12	1.30*	0.57*	2.18	1.13	2.89	1.58	3.21	1.98	3.50	2.60	3.64	2.99	3.74	3.50		

* Deviator stress constant (see Figure 2 of Reference 3)

A = Deviator stress, kg/cm^2

B = Pore pressure, kg/cm^2

TABLE V

CONSOLIDATED UNDRAINED STAGE TESTS ON SAMPLE 96-4

(see also Reference (3))

Specimen No.	σ_c^1	Strain, %															
		0.25		0.50		0.75		1.0		1.5		2.0		3.0		5.0	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
96-4-17	2	0.68	0.33	0.95	0.62	1.10	0.82	1.18	0.96	1.28	1.15						
	3	0.88	0.43	1.26	0.79	1.48	1.07	1.61	1.29	1.74	1.58	1.78	1.76				
	4	1.15	0.45	1.77	0.92	2.08	1.34	2.24	1.61	2.42	1.96	2.49	2.18				
	6	1.77	0.53	2.75	1.21	3.24	1.83	3.51	2.26	3.79	2.82	3.91	3.18	3.97	3.67		
96-4-18	2	0.64	0.42	0.96	0.69	1.11	0.88	1.19	1.03	1.26	1.22						
	3	1.05	0.50	1.43	0.86	1.65	1.13	1.76	1.33	1.88	1.60	1.93	1.77				
	4	1.23	0.50	1.89	1.00	2.25	1.38	2.42	1.62	2.62	1.97	2.71	2.22	2.75	2.50		
	6	1.98	0.77	2.87	1.44	3.37	1.95	3.66	2.36	3.97	2.93	4.10	3.27	4.18	3.65	4.13	4.08

σ_c^1 = Effective consolidation stress

A = Deviator stress, kg/cm^2

B = Pore pressure, kg/cm^2

TABLE VI

CONSOLIDATED DRAINED TESTS ON SAMPLES 96-3 AND 96-4

Specimen No.	Water Content, %		σ_c^1, kg/cm^2	T_c, min	ΔV_c, %	ΔV_t, %	Rate of strain, %/hr
	Initial	Final					
96-4-13	57.1	35.1	3	6200	13.6	23.6	2.0/0.4
96-4-14	58.3	35.9	3	4000	12.5	23.6	0.2
96-4-15	61.6	30.6	6	6700	22.4	31.6	0.4
96-4-16	57.5	30.2	6	4200	21.3	29.0	0.2
96-3-1	57.6	29.8	6	4300	20.9	29.6	0.2
96-3-2	52.6	25.3	6	4000	21.8	31.6	0.2
96-3-3	57.4	38.3	6	4000	18.8	20.6	-
96-3-4	55.9	36.4	6	3900	18.3	21.2	-

