IMPROVING THE PROPERTIES OF SOFT CLAY USING LIMESTONE

Eman Adnan[1, a], Maki Jafar Al Waily[1,b] and Zahraa F. Jawad [1,c *].

Construction and Building Department Al Furat Al Awsat Technical University, Najaf, Iraq

aeman.adnan.tcm.18@student.atu.edu.iql, amaki_jafar@atu.edu.iq, cdr_zahraajawad@atu.edu.iq*

Abstract:
The influence of local components on the geotechnical properties of clay soils was explored softness in this research. This study used limestone. These elements were used in quantities different (1, 2, 3, 4) from the weight of the soil. The study determined the ideal proportions for the additives by performing several unconfined compressive strength tests and 20 sample tests. A cubic soil tank with a side length of 26 cm was manufactured for evaluation of Weight-bearing capacity after determining the optimal proportions of the additive. A load test was performed using a circular model base with a diameter of 7 cm, which was placed on the surface of the soil. The results of the analysis indicate that the incorporation of local constituents into the soil leads to an increase in shear strength Uncasted for treated soil. The results of the study indicate that the incorporation of local materials into the soil is not Pretreatment significantly increased the shear resistance of the uncoated. Specifically, show use of Limestone significantly improved the mechanical properties of the soil. I yielded The shear strength of the uncast, which was initially measured at 5 kPa, significantly increased to 7.5 kPa and later to 15 kPa. In addition, it showed shear resistance a similar trend, increasing from 25 kPa to 27 kPa and eventually to 34 kPa Pascal. The use of limestone has been found to improve the bearing capacity of soils, with Similar decrease in uncut shear strength. Also, for shear strength (cu = 12 kPa) Limestone as a soil additive reduces settling ratio, Sr, (Streated / Suntreated) by (0.7, 0.56, 0.46, and 0.33) with added ratios of (1, 2), 3, and 4.

Keywords: (shear strength , soft soil, limestone, stabilization, Bearing Improvement)

Introduction

One of the widely accessible materials for construction is soil. The majority of construction is done on top of or in conjunction with the earth. By aiming to strengthen or maintain the soil mass's stability and the soil's chemical change to enhance its engineering capabilities. Soil stabilization is the most significant construction component frequently employed concerning road paving and foundation building [1] . The concept of stabilization is 5000 years old [2].

One method for improving soil is stabilization utilizing solid waste materials, which can improve the geotechnical characteristics of problematic soils and make them appropriate for building. A few industrial operations result in solid wastes, which are harmful to the environment.

Many academics have been working on stabilizing expansive soil utilizing different industrial solid wastes over the past few years [3-8]. in order to make difficult soils appropriate for use as building materials, notably for the construction of roads, embankments, earth dams, etc., some of the solid waste products have been employed[9]. When construction stones are cut and finished in Iraqi masonry companies, a lot of crushed limestone is created[10]. In general, utilizing waste materials to stabilize soil provides benefits for the environment and is likely less expensive[11]. In addition, many facilities in the city of Erbil in the Iraqi Kurdistan Region produce limestone powder for use as a filler in the formulation of asphalt mixes. It can profit from these industries for soil stabilization with a mix of crushed limestone by-product in the vicinity since a significant volume of stabilizer is needed. There haven't been many research done on employing limestone powder to stabilize very expansive soils. Al-Azzo[10]. research was done on the impact of crushed limestone (passing sieve #40) on the engineering characteristics of high expansive clay. Crushed limestone dust was mixed with the loose soil in the research in amounts of 2%, 4%, 6%, 8%, and 10%. The expansion qualities were found to be significantly reduced, and there was a discernible fall in the plasticity requirements. For medium expansive soil, Maulood [12] employed limestone powder (passing sieve #40) in varying proportions as a filler material (7.5%, 10%, 12.5, and 15%) to reduce cracks during the air-drying stage. Cement, lime, fly ash, and other admixtures have all been utilized by various researchers to stabilize the geotechnical characteristics of expansive soil [13-15]. The qualities of the soil are improved by these produced agent additions when they are put in the suitable amounts. Some of these stabilizers may be harmful to the environment when used, particularly while these materials are being produced[16-21]. Therefore, it is essential to choose a stabilizer made of a substance that is less hazardous to the environment.

