Journal of Engineering and Sustainable Development
www.jeasd.org
Vol. 20, No.05, September 2016
ISSN 2520-0917

IMPROVEMENT OF SHEAR STRENGTH PARAMETERS OF MODEL ORGANIC SOILS

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Abstract: The characteristics of organic soil are low permeability, low shear strength and high compressibility, therefore organic soil has to be improved before any engineering works can commence. In this study dry kaolinite is used as a clay minerals and fresh reed as an organic material for different percentages (0%, 2%, 5%, 8%, 12% and 20%) by dry weight. Lime is used as a treatment material for different percentages (0%, 3%, 6% and 9%) by dry weight. The experimental work includes a series of compaction and direct shear tests conducted on 48 samples. The effect of addition of lime on shear strength parameters of non-decomposed and decomposed model organic soil was studied. The results showed that the cohesion values (c) increase with increasing organic content up to 5% for non-decomposed samples and up to 7.0% for decomposed samples while angle of internal friction (φ) increases with the increase in organic content for both decomposed and non-decomposed samples. Also use of lime has increased the angle of internal friction of soil especially when used within the range of (0-3) % lime content.

Keywords: *organic content, shear strength, cohesion, angle of internal friction, lime.*

تحسين معاملات قوة القص لتربة عضوية نموذجية

الخلاصة : خصائص التربة العضوية هي قليلة النفاذية، قوة القص منخفضة وانضغاطية عالية. لذلك تحتاج التربة العضوية الى تحسينها قبل البدء في اي اعمال هندسية. في هذه الدراسة استخدم الكاؤلين كمصدر لمعدن الطين، والقصب الطازج كمصدر للمادة العضوية وبنسب مختلفة (٠، ٢، ٥، ٨، ١٢، ٢٠) % من الوزن الجاف. استخدمت النورة كمادة معالجة وبنسب مختلفة (٣، ٦، ٩)% من الوزن الجاف.يشمل العمل المختبري سلسلة من الفحوصات (الرص و القص) التي اجريت على ٤٨ عينة. تم دراسة تأثير اضافة النورة على معاملات قوة القص للتربة العضوية النموذجية المتحللة وغير المتحللة. أظهرت النتائج بأن مؤشر التماسك (c) يزداد مع زيادة نسبة المادة العضوية الى أن تصل الى ٥% للنماذج غير المتحللة وتصل الى ٧,٠% للنماذج المتحللة، بينما ازدادت زاوية الاحتكاك الداخلي مع زيادة نسبة المادة العضوية لكل النماذج (المتحللة وغيرالمتحللة). كذلك فان استخدام النورة أدى الى زيادة زاوية الاحتكاك الداخلي للتربة وخاصة بين (٠-٣)% من محتوى النورة.

1. Introduction

Organic materials in soil are created from decomposition of animal and plant residues. When this material incorporated in the soil is attacked by variety of worms, microbes and insects in the soil if the soil is moist. A large number of studies

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investigated the behavior of organic soil. These behaviors are represented by high compressibility, poor shear strength, and high magnitude and rates of creep.

Abbass et al.[1] found that the organic content plays an important role in reducing the maximum dry density and increasing the optimum water content. Similar results were obtained by Habbi [2]. Zbar et al.[3] concluded that the optimum water content and maximum dry density decreased with increasing organic matter due to decreasing the specific gravity.

Yunus [4] found that the addition of lime decreases the maximum dry density and increases the optimum water content. Rafizul et al.[5] illustrated the geotechnical properties of treated soil prepared in the laboratory by mixing bentonite, lime and cement at varying content of (5, 10, 15, 20 and 25) % of dry mass of organic soil. They found that the optimum moisture content decreases while the maximum dry density increased with increasing the admixture content.

Thiyyakkandi and Annex [6] found that the increase in organic content significantly decreases (parabolic variation) in the unconfined compressive strength (q_u) of soil and increases in the failure strain. Rabbee and Rafizul [7] found that the USS (undrained shear strength) of soil decreased linearly from 41.0 to 18.34 kPa with increasing the organic content from 5 to 35%.

Moayediet et al. [8] explained the effect of sodium silicate to stabilized organic soil. They illustrated that the addition of 3mol/L and more sodium silicate led to an increase but still early to decide that such stabilizer alone is good enough to be chosen as a main injecting grout due to its solubility after submerging through water. Tastan et al.[9], studied the stabilization of organic soils with fly ash. The result showed that the UCS of organic soils can be increased by adding fly ash, but the degree of increase depends on the characteristics of the fly ash and type of soil. Ali [10] investigated the improvement of engineering properties of organic soil by mixing with different percent of chemical liquid consists of cement, lime and fly ash. The results showed that the liquid treated was active to improve strength especially after 7 days of curing period and recommended the chemical constituents of the liquid treated were vigorously responded with the clay platelets.

