STRENGTH DEVELOPMENT OF LIME TREATED CLAYS

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INTRODUCTION The study is concerned with the strength development of quicklime stabilized soft Bangkok clay. Unconfined compression tests were carried out after curing periods of 7, 15, 30, 60, 90, 135 and 180 days, and the lime content was varied from 2.5 to 15%.. The unconfined tests were conducted according to ASTM 2166-66 and a strain rate of 1%/min was used. Details of sample preparation have been discussed by Balasubramaniam & Buensuceso (1989). A summary of the results of the unconfined compression tests is presented in Table 1.

RESULTS AND DISCUSSIONS Figure 1 shows typical stress-strain curves at different curing periods. For stabilized samples, a brittle type of behavior is seen, particularly after long curing periods. In general, failure strains are from 1 to 5%. Shear type of failure was observed in all tests, with the angles of the failure plane between 54-68°. The strength development of lime stabilized samples is illustrated in Fig. 2. The strength gain of specimens with 2.5% lime was nominal, while 5 to 15% lime contents resulted in strength increases of about 5, 14 and 30 times, after 4, 8 and 12 weeks, respectively. The effect of varying the lime content becomes evident only after 2 months, and it appears that 10% lime content leads to the highest strength improvement. If the unconfined tests were conducted only up to 1 month curing period, a 5% lime content might have been selected as an optimum.

Figure 2 reveals that there is an initial period of about 30 days wherein the strength development is gradual. After 30 days, however, a large increase in strength occurs (except for 2.5% lime content) until about 90 days of curing at which the strength development tapers off. Similar observations have been made for lime stabilized sensitive clays in Canada by Locat et. al (1990), whose proposed conceptual model shown in Fig. 3 may be used to explain the strength development of stabilized soft Bangkok clays as follows. Phase I is a period of slow, gradual strength increase; this phase corresponds to an initial period when the cementation effects are not yet mechanically felt (even if

Table 1 Unconfined compression test results

Curing Time (weeks)	Lime Content (%)	Total Unit Weight (t/m³)	Dry Unit Weight (t/m³)	Water Content (%)	q_u (t/m²)	ϵ_f (%)	Angle of Failure** (degrees)
1	2.5	1.508	0.844	78.04	3 61	4 58	56
	5	1 520	0.868	74 53	7.23	3 12	61
	7.5	1.508	0 868	73.58	7.54	3 52	60
	10	1.535	0 889	70.85	9 42	4 3	60
	12.5	1.532	0 904	68.48	10 02	4 58	60
	15	1.550	0.902	70.10	11.94	4 86	60
2	2 5	1.509	0 843	78 38	4.87	3.17	58
	5	1 527	0 858	77.13	9 29	3 73	62
	7.5	1.522	0 869	73.39	11.09	3.24	60
	10	1.539	0 890	71.61	11.34	4.44	60
	12.5	1 520	0 888	70 53	11.92	3 73	60
	15	1 549	0.905	69.21	12.88	4.44	68
4	2 5	1 504	0 843	78.03	5.32	1 97	55
	5	1 520	0 864	75.96	14 85	3.87	60
	7 5	1 521	0 858	76 81	12 54	3 52	58
	10	1 530	0 879	72 71	11.58	3 94	61
	12.5	1 532	0 895	70 29	12 3	3.73	68
	15	1.546	0 913	68.76	14.42	4 08	65
8	2.5	1.527	0 867	75 83	6 15	3.03	54
	5	1.523	0 882	72.42	25.54	3.03	61
	7.5	1.517	0 866	73 96	28.42	2 46	65
	10	1 532	0 881	73.43	38 17	2.68	63
	12.5	1.526	0.874	72.21	35.57	2.46	65
	15	1.526	0 892	69.17	42.08	1.97	65
12	5	1 525	0.885	72.28	21.99	1.97	*
	7 5	1.564	0.921	69 68	57.90	2.3	*
	10	1.590	0.943	68.65	104.18	1.99	*
18	5	1 530	0 881	73 73	21.67	3.38	*
	7.5	1 540	0 894	72.15	43 32	1.55	*
	10	1.555	0.903	71.37	113.62	2.11	*
24	5	1.539	0 875	78 23	21.92	2 11	*
	7 5	1 530	0 884	72 99	83 35	2.02	*
	10	1.520	0.889	70.90	45 03	1.98	*

* failure was sudden, with samples breaking into small pieces
** angle of failure with respect to the horizontal axis