2. Experimental Work

2.1. Soil Properties

The soil samples used in the study were brought from the area of Babel/Al-Mahaweel, and soil samples were taken at depths ranging between (1-2) meters. The soil was examined in the laboratories of the Department of Building and Construction, Musayyib Technical College, using laboratory equipment and instruments. The following physical tests were performed:

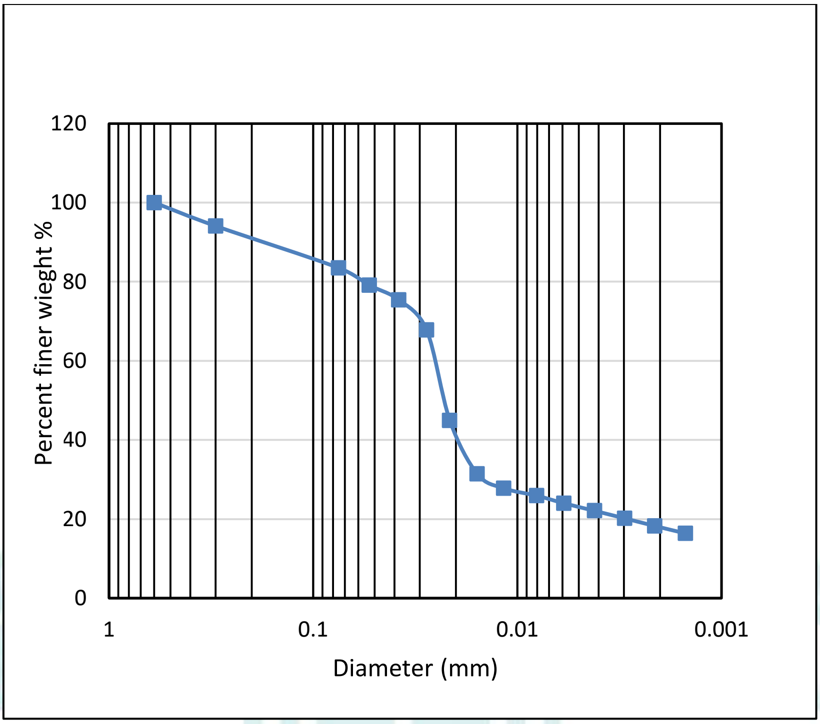


Figure.1 Grain size distribution of the soil

1- Grain size dispersion as determined by ASTM D422 (sieve analysis and hydrometer test)
2- Limits for Atterberg (liquid and plastic) based on ASTM D4318
As indicated in Figure 1, the test results revealed that the soil contained 16.5% sand, 67.11% sand silt, and 16.39% clay. The Standard Soil Classification method classifies inorganic soil as having particular silt and clay. as ML. Table (1) displays the soil's physical characteristics.

Table (1): Soil Properties

Index Property	Index value	Standard Specification
Specific gravity G_s	2.7	ASTM D 854
Liquid limit (%)	42	ASTM D 4318
Plastic limit %	20	ASTM D 4318
Plasticity index (PI)	22	ASTM D 4318
% Passing sieve No. 200	83.5	ASTM D 422

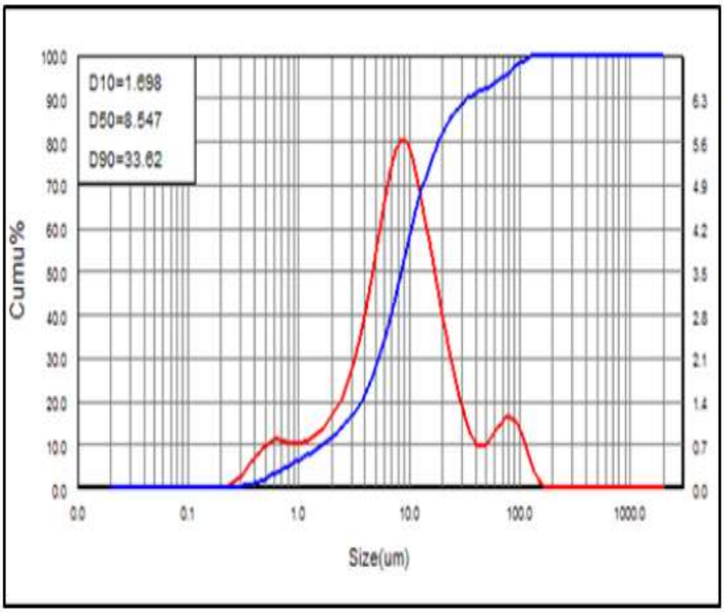
Sand content	16.5	ASTM D 422
Silt content	63.5	ASTM D 422
Clay content < 0.005 mm	20	ASTM D 422
Optimum moisture (modified %)	14.8	ASTM D 1557
Modified dry unit weight (kN/m^3)	17.87	ASTM D 1557
Symbol according to Unified Soil Classification System	ML	D 2487

2.2. Limestone Properties

The calcium carbonate used is natural limestone. The characteristics of limestone are shown in Table(2), and the spread of grain size of the crushed limestone used in the experiments is shown in Figure (2), XRD graph is shown in Figure (3).

