Pakistan Journal of Science (Vol. 66 No. 1 March, 2014)

STABILIZATION OF SUBGRADE SOILS USING CEMENT AND LIME: A CASE STUDY OF KALA SHAH KAKU, LAHORE, PAKISTAN

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ABSTRACT: The purpose of this study has to stabilize subsoil using soil improvement techniques to reduce the cost of construction. For this purpose, disturb samples from Kala Shah Kaku (KSK) were tested to evaluate the effect of different additives on strength of soil. Index properties of soil such as grain size analysis, Atterberg's limits and specific gravity were also determined for selected soil samples. Further two different additives i.e. Lime and Ordinary Portland cement (OPC), were chosen for treatment of soil obtained from KSK area. Samples were remolded by addition of additives in varying percentages up to 2-8% cement and 4-15% lime by dry weight of the soil. All the remolded samples were compacted at Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) as per Modified Procter Test and were then subjected to Unconfined Compression strength (UCS) and California Bearing ratio (CBR) tests. The effect of modifications in engineering properties was evaluated by treated soil samples with aging. Unconfined compressive strength (UCS) was determined in different time intervals i.e. on the same day (immediately after remolding), after 7 days, 14days and 28days.The samples for soaked CBR value were tested after 96 hours. From the study, it was concluded that the application of cement & lime showed tremendous improvement in UCS and CBR value with increase in cement or lime contents. Further, it was found that addition of cement showed better results at an optimum dosage of 4 to 6 percent than optimum percentage for lime i.e. 8%.

Key words: Ground Improvement, Binders, Index Properties, California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS)

INTRODUCTION

Modification and stabilization of sub grades by chemical stabilization is a well-established and time-tested practice. The addition of lime and cement to reactive fine-grained soil has beneficial effect on their engineering properties, including reduction in plasticity, swell potential, improved workability, increased strength, stiffness, and enhanced durability (Jiang et al., 2013; Bagui, 2012; Miao et al., 2012; and Bergado et al., 1996). In addition, lime and cement have been used to improve the strength and stiffness properties of sub grade materials. Lime can substantially increase the stability, impermeability, and load-bearing capacity of the subgrade soil (Rayes and Ahmed, 1974).

The geology of Kala Shah Kaku, Lahore, Pakistan is predominantly composed of alluvial deposits of Quaternary age with significant variation in composition of these deposits. The exploration drilling logs indicated that the deposits were in the form of layers which were composed of clay, sandy silt, and silty sand. Due to heterogenous characteristic of Kala Shah Kaku soil, soil improvement studies were required for the area. The surface soil at Kala Shah Kaku was silty and clayey soil with low strength. They lose their shear strength with the rise of moisture contents and have low California Bearing Ratio (CBR) value. Due to their low bearing capacity, roads cannot be constructed on this soil, therefore in the past, roads were constructed on sub grade prepared using borrowed granular material (sand). This method was expensive so there was a need to find an alternate solution which was suitable and economical. The researchers used cement and lime stabilization as an alternate solution of soil replacement, as no such study was carried out earlier in the area.

In this study, ground improvement techniques were used to improve the near surface soil at Kala Shah Kaku (Figure 1) with an objective to investigate the effect of lime and cement mixed with in-situ soil on various properties like shear strength, compaction characteristics and CBR through laboratory tests and compared the strength gain of stabilized soils with time.

Figure 1: Location map of the studied area

MATERIALS AND METHODS

Three soil samples were collected from 3ft depth below the ground surface from different locations in the study area. The collected samples were treated with cement and lime of various mix ratios. The cement and lime were applied to the natural soil by loose volume and dry mass of the soil respectively. Subsequently, the treated soil samples were tested for UCS and CBR values. The samples for soaked CBR were cured for 96 hours in compacted state in the CBR moulds. Curing was undertaken in the laboratory without controlling both temperature and humidity.

