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Study The Effect of Traditional Iraqi Stabilizers (Cement and Lime) on Some Properties of Iraqi Clay Soils

Abstract- *This study provides practical results in the use of the composite from sulfate resistance Portland cement (PC) and Quicklime (LQ) to improve and stabilize of soils in Al - Zaafaraniya site in Baghdad governorate and the Garma Ali site in Al Basra governorate, Iraq. PC and LQ were added in percentages of 2,4,6,8 and 10% and 2 and 4%, by dry weight, respectively. Laboratory tests to determine Atterberg's limits, standard proctor test, USC test and UUU test (unconsolidation, undrained and unsaturated) were conducted. The results achieved a significant improvement in orkability, unconfined compressive strength and shear strength. The results of the unconfined compressive strength test and UUU test for natural and improved soil reveal that the shear strength increase as lime and cement content increase and with increasing curing (0, 7 and 28)days.*

Keywords- *Soil Stabilization, Cement, Quicklime, Unconfined Compression Test, UUU Test, Curing Period*

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1. Introduction

The One of the most difficult problems confronting the civil engineering works is when the subgrade is found to be clay. Known the clayey soils by possessing a high rate of clay content, which leads to swelling, high compressibility and low shear strength if it is allowed increasing water content [1]. This increase in moisture content probably comes from rains, floods, leaking sewer lines, or from the reduction of surface evaporation when an area is covered by a building up or pavement. Considerably from clayey soils, cause the cracking and fracture of pavement, railways, highway embankment, roadways, foundations and channel or reservoir linings [2]. To proceed with this alternative, soil stabilization using lime and/or hydraulic binders, etc. is a widespread technique employed to improve the workability and hydromechanical properties of soils [3]. Stability with lime and cement are mainly and commonly used in the above-mentioned works and they have been under continuous development since its launch in The middle of the last century. Lime is used primarily to dewater the soil in order to improve the workability and its bearing capacity. This Lime modification is widely used for building embankment and subgrade of clayey soil since the effect is rapid and modifies the geotechnical characteristics of the soil like the plastic limit, the shear strength and the soil compaction

characteristics. Later the pozzolanic reaction between the soil minerals and lime in the presence of water leads to the formation of secondary cementitious products (C-S-H, C-A-S-H,…) increasing the soil cohesion and its resistance [4]. The effects of the pozzolanic reaction are mainly effective at long term. If the mechanical resistance of the material is essential at short term, the soil stabilization goes using cement. Cement stabilization is quick, does not need mellowing time and provides a non-leaching platform [5]. Cement can be used for stabilization of a wide range of soils and the best performances of soils treated with cement have been observed on silt as well as on coarse-grained materials [6]. Furthermore, in practice, in the world, a mixed treatment with lime and cement is used since the mixture allows facilitating the workability without disturbing the effect of the cement in the gain of resistance at long term. The addition of lime and cement exerts impacts on the material microstructure. The flocculation/aggregation of clay particles after adding lime or cement modifies, for one thing, the material particle size distribution [7] and, consequently, influences

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pore distribution over a very short term [8], although this distribution is evolving during the curing period as well as in jointly with both the pozzolanic and hydraulic reactions [9,10] followed up by representing the lime distribution in a soil sample. This paper present the esult of the ffect of quicklime & cement on Waterberg limits, standard compaction test, undrained triaxial shear behavior and unconfined compressive strength of two Iraqi (Baghdad and AL – Basra) cohesive soils classified as CL and CH ccording to the unified soil lassification system (USCS).

2. Experiment of Investigation

I. Material Used

1. Soils

In this study, two soil samples (A and B) were used obtained from two different locations. The first soil sample (A) from Al-Zaafaraniya site in Baghdad city. The second soil sample (B) from the Garma Ali site about 538 km south of Baghdad in Al Basra city. The engineering properties of clayey soils are presented in Table 1. Figure 1 shows the grain size distribution of soils used.

2. Types and Properties of Additives

The cement used to be sulfate resistance Portland cement (type V) manufactured by (Al Jessir) factory in Iraq. The type of lime used was quicklime (unhydrated) manufactured from limestone by the Alnoora factory in Kerbella governorate in Iraq. Table 2 and 3 shows the Physical and chemical properties of the cement and quicklime, respectively.