Table: (2) Properties of limestone [22]

Property	Value or description
Material structure	micro $CaCO_3$
Color	Light brown
Particle size	100-200 µm



Figure(2): Particle size distribution of limestone [22]

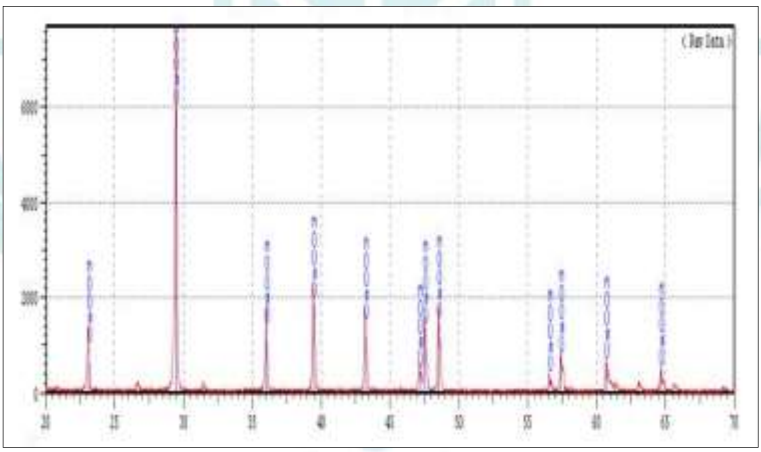


Figure (3): The characterization measurement (XRD) pattern of limestone[22].

2.3 Setup for the Test

Glass container: The model tests were conducted in a tank with a frame made of steel with dimensions of 26 cm * 26 cm * 26 cm, inside which glass panels were installed, as shown in Figure (4).

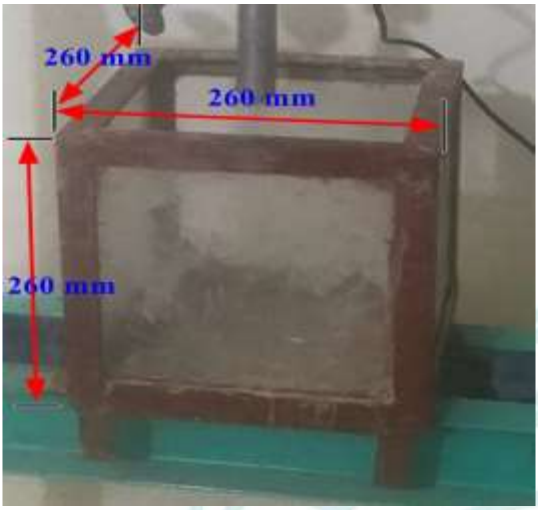


Figure.(4) Glass Container

2.4 Loading Form Work

The whole apparatus is seen in detail in Figure (5) and comprises primarily a glass cage, a loading frame, gauges, and a circular disc placed over the soil's top surface.

Figure.(5) The loading frame

2.5 Creation and Evaluation of Models

In the process of preparing the soil bed, the unconfined shear force of the soil must be determined before preparing the soil layer as shown in Figure (6). An unconfined shear device was used to determine the shear strength.

The soil model is then created in the manner described below:

(1) A crushing machine was used to do further crushing after the natural soil had initially been broken up into little pieces with a hammer and dried in a kiln.
(2) A quantity of soil was mixed with a sufficient amount of water approximately corresponding to the cu(5,10,12,15,25) range. This range of water content was chosen from Figure (6).
(3) After mixing it with water and covering it tightly with a layer of nylon and leaving it for 4 days, then the soil is placed in the form of layers inside the glass container, and each layer is pressed well so that the thickness of each layer is equal. About 5 cm and the paving process continues until the final thickness of the soil layer.

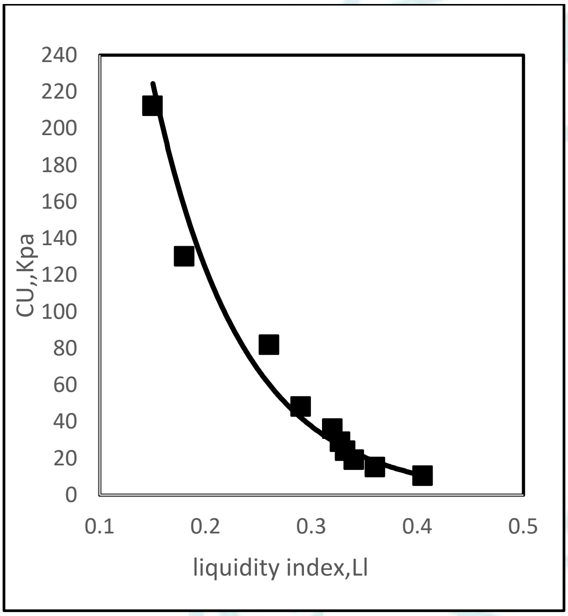


Figure.(6) Shear strength-liquidity index, L.I relationship

2.6 Model Checking Process

The following typical experiments are performed according to the test schedule:

