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Strength Parameters of Soil Improved by Cement and Lime

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Abstract

This research aims to investigate in the strength of sand soil treated with different percentages (3%, 5%, 7%) of cement and (5%, 10%, 7%, 15%) of lime, two different of the dry unit weights (14.4,15.8) kN/m^3. The specimens were examining after (28) days. The study included a number of unconfined compression tests. The UCS increased as cement content increased. It is noticed that the axial stress increases 225% for soil with γd =15.8 kN/m^3 and 153% for soil with γd =14.4 kN/m^3 with increasing cement content from 3% to 7%.The results show that the UCS increased as lime content increased It is noticed that the axial stress increases165% for soil with γd =15.8 kN/m^3 and 238% for soil with γd =14.4 kN/m^3 with increasing lime content from 5% to 15%, as the soil showed a significant improvement in the strength of cement-treated soil compared to the lime-treated soil.

Keywords: strength, cement, lime, unconfined, sand.

1. Introduction

Recently, the soil has seen chemical stabilization or addition of various natural and synthetic materials. The most common construction materials used to stabilize soils are lime, cement, and pozzolanic materials **[1].** The most preferred materials are lime and cement. To confirm the impact of additives on soil strength, researchers from all around the world have used Unconfined Compressive Strength (UCS) and another tests. Many researchers such as **[2][3] [4]**, have done studies based on the unconfined compression tests. The unconfined compressive strength of soil-cement mixes has been successfully employed to characterize their mechanical properties **[5]**. According to research conducted by **[6]** mixtures with higher cement contents have higher strengths than combinations with lower cement contents. Previous research by **[7]** demonstrated that the water/cement ratio defined as the water mass divided by the cement mass, was a useful parameter in the analysis of the strength development of cemented soils in which the pores of the specimens were predominantly water-filled, so that the water content reflected the amount of voids. According **[8]** the cement content had a large effect on the strength of soils, and the unconfined compressive strength increased nearly linearly as the cement content increased.

Lime stabilization is a cost-effective method that reduces soil plasticity, improves soil workability, and raises the mechanical properties of soil like CBR values, unconfined compressive strength, shear strength, and tensile strength, this technique has a significant impact on fine soil and has many benefits **[9][10]**. Researchers in **[9]** examined the effectiveness of applying quick and hydrated lime to the soil of tropical and subtropical regions separately at different percentages (0%, 2.5%, 7.5%, and 10%) results showed that regardless of the type, there is generally an increase in UCS with lime content. According to **[11]**, after 28 days of curing, the UCS strength increased by around 60% as a result of pozzolanic processes. The clay minerology, soil pH, silica-alumina content, kind of lime, water content, temperature, and curing period are among the factors having a significant impact on strength gain**[12]. [1]** has been studied in the impact of various lime and natural pozzolanic dosages on the geotechnical characteristics of a silt sand soil. The results showed lime improves soil's compressive strength, and mixing both lime and pozzolan results in increased compressive strength significantly that can reach about sixteen times that of untreated soil. In this research the effects of using diffrent percentages of cement and lime were investigated for strength of a sandy soil.

2. Materials

The study's soil sand air-dried was taken from a location near the Nasiriya city in the southern of Iraq. The sand's physical propertiesare given in Table 1. According to the Unified Soil Classification System (USCS) the sand used is classified as a poor sand (SP), the Figure 1 shows Results sieve analysis test of the sand. The cement used to be resistant to sulfates. Type V Portland cement produced in Iraq by the (Al Jessir) factory Table 2 show the Physical and chemical of the characteristics cement. Hydrated lime, known as Calcium hydroxide, is a fine, white powder. Table 3 show characteristics of hydrated lime. Tap water was used in all the experimental works except specific gravity test used distilled.

Table 1 Physical properties of sand

(Gs)	(Cu)	(Cc)	Classification of soil (USCS)	$\gamma_{d\ min.}$ (kN/m³)	$\gamma_{d\ max.}$ (kN/m³)	e min.	e max.	The angle of internal friction(φ)at	
								γ_d =15.8(kN/m³)	γ_d =14.4(kN/m³)
2.61	2.6	1.24	SP	13.5	16.6	0.54	0.89	35.5	31

Table 2 The Cement physical and Chemical characteristics (Data sheet**)**

Physical properties				
Specific gravity (G.S)	Average compressive strength, curing 3 days ,(Mpa)	Average compressive strength, curing 7 days ,(Mpa)	initial time of setting ,(min.)	Final time of setting ,(hour)
3.15	17	26	93	4.28