II. Laboratory Tests

A series of laboratory tests consisting of Atterberg limits, compaction, shear strength and unconfined compressive strength were conducted on the two selected clayey soils. The combinations of Portland cement and quicklime (PC and LQ) were used for stabilization of the two soils. The percentages of PC were 0, 2, 4, 6, 8 and 10%. While the percentages of LQ were 0, 2 and 4%. A total of 11 combinations based on soil A and soil B with mixed modes of stabilizers were studied (Table 4).

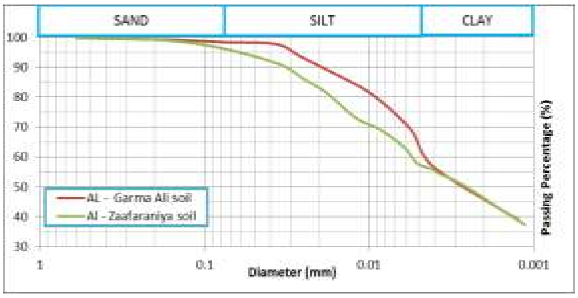


Figure 1: Particle Size Distribution of Soft Soils Used

Table 1: Physical and Chemical Properties of Natural Soils Used

Index Property	Test Standard	Index Valve	
		Soil A	Soil B
Initial water content (%)	ASTM D 2216	26	31
Depth (m)	---	0.5 -1.5	
Liquid Limit (L.L) (%)	ASTM D 4318	48	58
Plastic Limit (P.L) (%)	ASTM D 4318	21	27
Plasticity Index (P.I) (%)	ASTM D 4318	27	31
Activity of Clay (At)	Skempton formula At= (PI/{percent of clay< 0.002mm})	0.6	0.56
Specific Gravity (G.s)	ASTM D 854	2.72	2.75
Gravel (larger than 4.75mm) (G) %	ASTM D 422	0	0
Sand (0.075 to 4.75 mm) (S) %	ASTM D 422	4	2
Silt (0.005 to 0.075 mm) (M) %	ASTM D 422	38	35
Clay (less than 0.005mm) (C) %	ASTM D 422	58	63
Classification (USCS)	ASTM D 2487	CL	CH
Organic Material (O.M) (%)	ASTM D 2974	< 0.01	< 0.01
Calcium Oxide (CaO) (%)	Chemical Analysis	18.38	21.12
SO_3 Content (%)	Chemical Analysis	0.82	0.38
Total Dissolved Salt (TDS %)	Chemical Analysis	2.21	1.73
Total Solved Salt (TSS %)	Chemical Analysis	8.3	6.89
PH Value (%)	ASTM D 4972	7.95	8.69
MDD (KN/m3)	ASTM D 698	17.55	16.5
OMC (%)	ASTM D 698	16	20.5

Table 2: The Physical and Chemical Properties of the Cement

Index Property	Index Value
Physical Properties	
Specific gravity (G.S)	3.15

Compressive strength after 3 days (MPa)	17
Compressive strength after 7 days (MPa)	26
Time of initial setting (minute)	93
Time of final setting (hour)	4.28
Chemical Properties	
SiO_2 %	19.79
CaO %	63.8
MgO %	3.19
SO_3 %	2.15
C_3A %	3.27
L.O.I %	0.89

Table 3: The Physical and Chemical Properties of the Quicklime.

Index Properties	Index Value
Physical Properties	
Specific gravity (G.S)	2.99
Retained on Sieve # 30 (%by weight)	0
Retained on Sieve # 200 (%by weight)	11
Chemical Properties	
CaO %	92.3
Free Water (%)	0.08
IR (%)	2
SO_3 (%)	0.07
L.O.I (%)	25.3

Table 4: Stabilizer combination scheme for stabilizing soils

Designation	Sample mixture (%)		
	Soil	PC	LQ
PC 0% LQ 0%	100	0	0
PC 2% LQ 2%	96	2	2
PC 4% LQ 2%	94	4	2
PC 6% LQ 2%	92	6	2
PC 8% LQ 2%	90	8	2
PC 10% LQ 2%	88	10	2
PC 2% LQ 4%	94	2	4
PC 4% LQ 4%	92	4	4
PC 6% LQ 4%	90	6	4
PC 8% LQ 4%	88	8	4
PC 10% LQ 4%	86	10	4