(1) The footing assembly is positioned so that the center of the footing and the center of the hydraulic jack at the conclusion of the 4-day period.
(2) For the purpose of measuring the settlements of foundation model, a dial gauge with accuracy of 0.01 mm are put in place.
(3) At the conclusion of each load's term, the dial gauge readings are recorded.
(4) After that, loads are applied through a loading disk using load increments.
(5) A total of (2.5 min) is given for each load increment.
(6) For each load increment, the total load that is applied to the soil sample is noted. The overall settlement rose as the load grew until it doubled the diameter of the foundation

model, or 14 cm. This will help you comprehend the connection between load and settlement even after the failure limit.
(7) This loading is carried out on both untreated and additive-treated soil.

RESULTS

In this research, 20 test paradigms were made according to the test program for assaying the behavior of limestone Base(1,2,3,4)% Determination of tolerance (failure)When the settlement reaches 20% of the base diameter

3.1 Unconfined Shear Strength Test Results

The tensile strength of loose clay soils was evaluated on soils with varying CU before and after the addition of improvement materials at rates (1,2,3,4)(%) to determine the impact of additives on that strength. A cylindrical sample with a height of 78 mm and a width of 36 mm (L/D) = 2 was used for the test. An unconfined compression device is used to squeeze the cylindrical sample, which fails along the diagonal lines. The highest shear stress ratio is then calculated following ASTMD2166.4-2 Unconfined shear strength test results

3.2 Undrained Shear Strength of Soil Stabilized with Limestone

The primary purpose of using local materials to improve soil properties is to find materials that improve soil properties at a lower cost, in addition to reducing waste, because the cost is an important factor, unlike nanomaterials that have a high cost.Aside from that, limestone is widely available and can be considered a low-cost material with no health risks associated with its use.The outcome of a series of unconfined compewssion strength tests revealed that using limestone significantly increases the undrained shear strength of soft soil. Figure (7) shows the relationship between the undrained shear strength of limestone-stabilized soil and the liquidity index. Tables (3) summarize the shear strength improvement factored (SSIF) effect on shear strength The coefficient of improvement in shear strength for soil treated with limestone is between (1.34-1.67) for cu = 5 KPa and improved by a percentage ranging from (1.1-1.29) for cu = 25 KPa

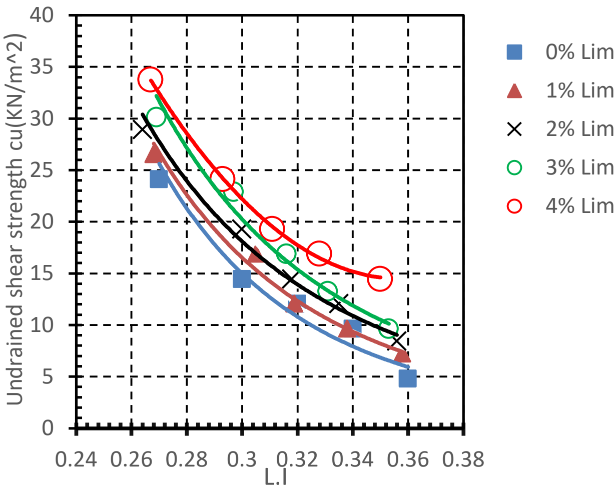


Figure (7): Shear strength -liquidity index, L.I relationship for soil treated with Limestone)

Table (3): Shear Strength Improvement Factor (SSIF) for soil treated with Limestone

Limestone / cu	1%	2%	3%	4%
5 kPa	1.34	1.43	1.5	1.67
10 kPa	1.07	1.2	1.27	1.43
12 kPa	1.05	1.17	1.29	1.38
15kPa	1.15	1.25	1.39	1.41
25kPa	1.1	1.17	1.2	1.29

Figures (8 - 12) are related to stress and deformation in untreated soil and soil treated with limestone of percentages (1,2,3,4) %. The surrounding soil is prepared with unconfined shear strength, cu (5,10,12,15,25) kPa, respectively. These samples are tested after 4 days when the load is applied to the soil treated with nano silica material at the point of failure 0.2 B. clear point of failure not found, and the applied load is increased to reach the point of failure. The results showed that the soil with cu = (5, 10, 12, 15, 25) kPa, failure type is general.