Chemical properties							
C3S %	C3A%	C2S%	SiO2 %	CaO%	MgO %	SO3%	L.O.I %
57	3.27	29	19.79	63.8	3.19	2.15	0.89

Table 3 Characteristics of hydrated lime

Property	value
form	Fine white powder
Cao (%)	66.851
Ca (OH)2 (%)	88.572
Co2 (%)	2.731
Specific gravity	2.321
Degree of fine on sieve 90 macro (%)	6

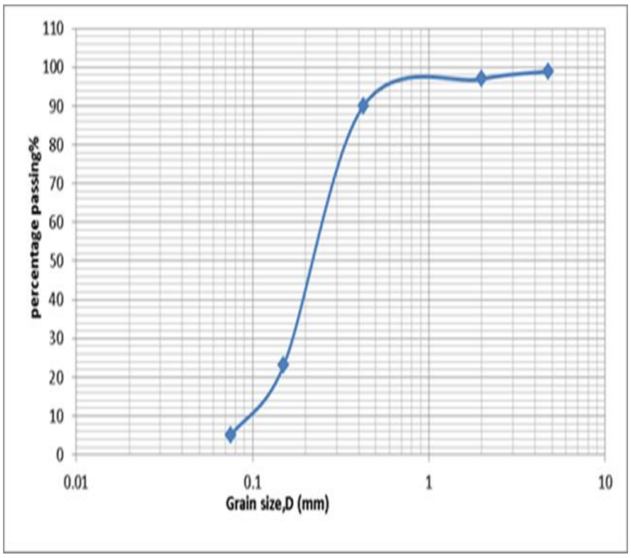


Fig.1 Results sieve analysis test of the sand

3. Unconfined Compression

3.1 Test Mixing and Preparation of Samples

The UCS tests were conducted on (14) specimens of soil with (3%,5%,7%) cement content and (5%, 7%, 10%, 15%) lime content, two different values of dry unit weights were used (14.4, 15.8) kN/m^3, 10% of moisture content and examines at period (28 days). Cylindrical specimens of (42mm in diameter, 84mm in height) were used. The additives and soil were mixed until the combination had a homogeneous, cement, lime, and water had been weighed. The quantity of cement and lime for each combination was determined by the mass of dry soil. Following the addition of the water, The mixing process was continued until the mixture was homogenous, in three layers each specimen was compressed. within a greased cylindrical plastic mould, once each layer achieved the required dry density .After the moulding process, the specimens were remained inside the plastic mould and wrapped in plastic sheet, placed in an airtight container and for twenty eight days in a place at 22 °C ± 1 °C Figure 2 shows the Specimens during the curing. The specimen's weight, diameter, and height were measured just before the test. Figure 3 illustrates the UCS test. Table 4 explain the results of UCS tests.

Fig.2 Specimens during the curing

(a) (b)

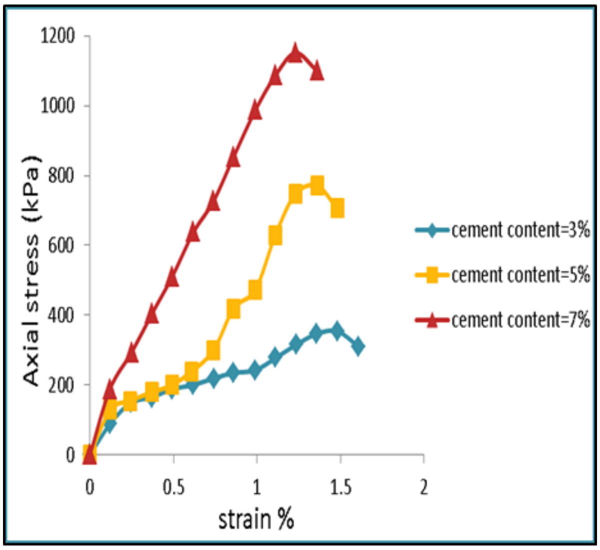
Fig.3 UCS test (a) a specimen under load, (b) a failed specimen