1. Atterberg Limits Tests

According to ASTM D4318 (2000) can be obtain on plastic limit (PL), liquid limit (LL) and plasticity index (PI).Where studied in this research the plasticity index (PI) whether be treated or untreated soils by used a composite from PC and LQ. initially, the dry soils by airs (passing # 40 sieves) and mix with the predetermined quantity of a composite (PC & LQ) in a dry state together. Add distilled water to the soil admixture. Permit water penetration into the soils and the mixing, the paste was allowed stand in an airtight container for about 24 hours to examining. After this calm, the paste was remixed with each stabilizer thoroughly for at least 15 min before the performance the first test. The plastic limit tests conducted on material prepared for the liquid limit test. The plastic limit was determined as the average of the three water contents and rounded to the nearest whole number. Both liquid and plastic limit tests were performed at room temperature.

2. Compaction Tests

The method given in the ASTM D689 (2000) was applied to determine the maximum dry density and water content which represents (OMC) of the soils. The soil mixtures, with and without dditives, were thoroughly mixed for 0.5 hour before process the compaction the first of ompaction tests were aimed at etermining the compaction properties of the soils ample only. Secondly, tests were performed to determine the proctor compaction properties of the treated soil with arying amount of PC & LQ.

3. Shear strength Tests

Triaxial compression tests according to ASTM D2850 (2003) were carried out on treated and untreated samples. Where prepared soil samples at a constant dry density of 15.7 KN/m^3 and water content equals 24% for soil (A) and 15 KN/m^3 and water content equals 28% for soil (B). To avoid loss moisture, the specimens were wrapped up with a plastic film after removing from molds. Tests were carried out at different curing periods (0,7 and 28days). The unsaturated, unconsolidated undrained (UUU) tests carried out in the triaxial compression tests were performed with cell ressure of 25and 50 kpa.

4. Unconfined Compressive Strength Tests

Unconfined compressive strength tests on compacted specimens were conducted according to the ASTM D2166 (2000). In addition, preparation of the specimen as like as specimens examined in the UUU test. Specimens were cured in a plastic bag to prevent moisture change. Tests were carried out at different curing periods (0,7 and 28 days).

3. Results and Discussion

I. Atterberg Limits

Figure 2 and 3 illustrate the influence of both compounds on the plasticity index of soil A and B respectively. The addition of 2%LQ and PC at a maximum value of 10%, resulting in a decrease in liquid limit from 48 % to 41.3 % for soil A and from 58% to 49 % for soil B, plastic limit increased from 21 % to 32 % and from 27 % to 38.6 % in soil A and soil B respectively. Hence, plasticity index decreased from 27 % to 9.2 % and from 31 % to 10.3 %. On the other hand, the addition of 4%LQ and PC at a maximum value of 10% result in also a decrease in liquid limit from 48 % to 40 % for soil A and from 58% to 47.1 % for soil B, plastic limit increased likewise from 21 % to 33.7 % and from 27 % to 40.4 % for soil A and soil B respectively. Furthermore, plasticity index decreased as well from 27 % to 6.3 % and from 31 % to 6.7 % for soil A and soil B respectively. The reduction in the plasticity index is attributed to the transformation in soil nature (granular nature after flocculation and agglomeration) and the resulted soil is as crumbly as sandy clay soil. Table 5 summarized of Atterberg limits values of soil A and B mixed with different percentages of composite.

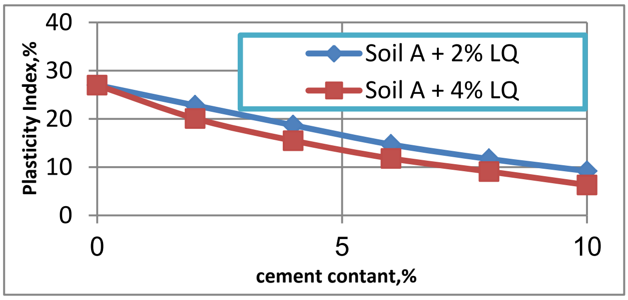


Figure 2: Plasticity index for natural and treated soil A with different (PC and LQ)