σ_c^1 = Effective consolidation stress

T_c = Time of consolidation

ΔV_c = Volume change during consolidation stage

ΔV_t = Total volume change during test

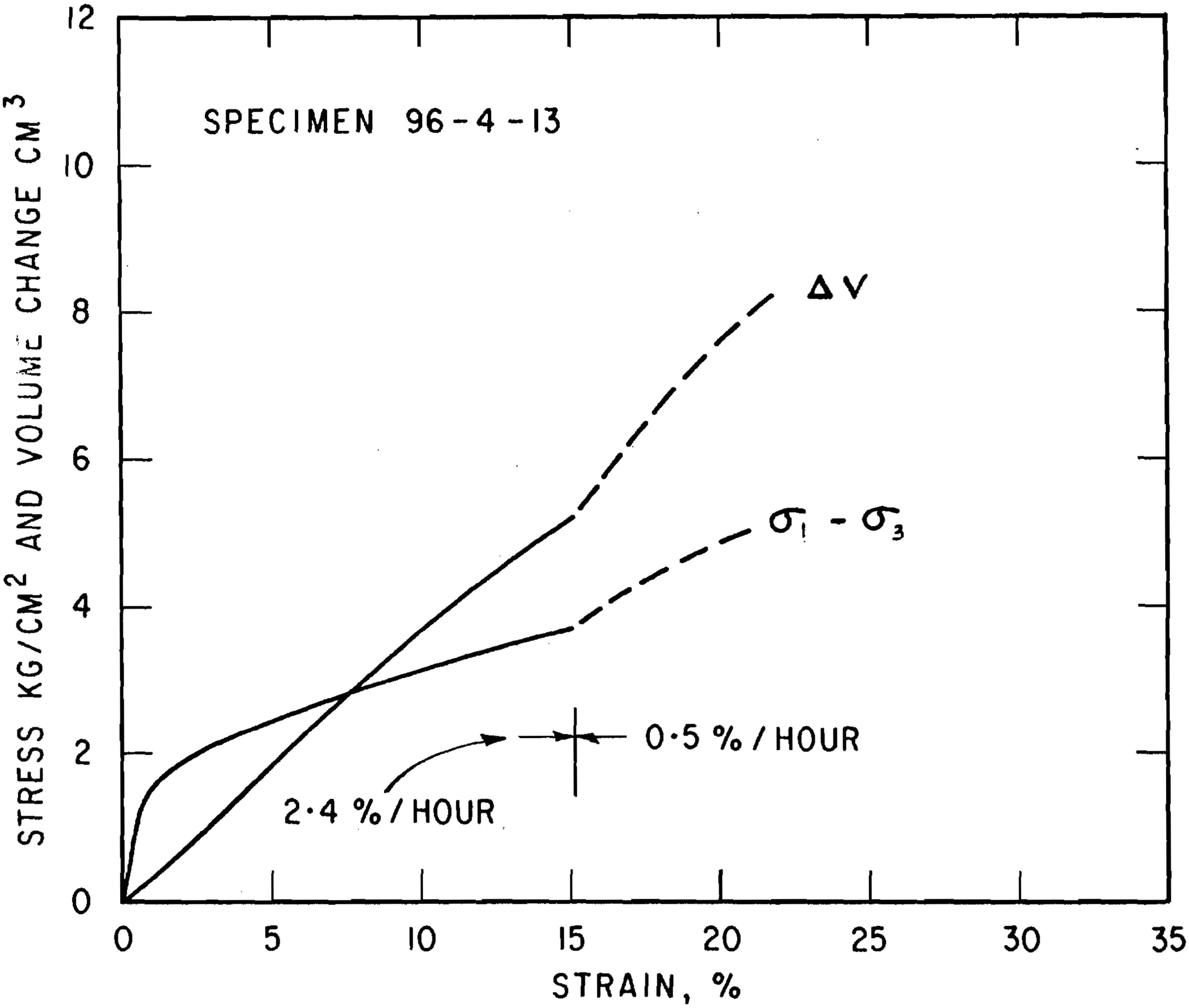

FIGURE 1

STRESS - STRAIN RELATION (DRAINED TEST)