The following percentages of cement and lime were employed in the study:

A. 2, 4, 6 and 8 percent cement by the dry weight of soil

B. 4, 6, 8, 10 and 15 percent lime by the dry weight of soil

The changes in the engineering properties of the stabilized soil were evaluated after mixing with cement or lime. Stabilizers were added in varying percentages i.e. 2, 4, 6, 8, 10 and 15 percent. Unconfined Compression Strength (UCS) tests were performed on the same day and then after 7, 14 and 28 days as shown in Figure 2a to see the gain in strength with aging. California Bearing Ratio (CBR) tests were conducted on natural soil and stabilized soil i.e. soil mixed with 2, 4, 6 and 8 percent cement and 4, 6, 8, 10 and 15percent lime. Samples for unsoaked CBR were tested on the same day and for soaked CBR after 4 days as shown in Figure 2b.

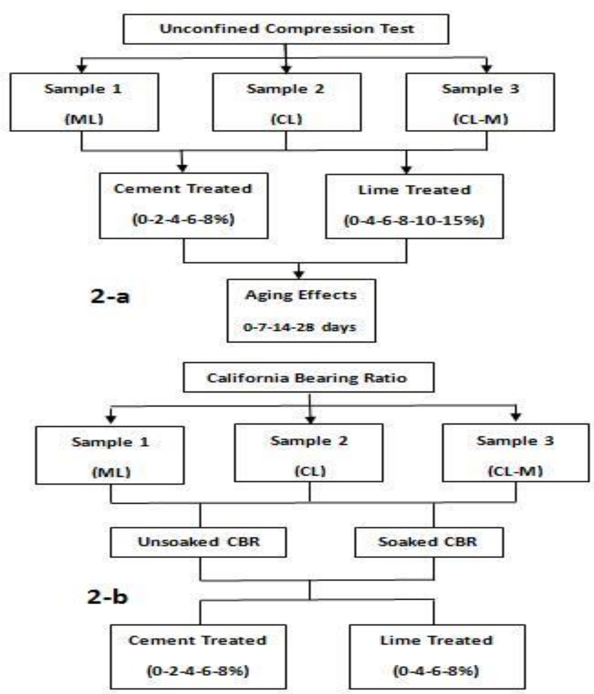


Figure 2: Tests performed on modified soil (a) Unconfined compression, (b) California Bearing Ratio

RESULTS AND DISCUSSION

Results shown in Table 1 are obtained by laboratory tests such as Sieve Analysis, Hydrometer Analysis, Atterberg's Limit Test, Specific Gravity Test, Modified Compaction Test, Unconfined Compression Test and California Bearing Ratio Test to evaluate the changes in important engineering properties of the soils;

Results indicated that the soil samples contained 84 to 94% fine soil, 6 to 16% sand and 1 to 2 % gravel.Gradation curve of samples is shown in Figure 3. Plasticity index varies from 3 to 12. Based on Particle size distribution and Atterberg limits, the samples were classified as low plastic silt (ML), lean clay (CL) and silty clay (CL-ML) according to ASTM D 2487. Group index values of the three samples were found to vary between 8 and 9. According to AASHTO classification system, the soils were classified as A-4 and A-6.

Table 1: Summary of untreated soil properties

Properties	Soil Type		
	Sample 1	Sample 2	Sample 3
	ML	CL	CL-ML
Particle size distribution (%)	84	94	84
Liquid Limit, LL (%)	24	27	26.5
Plastic Index, PI	3	12	5
Specific Gravity, Gs	2.7	2.66	2.62
Optimum Moisture Cotent (%)	11	9.5	9.5
Maximum dry unit weight (kN/m^3)	18.64	19.68	19.62
Undrained shear strength, 2c(kPa)	110	113	107
Unsoaked CBR (%)	3	4	3
Soaked CBR (%)	1.5	3	1