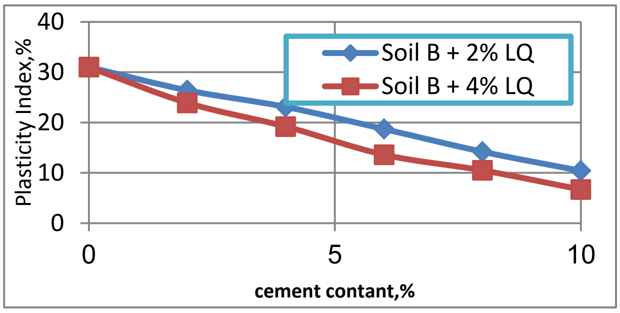


Figure 3: Plasticity index for natural and treated soil B with different (PC and LQ)

Table 5: Atterberg limits values of soil A and B mixed with different percentages of composite

The Additive		Soil A			Soil B		
% LQ	**% PC**	% P.L	% L.L	% P.I	% P.L	% L.L	% P.I
0	**0**	21	48	27	27	58	31
2	**2**	24	46.8	22.8	30.9	57.3	26.4
2	**4**	26.3	45	18.7	32.7	55.8	23.1
2	**6**	29	43.7	14.7	35.1	53.8	18.7
2	**8**	30.9	42.6	11.7	37.4	51.6	14.2
2	**10**	32	41.3	9.2	38.6	49	10.4
4	**2**	26	46.1	20.1	32.2	56.1	23.9
4	**4**	28.9	44.4	15.5	34.8	54	19.2
4	**6**	30.9	42.7	11.8	37.6	51.2	13.6
4	**8**	32.7	41.8	9.1	39.3	49.8	10.5
4	**10**	33.7	40	6.3	40.4	47.1	6.7

II. Compaction Characteristics

Twenty-two from both natural, untreated soils and treated soils with different percentages of PC and LQ were prepared to recognize the effect of compound admixture on the compaction properties. Figures 4 and 5 show the relationship between the maximum dry unit weight (MDD), moisture content (OMC) and different PC content for soils A and B with a 2% LQ, while Figures 6 and 7 present the effect commingle of 4% LQ and 2 to 10% PC on the optimum water content and the maximum dry unit weight (MDD) of the two treated soils. When the adding the composite (PC & LQ) can be seeing that increase the optimum moisture content and decreased the dry unit weight with increasing composite (PC & LQ) content. Similar behavior was also observed in the literature in the case of composite (PC & LQ) stabilized clayey soils. The showing of this behavior is maybe because of the following reasons: (1) the composite (PC and LQ) causes aggregation of the particles to ccupy large spaces and hence change the effective category of the soils. (2) The pozzolanic reaction between the clay present in the soils and the composite is responsible for the increase in OMC.