GR 2889-1

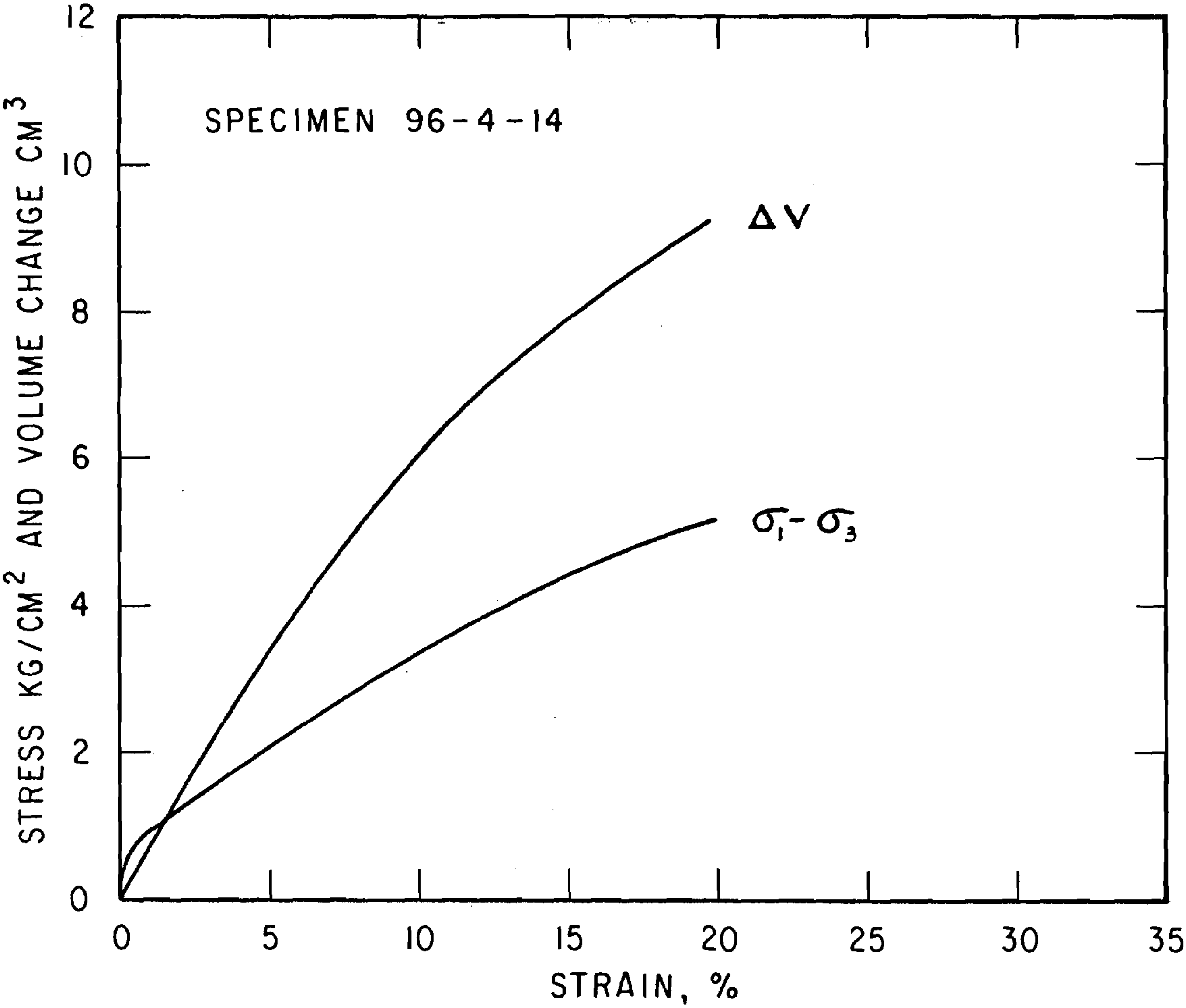

FIGURE 2

STRESS - STRAIN RELATION (DRAINED TEST)