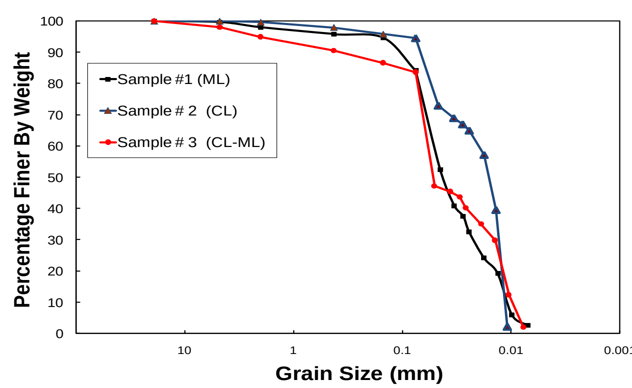


Figure 3: Gradation curves of soil samples

The results obtained from UCS tests as shown in Table 2 indicated that the addition of OPC to soil increased the UCS values. As the curing time for the stabilized soil samples increased, the UCS values also increased. Values of UCS increased considerably after 7 days curing period. The strength gained continued throughout 28 days curing period, but the maximum strength gained was between 7-14 days of curing as shown in Figure 4(a). After 14 days the strength gained was relatively slow. Relative increase of strength was maximum (99%) by adding cement from 2-4% then the increase was relatively slower i.e. 30% and 1.5%. Results of soil stabilized with lime are shown in Figure 4 (b). The results indicated that relative increase of strength was 79% by adding lime from 4-6%. The results were in accordance with findings of Hassan (2006) which showed that UC strength of cement stabilized clay increased with decreased water contents ratio.

Table 2: Test performed on modified soils with 7 days interval

Sample No.	Days	Undrained shear strength, 2c(kPa)									
		Cement (%)					Lime				
		0	2	4	6	8	4	6	8	10	15
1 (ML)	0	110	118	121	138	139	159	172	187	195	198
	7	NA	315	600	777	791	229	360	516	528	533
	14		625	1206	1549	1554	567	800	958	963	969
	28		631	1212	1549	1561	619	852	1003	1009	1013
2 (CL)	0	113	142	177	182	202	181	195	234	237	242
	7	NA	310	606	760	766	304	411	573	585	596
	14		596	1212	1497	1537	561	1000	1164	1176	1187
	28		611	1217	1594	1617	590	1057	1233	1239	1250
3 (CL-ML)	0	107	143	170	177	198	174	202	226	230	233
	7	NA	472	826	846	857	247	400	499	505	510
	14		938	1652	1680	1692	396	806	1032	1040	1052
	28		952	1663	1686	1697	447	897	1090	1097	1109

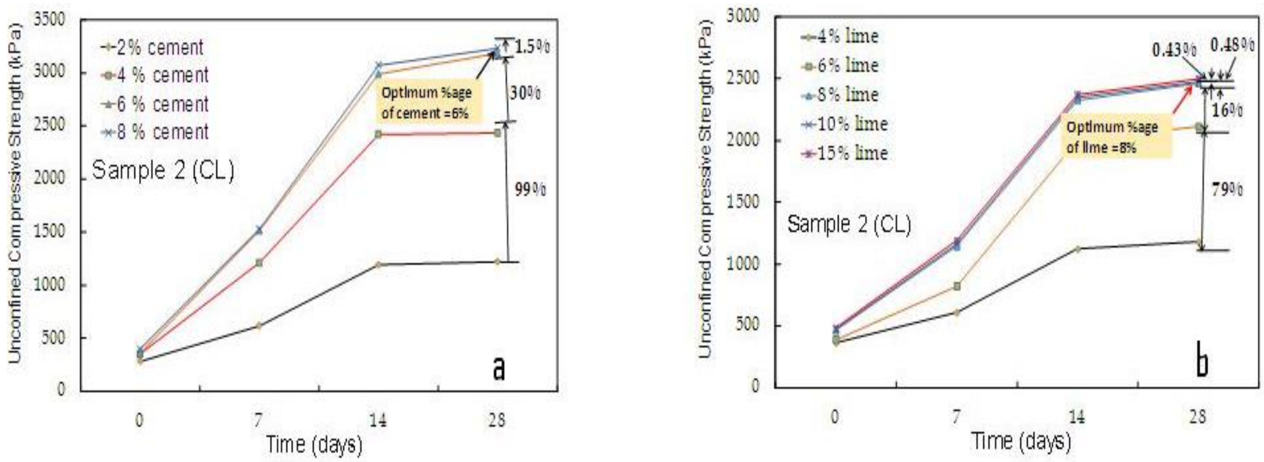
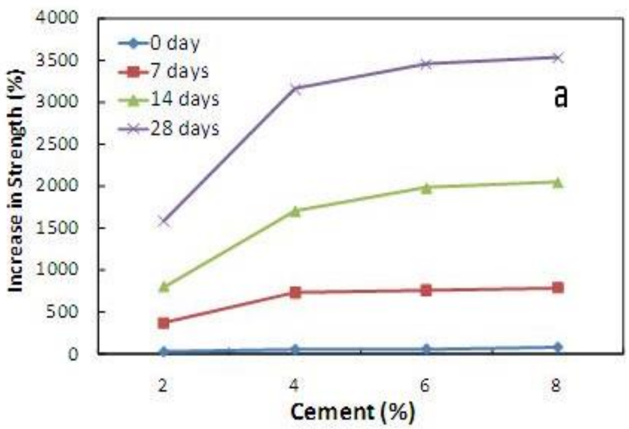