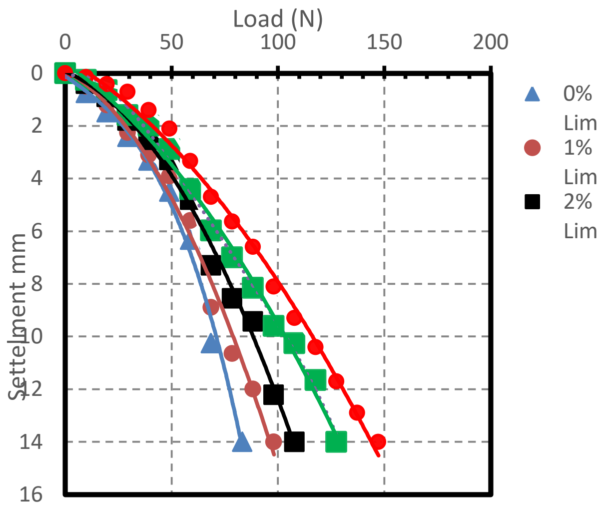


Figure (8): Load versus settlement for the soil treated with Limestone, cu=5kPa

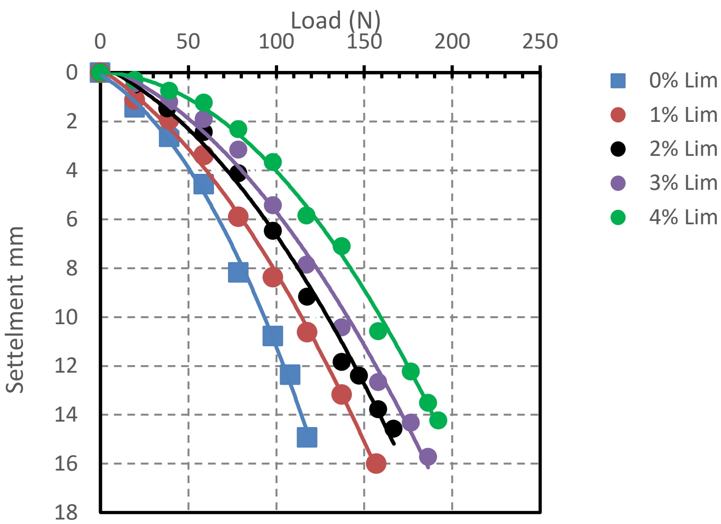


Figure (9): Load versus settlement for the soil treated with Limestone, cu=10kPa

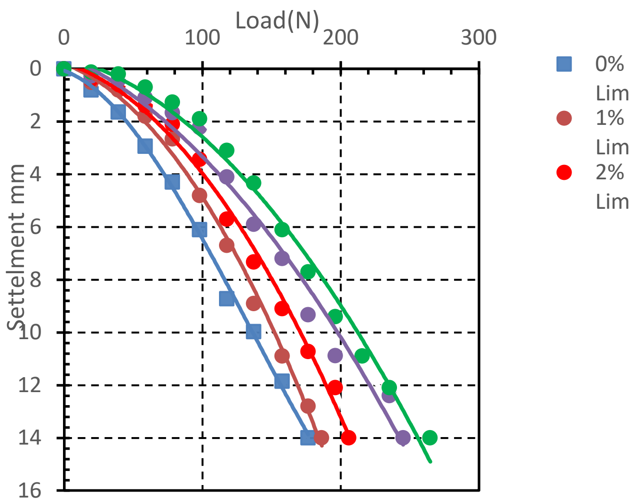
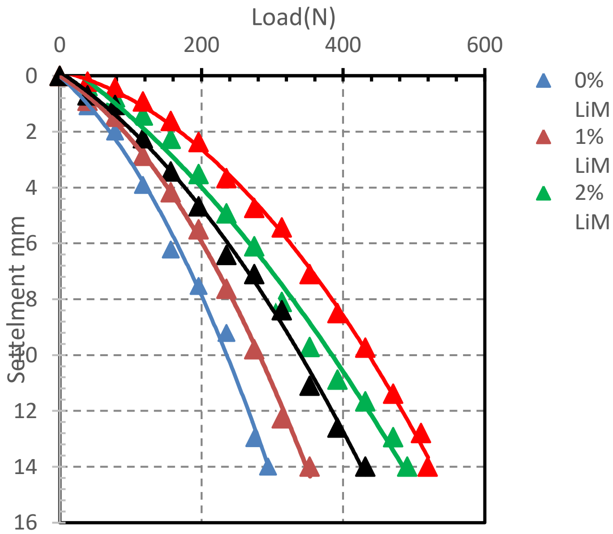
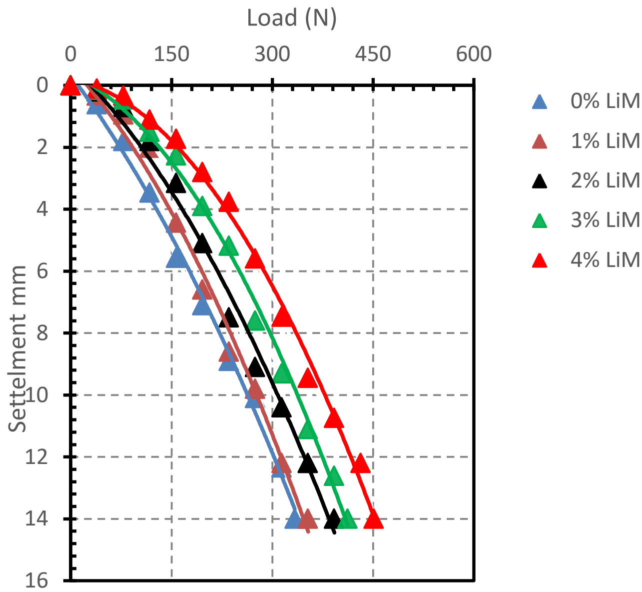