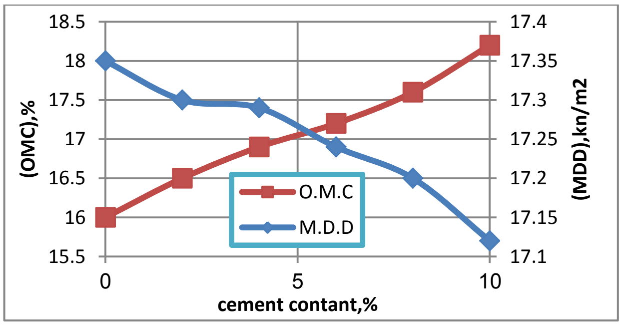


Figure 4: Relationship between MDD and OMC soil A with different PC and 2% LQ

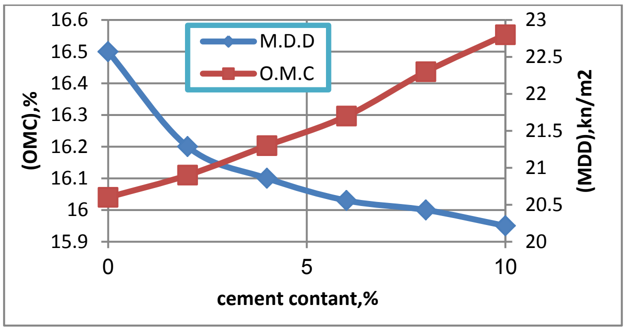


Figure 5: Relationship between MDD and OMC soil B with different PC and 2% LQ

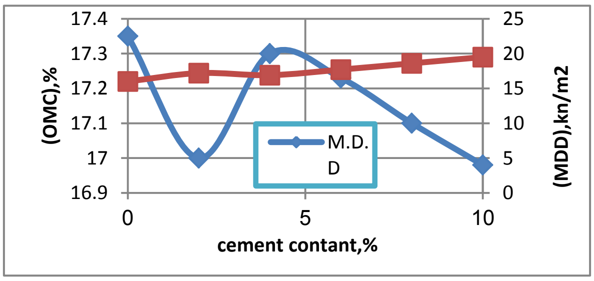


Figure 6: Relationship between MDD and OMC soil A with different PC and 4% LQ

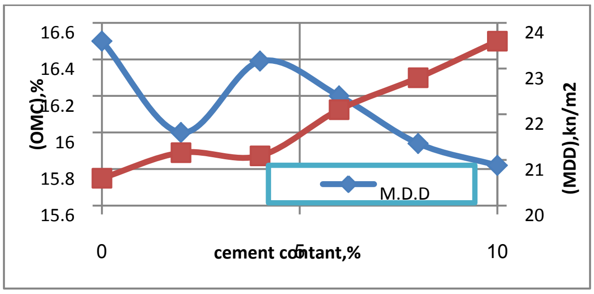
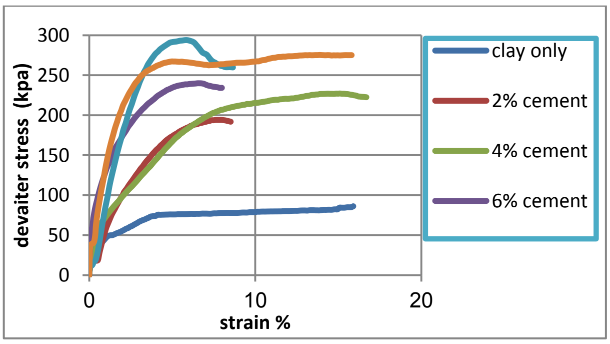


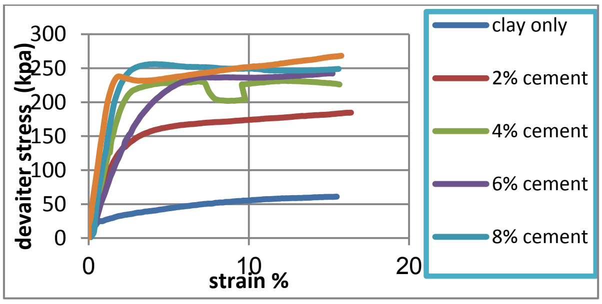
Figure 7: Relationship between MDD and OMC soil B with different PC and 4% LQ

III. The triaxial UUU test

The effects of combination PC and LQ on the relationships between stress & strain of the soil A and the soil B at the chamber pressure of 25 and 50 kpa are illustrated in Figure 8, 9, 10 and 11.

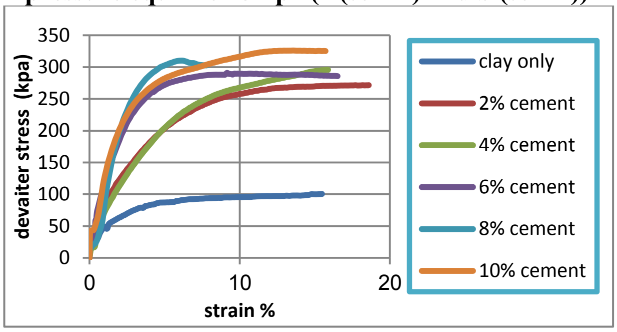


(a)

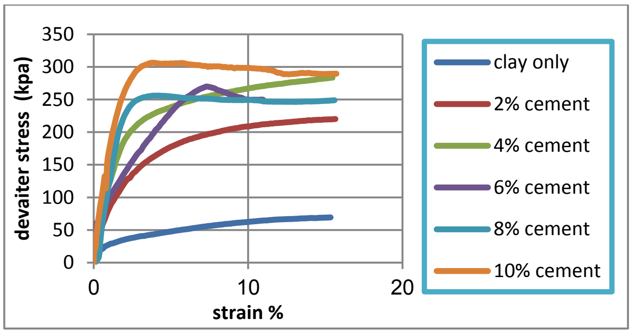


(b)

Figure 8: The relationship between the devaiter stress and the strain of UUU tests for the treated and non-treated soil specimens with 2% LQ and different ratios of stabilizer PC at the chamber pressure equal to 25 kpa (a (soil A) and b (soil B))