BR 2889-2

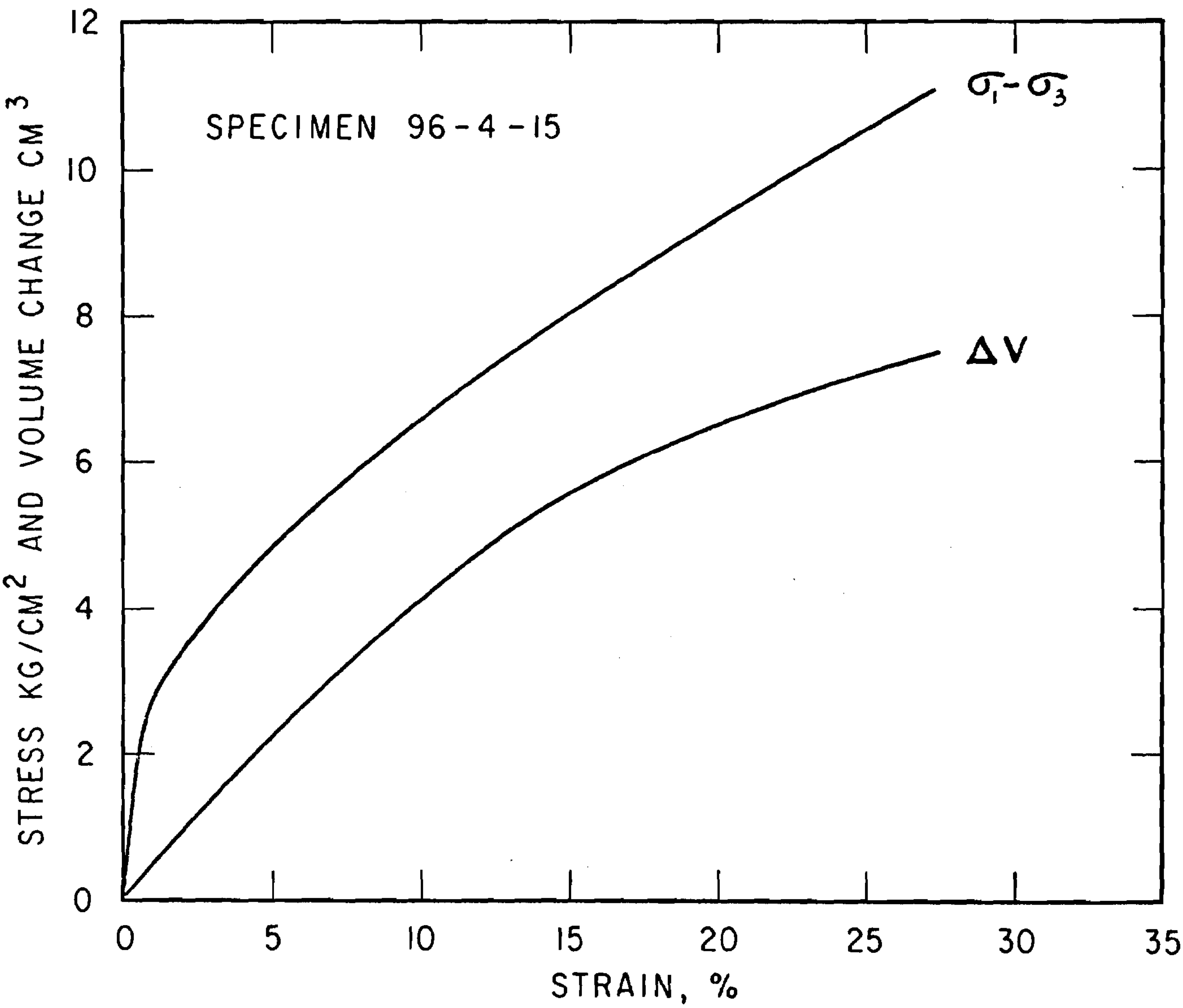

FIGURE 3

STRESS - STRAIN RELATION (DRAINED TEST)