Figure (10): Load versus settlement for the soil treated with Limestone, cu=12kPa



Figure(11): Load versus settlement for the soil treated with Limestone, cu=15kPa



Figure(12): Load versus settlement for the soil treated with Limestone, cu=25kPa

3.3 Bearing Improvement Ratio

The impact of addition limestone on the shear strength is observed for data collected which clearly showed this improvement.

figure (13) demonstrates the general characteristics of a foundation's load settlement curves with or without treatment. The bearing capacity ratio may be defined as follows using this idea:

$$BIR_u = \frac{q_{u(R)}}{q_u} \quad \text{...(4-2)}$$

And $$BIR_u = \frac{q_{u(R)}}{q_u} \quad \text{...(4-3)}$$

Where:

BCR_u = bearing efficiency ratio in relation to maximum load

BCR_s= bearing enhancement ratio for the foundation at a certain settlement, s.

$q_{R,q}$= load per unit area on the foundation with and without treatment, respectively, at a settlement level of s su.

$q_{u(R),q}$= ultimate carrying capacity after therapy and without it, if any.

s_u = oundation settlement on untreated soil under ultimate load.

The bearing improvement ratio was calculated for limestone material the improvement ratio found to be ranging (1.13-1.55) with cu = 5kPa, (1.34-1.97) with cu = 10kPa, (1.2-1.8) with cu = 12kPa, (1.18-1.69) with cu = 15kPa, and finally the improvement ratio ranging (1.1-1.6) with cu = 25kPa. Table (4) displays the bearing improvement ratio for limestone material.

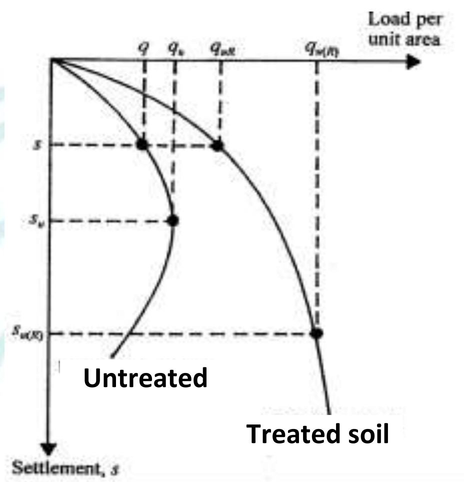


Figure (13): Local shear failure in soil, (after Das, 1999)[23].

Table (4): Bearing improvement ratio for soil by using limestone nanomaterials

cu	Limestone			
	1%	2%	3%	4%
	BIRs, $q_{treated}/q_{untreated}$			
5kPa	1.13	1.23	1.38	1.55
10kPa	1.34	1.48	1.68	1.97
12kPa	1.2	1.4	1.6	1.8
15kPa	1.18	1.3	1.44	1.69
25kPa	1.1	1.2	1.4	1.6

3-4 Settlement Reduction Ratio

Calculations are utilized to examine how the addition impacts the soil's capacity to retain stability. Soil settlement is handled using local material (limestone) at final load (the last point of the load leveling curve).Table (5) displays the leveling reduction ratio that was identified during the testing of several models. The similar pattern persisted in all groups: a quick drop in the father was followed by early stress bursts. The indicator of the most efficient stabilizing reduction is the lowest settling reduction ratio.