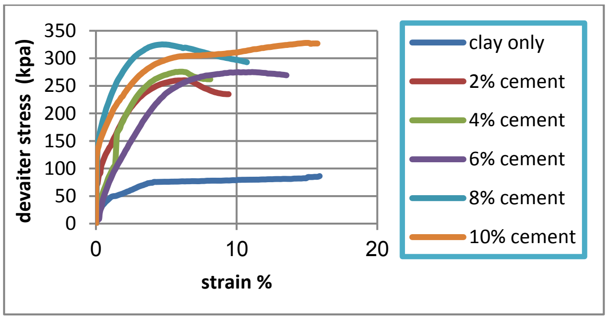


(a)

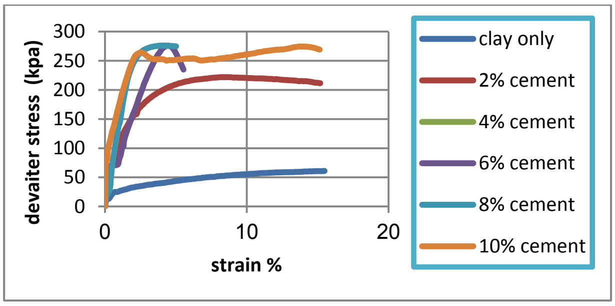


(b)

Figure 9: The relationship between the devaiter stress and the strain of UUU tests for the treated and non-treated soil specimens with 2% LQ and different ratios of stabilizer PC at the chamber pressure equal to 50 kpa (a (soil A) and b (soil B))

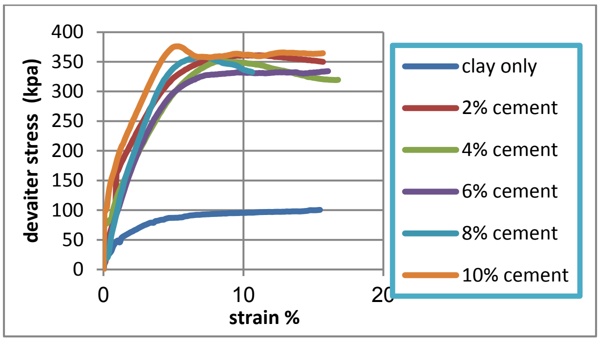


(a)

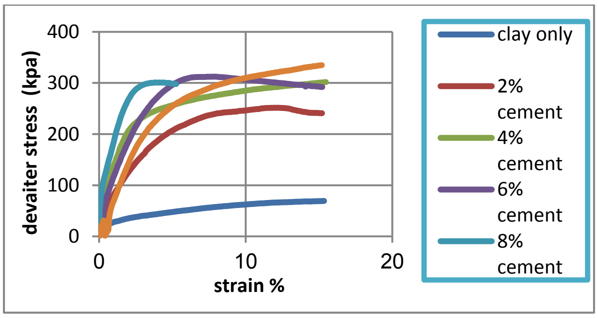


(b)

Figure 10: The relationship between the devaiter stress and the strain of UUU tests for the treated and non-treated soil specimens with 4% LQ and different ratios of stabilizer PC at the chamber pressure equal to 25 kpa (a (soil A) and b (soil B))



(a)



(b)

Figure 11: The relationship between the devaiter stress and the strain of UUU tests for the treated and non-treated soil specimens with 4% LQ and different ratios of stabilizer PC at the chamber pressure equal to 50 kpa (a (soil A) and b (soil B))

As illustrated in these Figures, when stress arrives its maximum in most of the untreated and treated soil A and B, the strain is 15% and stopped test, respectively. Furthermore, eak hear stresses and failure behaviors hassling to brittle materials were illustrated in the shear ailure mode for specimens of a combination of PC and LQ. On the other hand, the curves styles for samples enhanced with PC and LQ are identical to each other. Gave maximum the cohesive strength and the undrained shear strength via improved with a composite at 10% PC and 4% LQ for all soils. In addition, the value of shear stress when the failure of specimens treatment at rates mixing 2% LQ and 10% PC is similar approximately from the value to the shear stress of the failure of the specimens treated mixing ratios 4% LQ and 8% PC for all soils used in this study. The soil B specimens evidenced a considerable increase in the cohesion strength and the undrianed shear strength as compared to soil A. Presentation of the maximum shear strengths for softy clay Iraqi soils enhanced with a composite from PC and LQ. Table (6) contain and show effect PC and LQ on the cohesion strength (C) and internal of friction (Ø) with curing period (0,7 and 28 days).