Therefore organic soil has to be improved before starting any engineering works. The improvement can be represented by replacing the soil in the site with the superior material or; change the engineering properties of in situ soil according to standard requirement by adding another materials which known as soil stabilization [11]. Chemical stabilization methods are presented to provide mitigation of total and differential settlements, soil strength improvement, reduced construction costs, shorter construction period, and other characteristics which may influence on their operation to specific projects on organic soil.

2. Experimental Work

2.1 Materials

1. Soil: the kaolinite clay, taken from local market, was used as a soil mass.

2. Organic Materials: The fresh reeds as a source of organic materials were taken from AL-Talbiya in Baghdad city is air dried, chopped to small pieces and then sieved. The materials passing sieve No.10 and retained on sieve No.200 were considered as fibrous organic materials.
3. Lime: Quick lime was used as a treatment material taken from local market.

2.2 Preparation of soil samples

The soil samples were mixed with fresh reed in two different methods:
The first method by mixing dry kaolinite with fresh reed at different percentages (0, 2, 5, 8, 12, 20) % by dry weight of soil. Then each sample (with certain percentage of fresh reed) was stabilized by adding three different percentages of lime (3, 6, 9)% by dry weight of sample.

The second method by mixing kaolinite as a clay minerals with fresh reed as a source of organic materials at different percentages (0, 2, 5, 8, 12, 20) % by dry weight of soil at a saturation condition. Saturation condition was checked by left the samples in a bucket for six months soaked in water to achieve decomposition of organic material. After this period of soaking the samples were air-dried, grinded and sieved to remove the non-decomposed reed materials. Each sample was stabilized by adding three different percentages of lime (3, 6, 9) % by dry weight of sample.

2.3 Laboratory investigation

The Physical and classification properties of kaolinite are tested in the Soil Laboratory/College of Engineering at Al-Mustansiriayah University as shown in Table (1) and chemical properties of Kaolinite and lime are tested in General Company of Geological Survey and Mining as shown in Tables (2) and (3) respectively.

Table (1) Physical and classification properties of Kaolinite.

Properties	Value	Standard
Specific Gravity (G_s)	2.63	ASTM D 854-00
Liquid Limit (L.L.)%	51.45	B.S.1377:1975
Plastic Limit (P.L.)%	28	B.S.1377:1975
Plasticity Index (P.I)%	23.45	
Standard Compaction Test Maximum dry unit weight ɣd max. (kN/m^3)	15.84	
Optimum water content (%) (o.w.c)	22.21	ASTM D698-78
Unified Soil Classification System (USCS)	CH*	ASTM D2487-06

* CH: Clay of high plasticity.

Table (2) Chemical composition of kaolinite.

Chemical Element	Percent (%)
SiO_2	50.9
Al_2O_3	42.3
CaO	2.4
Fe_2O_3	1.7
MgO	0.8
Loss of Ignition	1.8

Table (3) Chemical composition of lime.

Chemical Element	Percent (%)
CaO	69.8
MgO	2.4
Fe_2O_3	1.9
AL_2O_3	1.2
SiO_2	2.3
SO_3	0.5
CO_2	2.7
Loss of Ignition	19.1

2.4 Testing program

A detailed testing program was conducted on the modeled organic soil. All tests are summarized in the flow chart shown in Figure (1).