Table(5) Summary of settlement reduction ratio (S_r) (Settlement $_{treated}$ /Settlement $_{untreated}$) from various model tests.

cu	Limestone			
	1%	2%	3%	4%
	S_r			
5kPa	0.75	0.59	0.47	0.36
10kPa	0.7	0.56	0.46	0.33
12kPa	0.91	0.75	0.58	0.5
15kPa	0.78	0.6	0.5	0.35
25kPa	0.95	0.79	0.68	0.48

3-5 Settlement After 24 Hours of Loading

When loading the soil with a constant load for 24 hours for the treated soil, and for the untreated soil during this period, the stability of the soil is measured at equal time intervals. It is noted that the settlement is decreasing, and this indicates that the added substance contributes to the stability of the soil. and the curve of the relationship between time and settlement as shown in Figures (14-18).

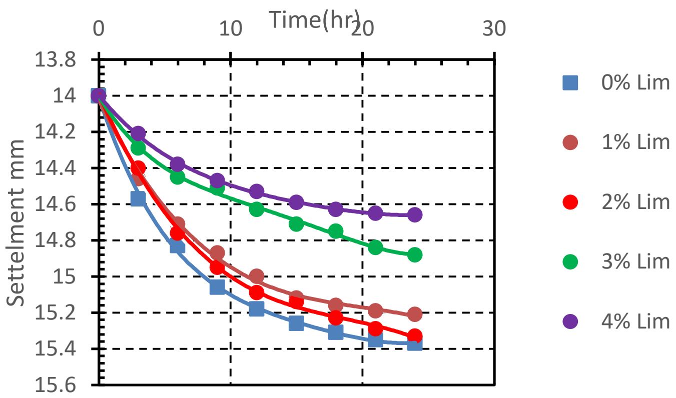


Figure (14) Settlement 24 hours of static loading treated with limestone, cu = 25kPa

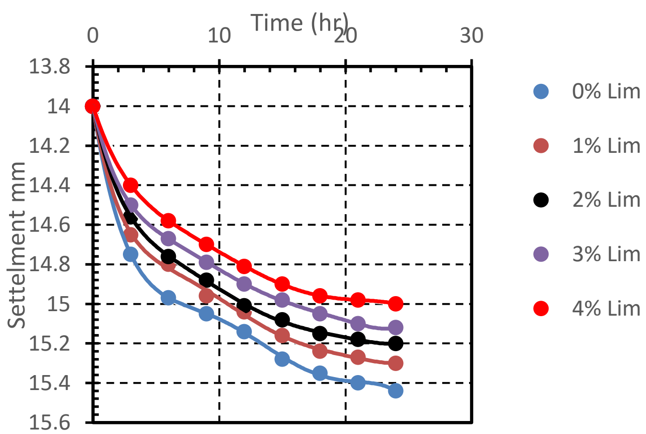


Figure (15) Settlement 24 hours of static loading treated with limestone, cu=15kPa

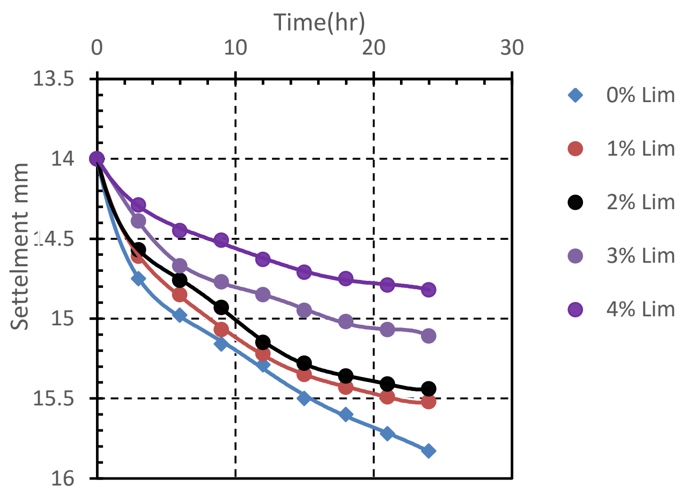
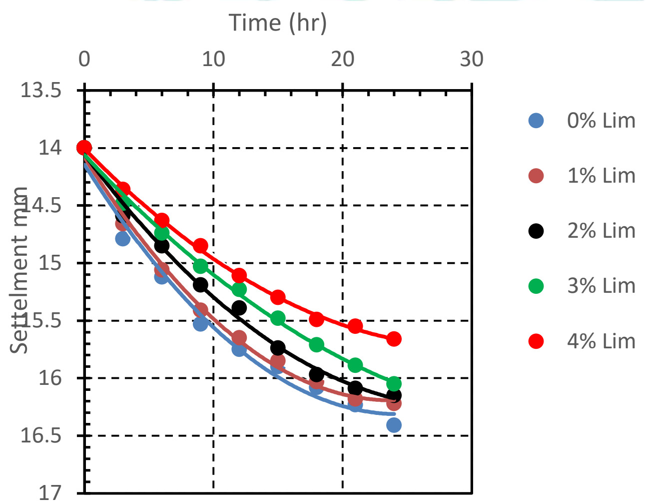