Figure 4: Effect of cement (a) and lime (b) on unconfined compressive strength (qu) at various percentages of cement with time.

The increase in compressive strength (in percentage) with respect to untreated soil due to cement or lime is shown in Figures 5(a) and 5(b) respectively. These figures show that the compressive strength increases with the addition of cement and lime and increasing the curing time also improved the compressive strength.

The effect of lime mixing is shown in figure 5(b). General trend was an increase in compressive strength by increasing lime quantity and with aging. The strength results were consistent and uniform by mixing lime with soil. Among the percentages of lime mixed, 8% lime yields highest compressive strength values after 28 days curing. The results indicated that lime increased the stability, impermeability, and load-bearing capacity of the subgrade which was in accordance with the findings of Rayes and Ahmed (1974). Argu (2008) demonstrated that application of lime alone and chemical with lime showed significant improvement of varying degrees on the engineering properties of both the light grey and the red clay soils. However, no specific mix ratio showed better results for maximum improvement in engineering properties of each soil. This suggested desired improvement level of the engineering properties of treated soils.



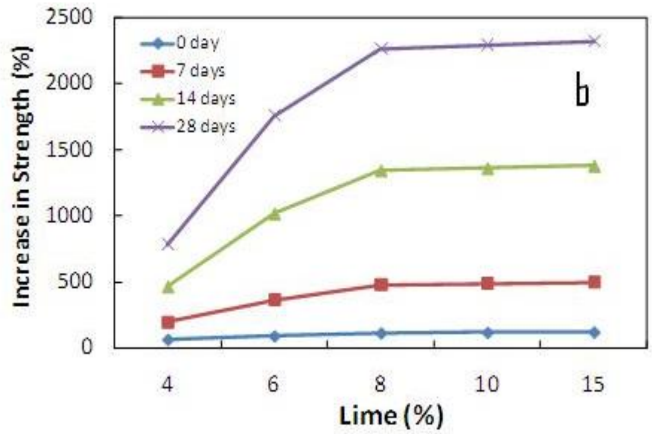


Figure 5: An example of increase in strength for cement (a) and lime (b) stabilized soils

The results of CBR experiments and increase in CBR values with respect to untreated soil due to cement or lime are shown in Table 3 and graphically in Figure 6. The applications of lime resulted in modest improvement in CBR value of KSK soils whereas, applications of cement resulted in remarkable improvement in CBR value of soil as shown in Figure 6. It was clearly shown from the table that maximum increase was observed in soaked CBR with lime which was 1100% whereas with cement it was 2600%.