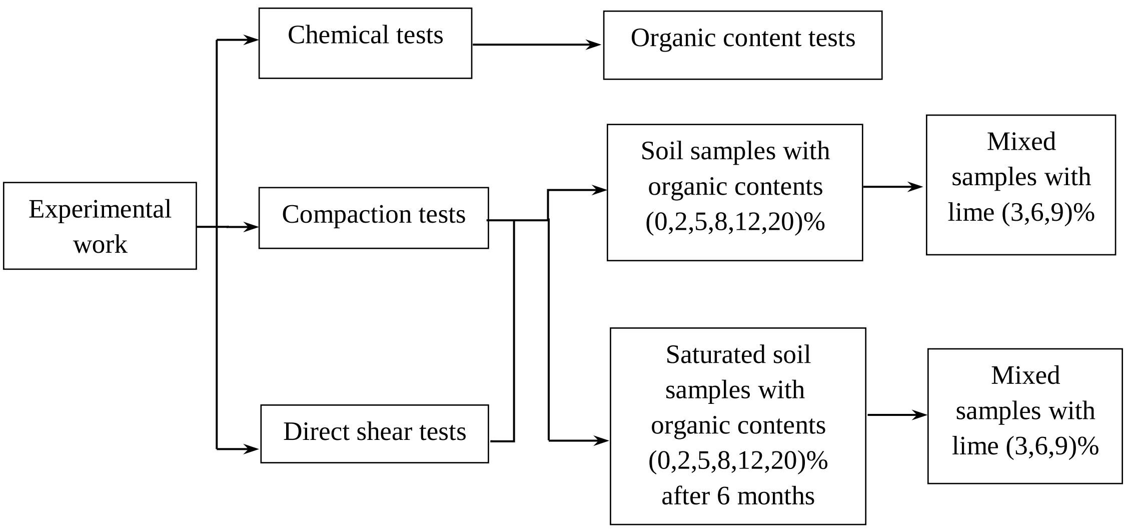

Figure (1) Flow chart of testing program.

2.5 Organic content test

Ignition method was used in this study to determine the percent of organic content in the soil according to ASTM D2974. The results of organic content tests by the ignition method are summarized in Table (4) after the decomposition of soil samples.

Table (4) Results of Ignition test method for samples after 6 months of saturation.

Organic content (O.C %)	
before	after
2	1.83
5	4.62
8	6.92
12	10.96
20	13.79

2.6 Compaction tests

The standard compaction effort was used according to ASTM D698-78.

2.7 Direct shear tests

A series of shear tests were carried out using the direct shear apparatus according to the (ASTM D3080-72). Calibrated proving ring of (2kN) capacity and (0.002 mm) precision dial gauge for horizontal deformation is used. The rate of strain adopted in this test was (1mm/min). All specimens were prepared in direct shear box with a size of (60 x 60 x 20) mm, under three selected normal stresses (39.51, 66.76, and 121.26) kPa. The samples were prepared by calculate the sample weight corresponding to 90% of maximum dry unit weight at optimum water content, according to equation (1).

$$W = (6.606 \times \gamma_{d max}) \times (1 + O.W.C) \quad \ldots\ldots (1)$$

4. Result and Discussion

4.1 Compaction tests

The results of the compaction tests are shown in Tables (6) and (7) for non-decomposed and decomposed samples respectively.The maximum dry density are decreased with increasing the organic content for each percent of lime in both cases (non-decomposed and decomposed samples), while no significant effect was noticed with increasing lime content for all percent of organic content except at 12% and 20% organic content for non-decomposed samples. At these organic contents the maximum dry density was continuously increased due to the addition of lime. These results may be related to the effect of specific gravity of samples (increasing the specific gravity leads to increase max. dry density). The optimum water contents are increased with increased organic content for each percent of lime content in both cases, while no significant effect can be recognized when added lime for each percentage of organic content and for both non-decomposed and decomposed samples. These results are due to the insufficient time required to complete reaction between the lime with soil particles and lime with organic content.

Table (6) Values of maximum dry density for organic soil with different percentage of lime.

(a) Non-decomposed samples.

%O.C / % Lime	0	2	5	8	12	20
0	15.48	14.58	13.82	12.99	12.29	10.74
3	15.16	14.52	13.87	13.35	12.87	11.11
6	15.25	14.55	13.89	13.37	12.83	11.11
9	15.28	14.56	13.75	13.39	12.85	11.11

(b) Decomposed samples.

%O.C / % Lime	0	1.83	4.62	6.92	10.96	13.79
0	15.48	14.39	14.31	14.07	13.88	13.52
3	15.16	14.09	14.04	13.95	13.72	13.18
6	15.25	14.13	14.02	13.91	13.68	13.21
9	15.28	14.05	14.07	13.98	13.73	13.24

Table (7) Values of optimum water content for organic soil with different percentage of lime.

(a) Non-decomposed samples.

%O.C / % Lime	0	2	5	8	12	20
0	22.21	24.4	27.76	25.77	25.77	35.29
3	21	21.87	23.4	26.4	26.4	31.9
6	22.92	22.7	22.4	27.72	27.72	32.7
9	20.67	24.2	18.2	26.68	25.96	31.8

(b) Decomposed samples.