BA 2889-3

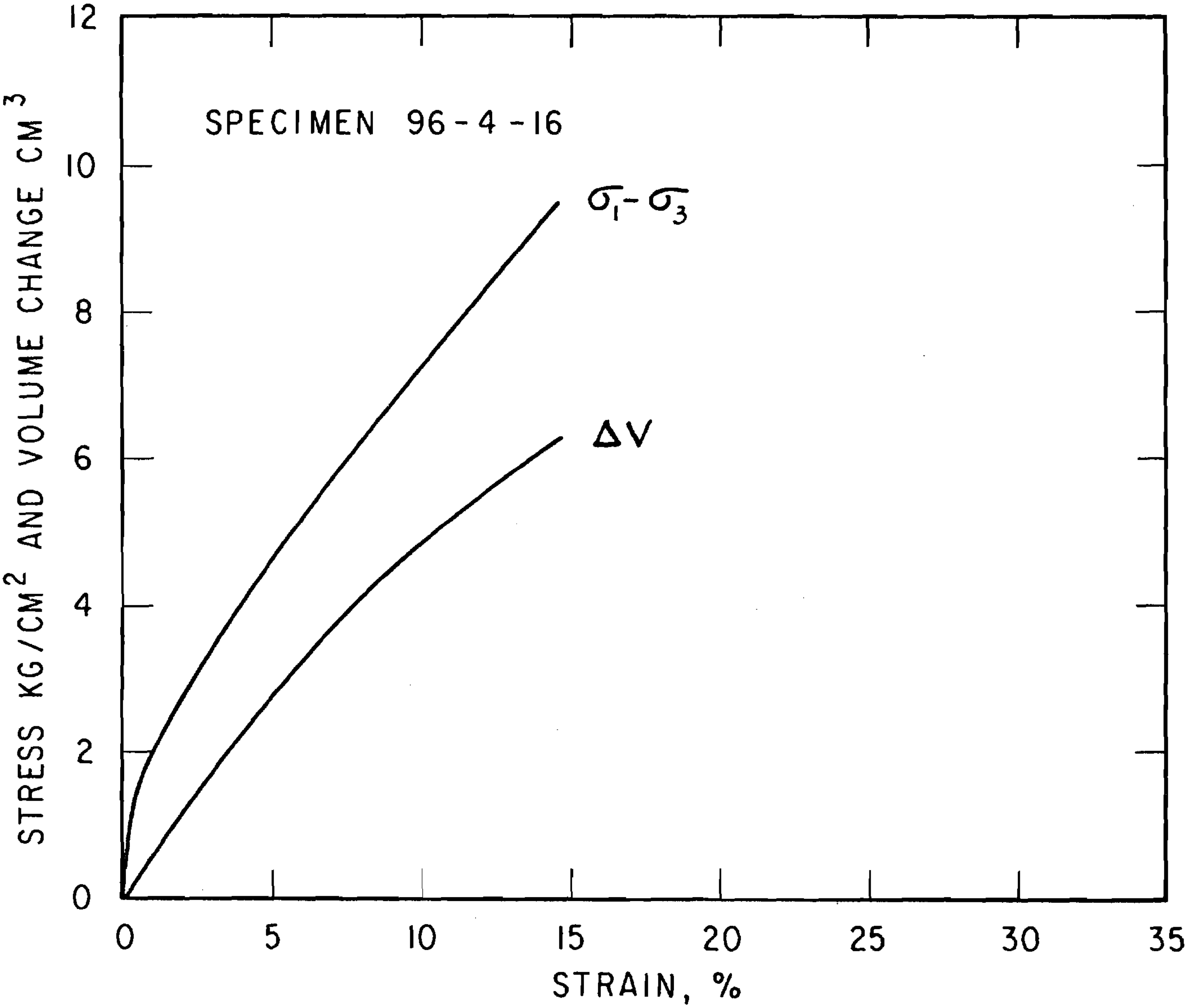

FIGURE 4

STRESS - STRAIN RELATION (DRAINED TEST)

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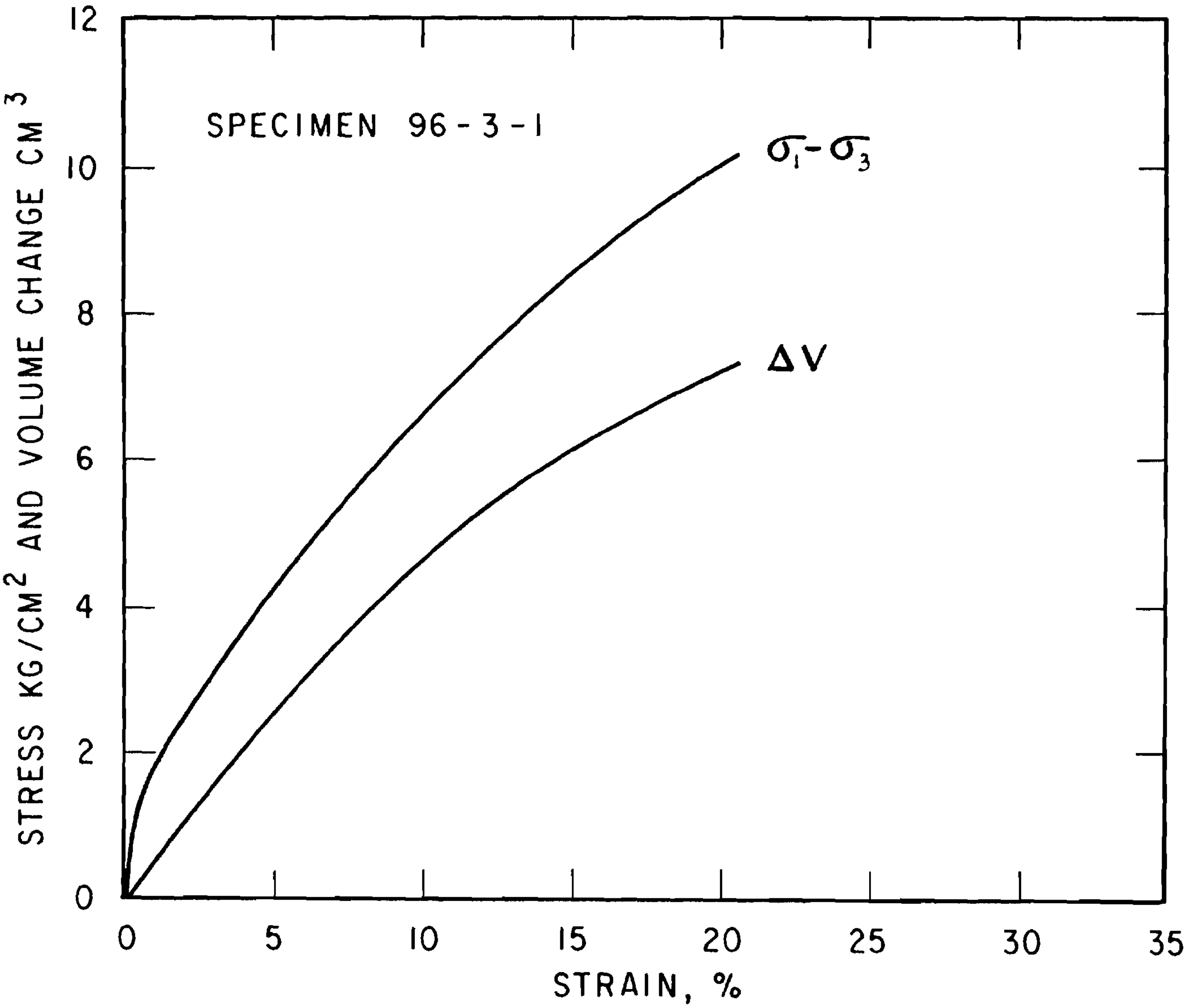