Table 3: Increase in CBR of Cement or Lime Stabilized Soils

Sample No.	Mix Type	Unsoaked CBR	Increase in Unsoaked CBR (%)	Soaked CBR	Increase in Soaked CBR (%)
1 (ML)	Natural soil	3		1	
	Soil+2%cement	6	100	3	200
	Soil+4%cement	9	200	4	300
	Soil+6%cement	16	433	7	600
	Soil+8%cement	32	967	14	1300
	Soil+2%lime	5	67	2	100
	Soil+4%lime	11	267	4	300
	Soil+6%lime	11	267	5	400
	Soil+8%lime	24	700	10	900
2 (CL)	Natural soil	4		3	
	Soil+2%cement	49	1125	19	533
	Soil+4%cement	49	1125	22	633
	Soil+6%cement	50	1150	32	967
	Soil+8%cement	50	1150	33	1000
	Soil+2%lime	26	550	13	333
	Soil+4%lime	29	625	22	633
	Soil+6%lime	31	675	30	900
	Soil+8%lime	44	1000	31	933
3 (CL-ML)	Natural soil	3		1	
	Soil+2%cement	14	367	6	500
	Soil+4%cement	24	700	12	1100
	Soil+6%cement	34	1033	18	1700
	Soil+8%cement	35	1067	27	2600
	Soil+2%lime	10	233	4	300
	Soil+4%lime	15	400	8	700
	Soil+6%lime	20	567	9	800
	Soil+8%lime	22	633	12	1100