IV. Unconfined Compressive Strength

The effect of combination between cement, quicklime and curing time on unconfined compressive strength is illustrated in Table 7 which include the undrained shear strength (Cu) for treated and untreated soils with curing period (0,7 and 28 days). Through this Table, it has been observed that the undrained shear strength (Cu) increase with increasing the composite (PC and LQ). It is clear that there was a continuous strength progress with respect to time due to cement hydration and pozzolanic reaction between soil particles and chemical stabilizer as well as any complicated reactions causing cementation of soil particles. Also, increase the strength of the soil for each period of treatment because the water content is decreased.

Table 6: The cohesion strength (C) and angle of friction (Ø°) values of soil A and B mixed with different percentages of composite (PC and LQ) with different curing period

The additive		Soil A						Soil B					
		Age 0 days		Age 7 days		Age 28 days		Age 0 days		Age 7 days		Age 28 days	
% PC	**% LQ**	C (kpa)	Ø°	C (kpa)	Ø°	C (kpa)	Ø°	C (kpa)	Ø°	C (kpa)	Ø°	C (kpa)	Ø°
0	**0**	26	5	-	-	-	-	25	3	-	-	-	-
2	**2**	37	38	225	38	410	43	46	27	289	42	500	40
4	**2**	50	33	390	36	645	41	67	26	410	40	703	39

6	**2**	60	29	500	34	800	39	75	20	590	38	911	37
8	**2**	75	28	679	31	990	37	84	19	740	35	1023	35
10	**2**	87	25	764	29	1114	36	96	16	905	32	1183	34
2	**4**	50	34	388	36	598	40	50	25	370	40	650	38
4	**4**	62	31	519	34	789	39	71	23	500	37	888	37
6	**4**	74	29	630	33	900	37	89	21	699	33	1044	36
8	**4**	85	27	750	32	1111	36	91	18	884	30	1197	34
10	**4**	94	24	899	30	1201	34	107	14	990	28	1329	33

Table 7: The undrained shear strength (Cu) value of soil A and B mixed with different percentages of composite (PC and LQ) with different curing period

The additive		Soil A			Soil B		
		Age 0 days	Age 7 days	Age 28 days	Age 0 days	Age 7 days	Age 28 days
% PC	**% LQ**	Undrained shear strength (Cu) (kpa)					
0	**0**	28	-	-	27	-	-
2	**2**	56.7	310	530	50.9	352	585
4	**2**	70	450	788	68.15	481	860
6	**2**	80	570	960	79	677	1058
8	**2**	90	740	1160	92	802	1170
10	**2**	101	889	1260	103	980	1290
2	**4**	61.5	425	690	54.78	410	712
4	**4**	76.3	577	910	78.7	580	955
6	**4**	86.6	692	1110	86.7	779	1110
8	**4**	98	860	1240	97.35	969	1260
10	**4**	115	956	1370	110	1109	1418

3. Conclusion

This study presents the effect of Portland cwmwnt (PC) and Quicklime (LQ) on Atterberg limits, compaction, shear strength and unconfined compressive strength of soft clay (cohesive) soils. Through the results of experiments that worked in this paper can be conclusions the following:

- Observes to reduce the rate of dehydration of the soil when adding small amounts of the compound (PC & LQ). It has been noted that the effect of the dehydration rate increase soil when adding high levels of the compound in the initial period during the first half hour at Add the mixture to the soil.
- The addition of a few percentage of PC and LQ cause low decreased in plasticity index, while a higher percentage of the composite (PC & LQ) led to a reduction in plasticity index. Thus, PC & LQ added soils have better workability.
- The addition PC & LQ increased the optimum water content and decreased maximum dry unit weight of the soils.
- PC & LQ treatment leads to significant increase in unconfined compressive strength of the soils. Improvement in mechanical behaviors of Al Basra city due to the composite (PC & LQ) treatment was noticeably higher than Baghdad city soils.
- PC & LQ treated soils exhibited much more brittle behavior compared with non – treated soils.

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Author’s biography

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