3.2 Test Results and Interpretation

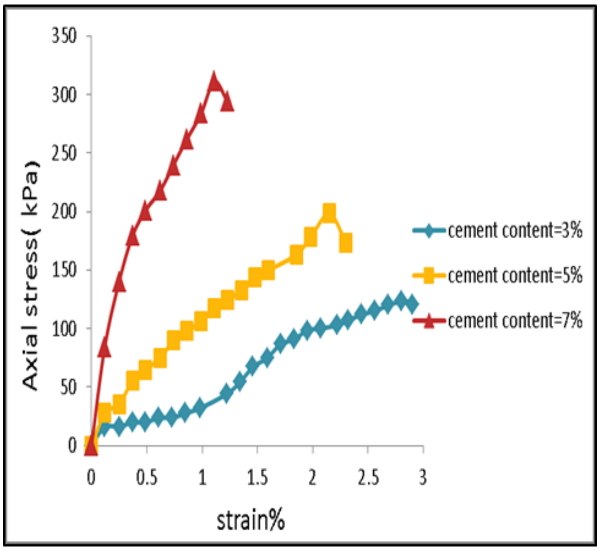
Table 4 explain the results of unconfined compressive strength tests. Figure 4 shows stress – strain relationship for different percentages from cement with different values of dry unit weights. The UCS increased as cement content increased, which is consistent with past investigation's results. It is noticed that the axial stress increases from 354.5 kPa to 1150.6 kPa for soil with γd =15.8 kN/m^3 and from 123 kPa to 310.8 kPa for soil with γd =14.4 kN/m^3 with increasing cement content from 3% to 7%. Thus, sand treated in Figure 4 exhibited ductile behavior for 3% Cement content and brittle behavior for treated soils with 5% and 7%.

Table 4 Results of Unconfined Compressive Strength Tests

Samples No.	Stabilized Agents	Percentage %	γd (kN/m^3)	UCS (kPa) for Curing time 28 days
1	Cement	3	14.4	123
2	Cement	5	14.4	198
3	Cement	7	14.4	310.8
4	Cement	3	15.8	354.5
5	Cement	5	15.8	770.2
6	Cement	7	15.8	1150.6
7	Lime	5	14.4	121.7
8	Lime	7	14.4	235.7
9	Lime	10	14.4	352.3
10	Lime	15	14.4	411
11	Lime	5	15.8	714.6
12	Lime	7	15.8	801.5
13	Lime	10	15.8	1227
14	Lime	15	15.8	1985.4



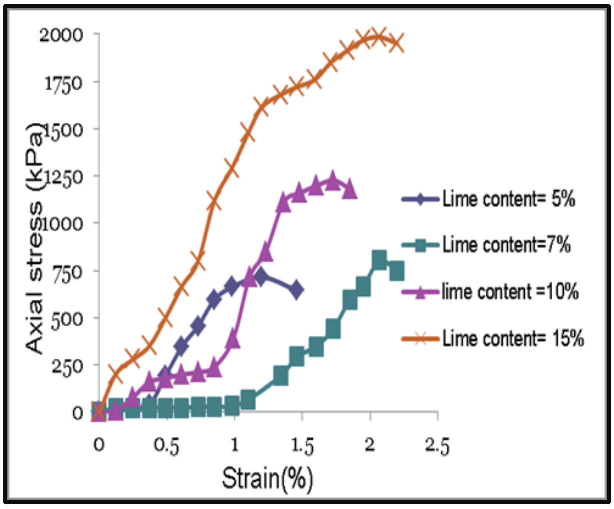
(a)



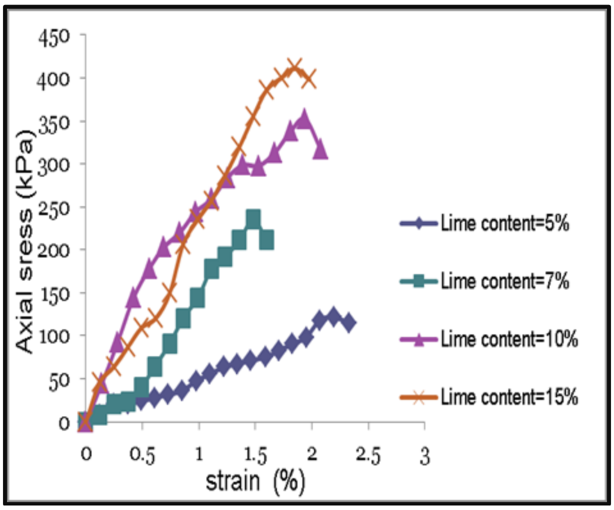
(b)

Fig.4 Stress – strain relationship for different percentages from cement and soil with (a)γd =15.8 kN/m^3, (b) γd =14.4 kN/m^3

Figure 5 illustrated the stress – strain relationship for different percentages from lime with two values of dry unit weights. The unconfined compressive strength `increased as lime content increased, which is consistent with past investigation's results. In Figure 5 It is noticed that the axial stress increases from 749.3 kPa to 1985.4 kPa for soil with γd =15.8 kN/m^3 and from 121.7 kPa to 411 kPa for soil with γd =14.4 kN/m^3 with increasing lime content from 5% to 15%. In Figure 5-a the sand treated with (5%,7%,10%,15%) exhibited a brittle behavior as well as in figure 5-b for sand treated with (7%,10 ,15%).