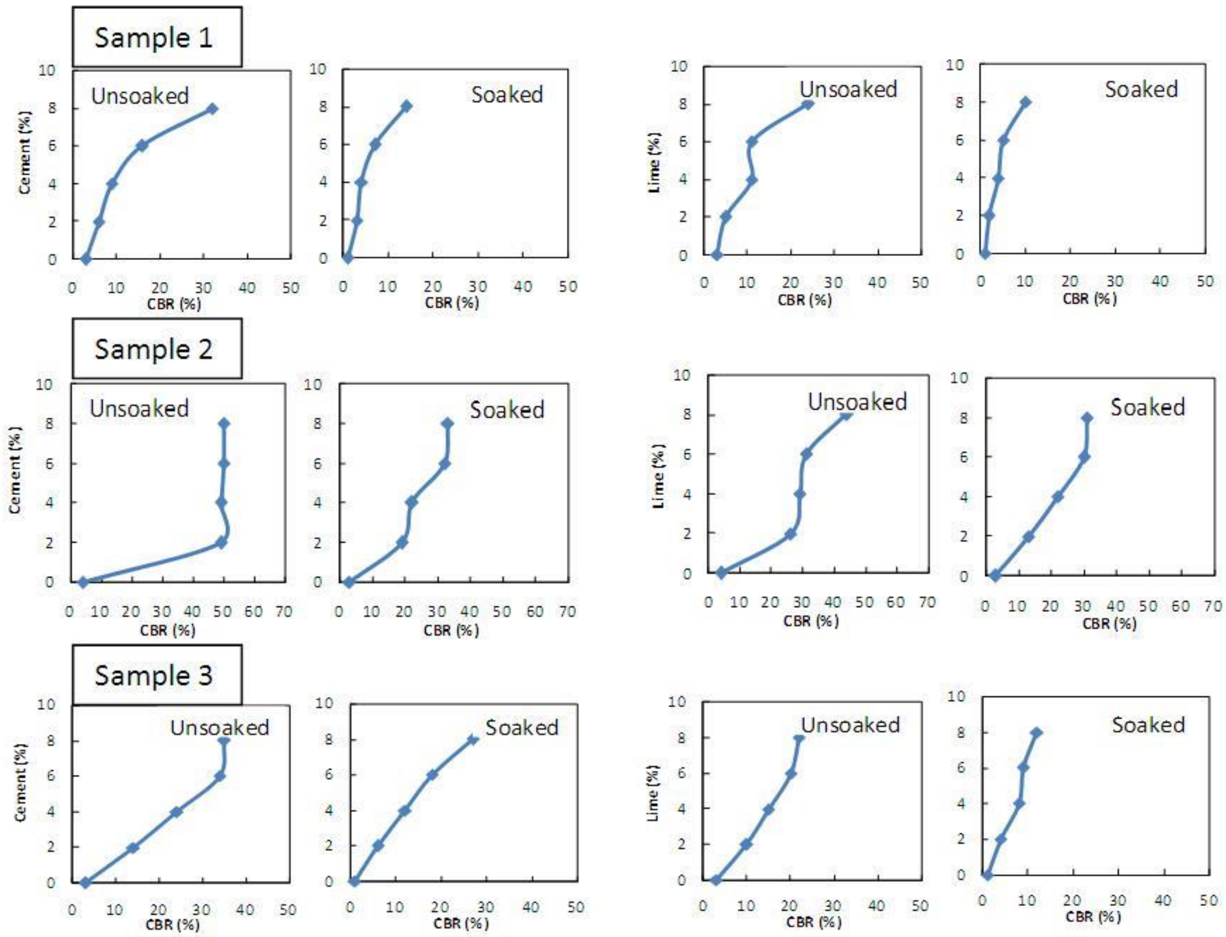


Figure 6: Relationship between CBR with amount of cement or lime of soaked and unsoaked samples

CBR results were plotted and a correlation was developed between unsoaked & soaked CBR values, It can be seen from Figure 7 that soaked CBR value was about half of Unsoaked CBR value (Soaked CBR = 0.57 × Unsoaked CBR). The results confirms the findings of Bagui (2012) which showed that thickness of soil-cement base and that of soil-lime sub-base decreased significantly as CBR was increased.

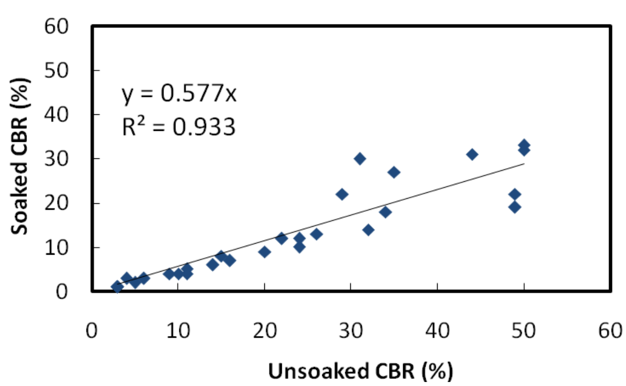


Figure 7: Correlation between unsoaked and soaked CBR values

Conclusion & Recommendations: Based on above results and discussion, following conclusions are drawn from this study:

1. Shear strength increased with the addition of cement and lime with passage of time. The maximum increase in shear strength was observed as 1311% and 1312% at 6 % cement after 28 days of mixing for ML and CL soils respectively, and it was 1454% for CL-ML soil at 4 % cement after 28 days.
2. The maximum increase in compressive strength was 813%, 991% and 919% % at 8% lime after 28 days of curing for ML, CL and CL-ML soils respectively.
3. The maximum increase in soaked CBR was 1300%, 1000% and 2600% at 8 % cement for ML, CL and CL-ML soils respectively.
4. From the results of the study, it was observed that the application of cement showed more improvements than lime in the strength, compaction characteristics and CBR value of Kala Shah Kaku campus soil.

Based on above conclusions, it is recommended to study the effect of different weather conditions on the response of the soil. It is further recommended that the effect of delay between mixing and compaction on strength and swelling properties of the soils should also be investigated, since immediate compaction after mixing is not practicable for large-scale applications.

Acknowledgement: Authors thank to all staff and colleagues in helping sample collection, lab tests and their technical input particularly Dr. Aziz Akbar, Civil Engineering Department, UET, Lahore.

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