Figure (16) Settlement 24 hours of static loading treated with limestone, cu =12kPa



Figure(17) Settlement 24 hours of static loading treated with limestone, cu =10kPa

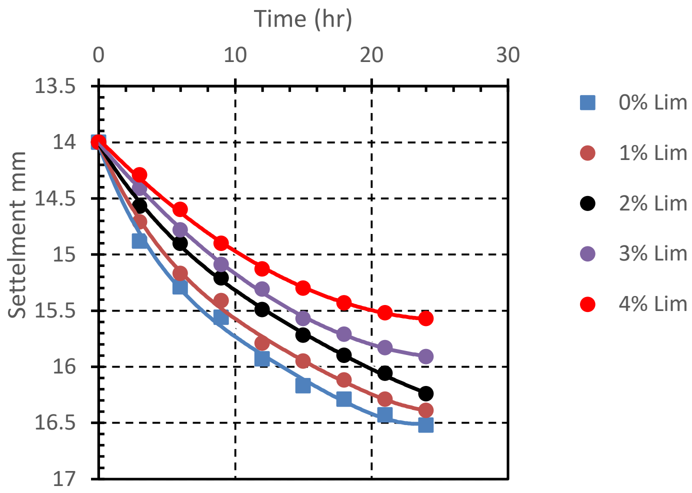


Figure (18) Settlement 24 hours of static loading treated with limestone, cu=5kPa

4. Conclusions

Depending on the results of the study, some conclusions can be drawn

4.1 Undrained Shear Strength of Soil Stabilized with Limestone

1.The undrained shear strength of soil exhibits a notable increase upon treatment with limestone within the range of 1% to 4%. Specifically, the value of cu rises from 5 kPa to a range of 7.5 kPa to 15 kPa. Upon the addition of the same quantity of light as previously applied, the soil exhibiting a shear strength of cu = 10 kPa underwent improvement, resulting in an increase to a range of 11kPa to 17 kPa.

2.The study found that soil treated with limestone exhibited a coefficient of improvement in shear strength, which is defined as ratio of the shear strength of the treated soil with limestone to the shear strength of the untreated soil, (cu_{tr}/cu_{un}) ranging from 1.34 to 1.67 for cu = 5 KPa, and a percentage improvement ranging from 1.1 to 1.29 for cu = 25 KPa.

٤.2. Improvement in Bearing Capacity

The test revealed the following information:

1.The success of the treatment procedure using limestone in increasing the bearing capacity is inversely related to the uncorrected shear strength of the soil. In particular, as the uncasted shear strength of the treated soil grows, the percentage improvement in bearing capacity decreases. This indicates that the processing method is more effective in soils with lower shear strength. The behavior of this phenomenon is very similar to its response when dealing with different augmentation procedures, such as the lime column approach.

2 . Loaded improvement ratio which is defined as the ratio of BC of limestone treated soil to B.C of natural soil. The $CaCO_3$ material showed an improvement of 1.55 to 1.13 with

cu = 5 kPa, (1.34–1.97) with 10 kPa, (1.2–1.8) with 12 kPa, (1.18–1.69) with 15 kPa, and (1.1–1.6) with 25 kPa.

3- It was noted that the increase in the percentage of loaded improvement is positively related to the increase in the percentage of the added substance.

4.3 Settlement Reduction Ratio

The testing revealed the following information:

1.The settlement reduction ratio (Sr), which is the ratio of settlement of soil with limestone to the settlement of natural soil, (Streated/Suntreated) exhibits an increasing trend with the enhancement of shear strength of the treated soil.

2. The inclusion of limestone to soils exhibiting a shear strength of cu=10kPa has been found to decrease the Sr settlement reduction ratio to values of 0.7, 0.56, 0.46, and 0.33.

Conflict of interest

“The authors declare that there are no conflicts of interest regarding the publication of this manuscript”.

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