FIGURE 5

STRESS - STRAIN RELATION (DRAINED TEST)

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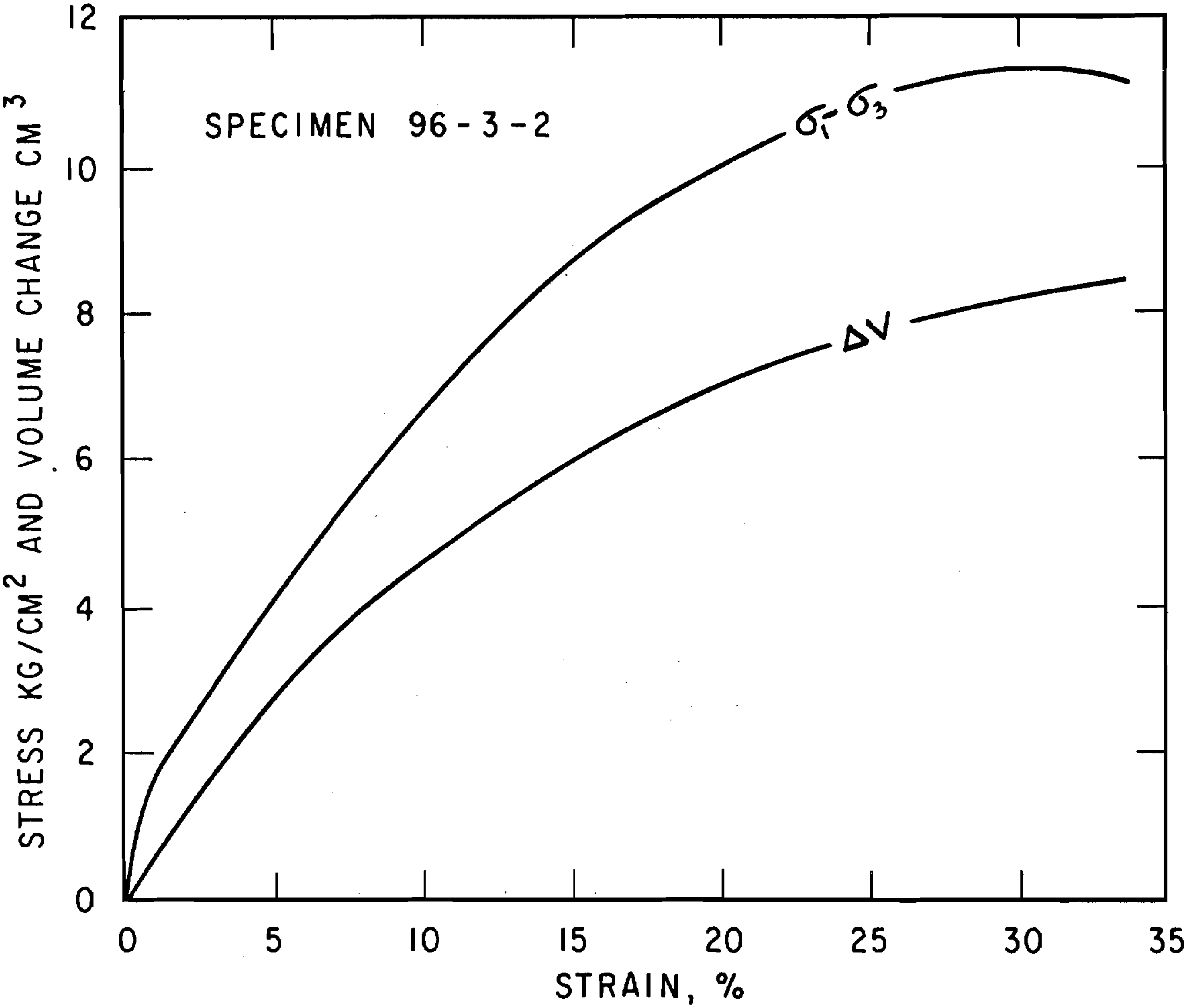