(a)



(b)

Fig.5 Stress – strain relationship for different percentages from lime and soil with (a) γd =15.8 kN/m^3 (b) γd =14.4 kN/m^3

Figures 6 and 7 illustrates how the stabilized agents content effect on the unconfined compressive strength for both dry unit weights. Figures 6 and 7 explain that the strength increases approximately linearly with increasing cement or lime content in both soils. It is noted that in the higher density of the sand the strength increases rapidly at sample treated with cement and lime, but increases at lower rate in the lower density of the sand. From these Figures are also clear the axial stress by cement was higher than lime for the same percentage for both soils was tested. The engineer can select the minimum density and amount of cement required to produce a mixture that meets the project's requirements for strength and stiffness at the lowest possible cost [8].

According to [13] the decrease in the UCS is caused by lime poor self-cementing properties. When combined with water, lime forms the cementitious materials calcium silicate hydrated, ettringite, and calcium hydroxide. While the primary bondage strength of the cemented soil is governed by calcium silicate hydrated and ettringite gels, calcium hydroxide is needed for lime to react with excess silica and alumina under pozzolanic reaction.

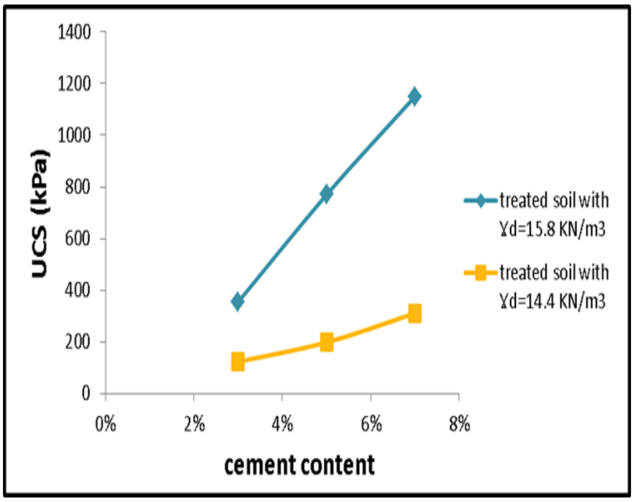


Fig.6 Variation of UCS for both treated soils with cement content

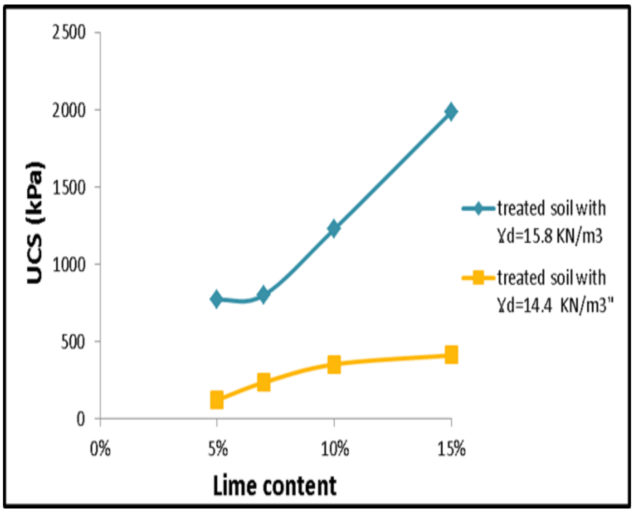


Fig.7 Variation of UCS for both treated soils with lime content

Conclusions

The UCS increased as cement content increased. It is noticed that the axial stress increases 225% for soil with γd =15.8 kN/m^3 and 153% for soil with γd =14.4 kN/m^3 with increasing cement content from 3% to 7%. The UCS increased lime content increased It is noticed that the axial stress increases165% for soil with γd =15.8 kN/m^3 and 238% for soil with γd =14.4 kN/m^3 with increasing lime content from 5% to 15%. It is noticed that the axial stress and brittlely of the soil increases with cement and lime content increasing, so for sand treated exhibited ductile behavior for 3% cement content and brittle behavior for treated soils with 5% and 7% cement content. The sand treated with (5%-15%) lime content and higher dry unit weight as well as (7%-15%) and lower dry unit weight exhibited a brittle behavior, and it was founded that a significant improvement in the strength of sand soil treated with cement compared to the sand soil treated with lime.

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