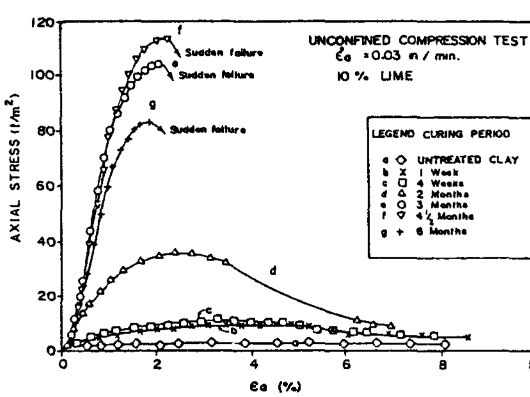

Fig. 1 Typical stress-strain behavior

chemical reactions are taking place). For stabilized Bangkok clays, phase I takes about 30 days. Meanwhile, phase II represents the period where the strength development significantly increases, mainly because the bridging between the soil particles is already efficient. For 2.5% lime content, the treated samples cannot be expected to reach phase II, even after 6 months of curing. Phase III is characterized by the slow-down of strength development. Locat et. al (1990) gave three reasons for the leveling of the strength development: (1) the completion of pozzolanic reactions due to the exhaustion of lime, (2) the difficulty for solutes to diffuse within the cemented soil matrix, and (3) the effects of the continuing reactions are not as pronounced as in phase II since the soil has attained a new, more rigid structure. These reasons, however, do *not* explain the observed decrease in strength after 90 days for samples with high lime contents. The strength decrease may most probably be due to testing errors and the difficulty in carrying out the unconfined tests on very rigid samples, but further studies are required before any conclusions can be made.

<u>CONCLUSIONS</u> The main conclusions that can be made from the results presented in the paper are the following.

1. The stress-strain behavior of lime stabilized soft Bangkok clay is similar to a brittle material; the brittle behavior is more pronounced at the optimum lime content and at longer curing periods.

2. The determination of the optimum lime content should be made based on observations for a period longer than one month. An optimum lime content of 10% was found for the most effective stabilization of soft Bangkok clays.

3. The strength development of lime stabilized clay may be considered to consist of three stages, which may be explained by the conceptual model proposed by Locat et. al (1990).

<u>REFERENCES</u> (1) Balasubramaniam, A.S. & Buensuceso, B.R. (1989). On the overconsolidated behaviour of lime treated soft clay. Proc. XII ICSMFE, Rio de Janeiro, 2, 1335-1338. (2) Locat, J., Berube, M., & Choquette, M. (1990). Laboratory investigations on the lime stabilization of sensitive clays: shear strength development. Can. Geotech. J., 27, 294-304.

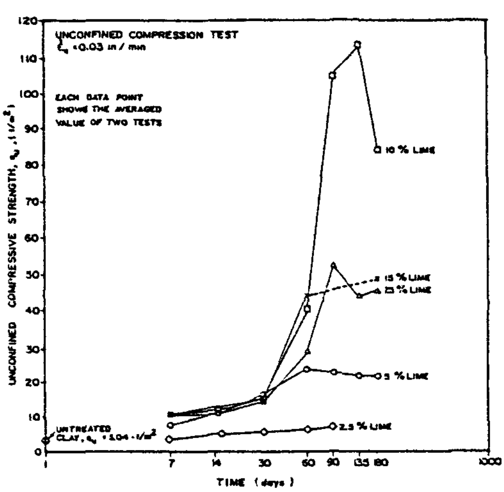

Fig. 2 Strength development with time

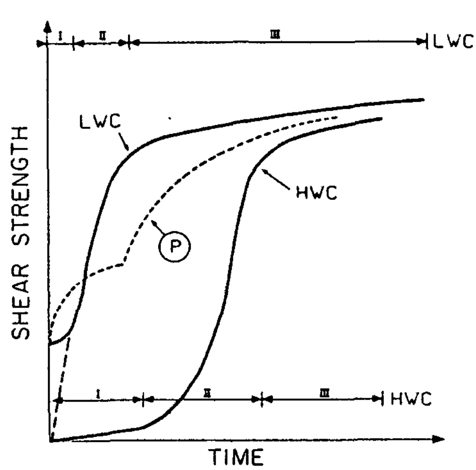

Fig. 3 Conceptual model of strength development
(After Locat et. al, 1990)