FIGURE 6

STRESS - STRAIN RELATION (DRAINED TEST)

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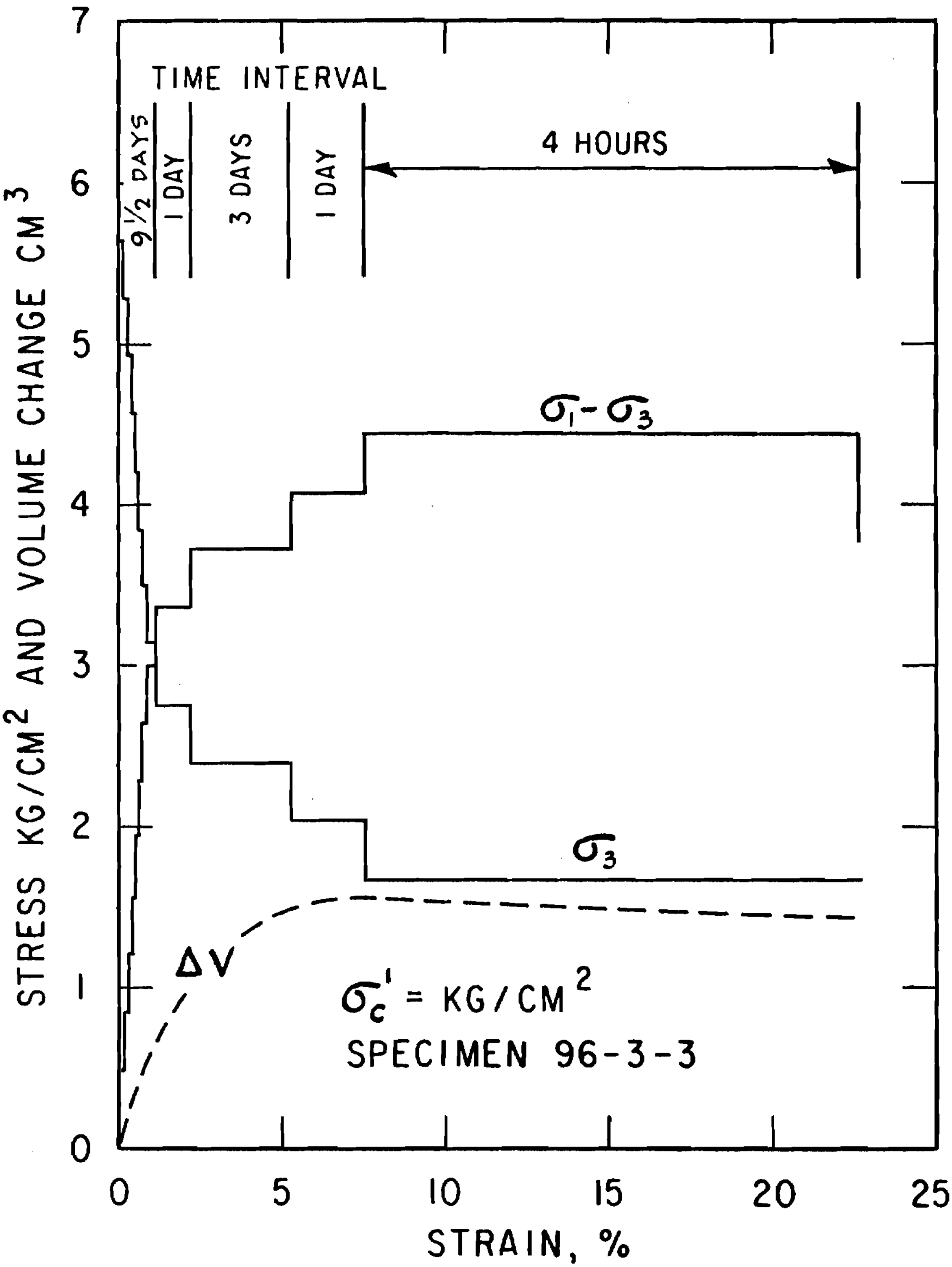

FIGURE 7

STRESS – STRAIN RELATION (DRAINED TEST WITH DECREASING σ_3)

BR 2889-7

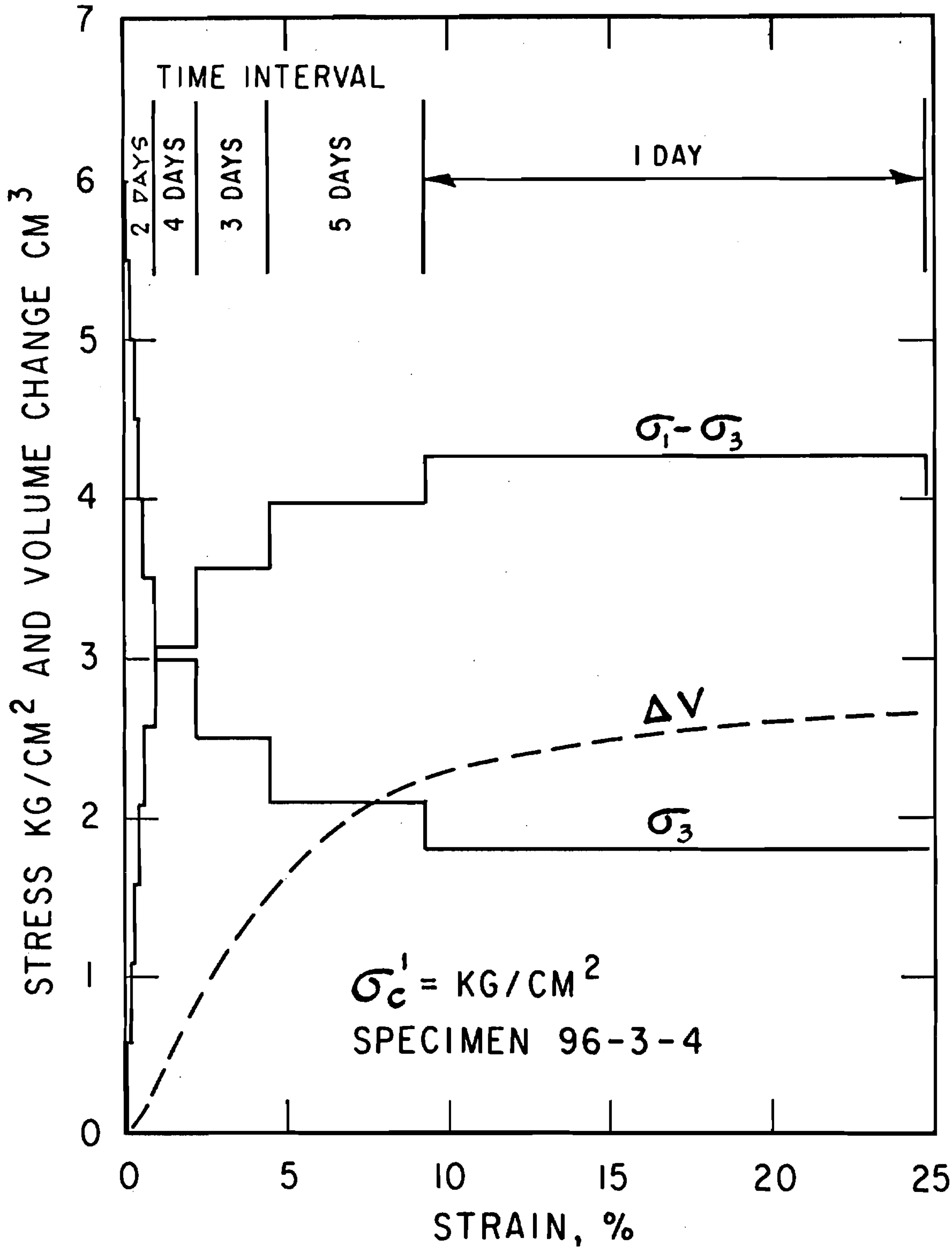

FIGURE 8

STRESS – STRAIN RELATION (DRAINED TEST WITH DECREASING σ_3)

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