%O.C / % Lime	0	1.83	4.62	6.92	10.96	13.79
0	22.21	25.75	26.67	28.49	28.68	28.98
3	21	26.87	25	27.01	28.3	27.34
6	24.14	27	25.49	27.56	28.57	27.78
9	24.66	28.13	28.02	27.87	28.98	28.43

4.2 Shear Strength Parameters

Figures (2) and (3) show the variation of cohesion of the soil at different lime contents for non-decomposed and decomposed samples at different percentages of organic contents respectively. Figures (4) and (5) show the relation between the angle of friction of the soil and lime contents for non-decomposed and decomposed samples for different percentage of organic material respectively. Summary of the results is given in Tables (8) and (9).

The cohesion of soil is increased with increasing organic content up to 6.92% then decreased for each percent of lime content for decomposed samples, while for non-decomposed samples, the cohesion decreased with increasing organic content up to 8% then increased for each percent of lime. The cohesion of soil is decreased with increasing lime content for small present of organic content (0, 2)% and increased for other percent (5, 8, 12, and 20%) for non-decomposed samples. For decomposed samples, in general, the cohesion decreased due to addition of lime, for all percentage of organic material. These results refer to the reaction between lime and soil particles, which cause a bonding of particles in to larger aggregates, thus the soil behave as a coarse-grained, while increasing the organic content leads to decrease soil particles react.

The angle of friction is decreased with increasing the organic content up to 2% for non-decomposed samples and up to 1.83% for decomposed samples then increased with increasing organic content for each percent of lime content except 0% lime content, it will be increased with increasing organic content. This result may be related to the fact that the friction between organic material and soil particles is greater than that between soil particles.

For both samples, the angle of friction is increased with increasing lime content for all percentage of organic content. These results attributes to the pozzolanic reaction occurs between lime and alumina and silica of the clay mineral and produces cementing material including calcium-silicate-hydrates and calcium alumina hydrates [12]. This reduction in the spread water layer permits the clay particles to become into closer contact with one another, causing agglomeration /flocculation of the clay particles, which changes the clay into a more sand-like or silt-like materials [13].

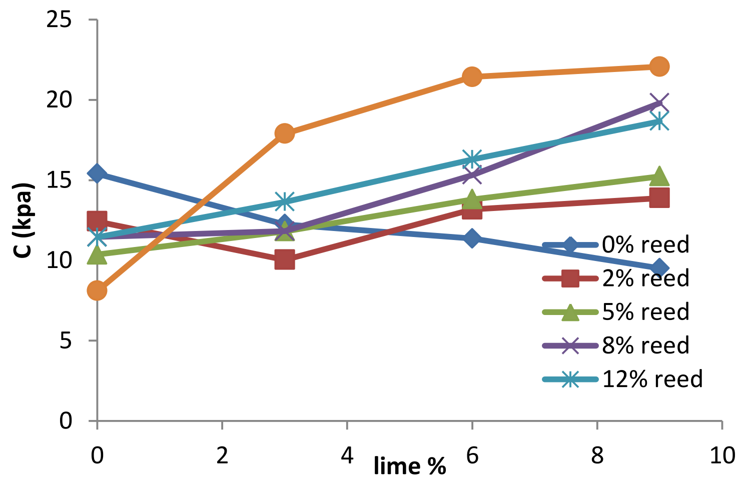

Figure (2) Effect of lime content on cohesion of the soil for non-decomposed samples with different percentage of organic soils.

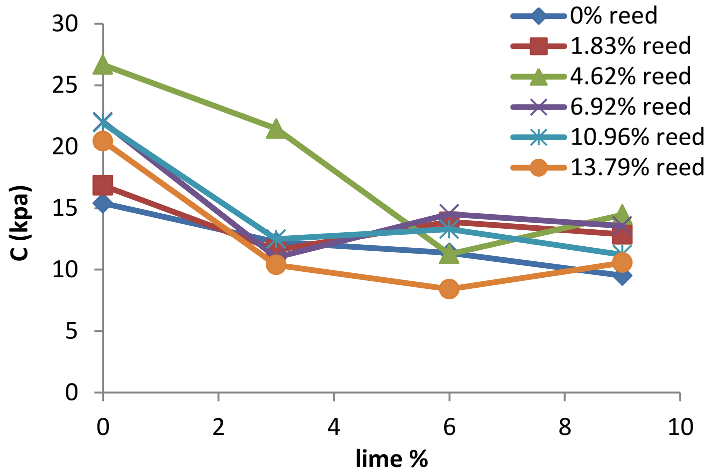

Figure (3) Effect of lime content on cohesion of the soil for decomposed samples with different percentage of organic soils.

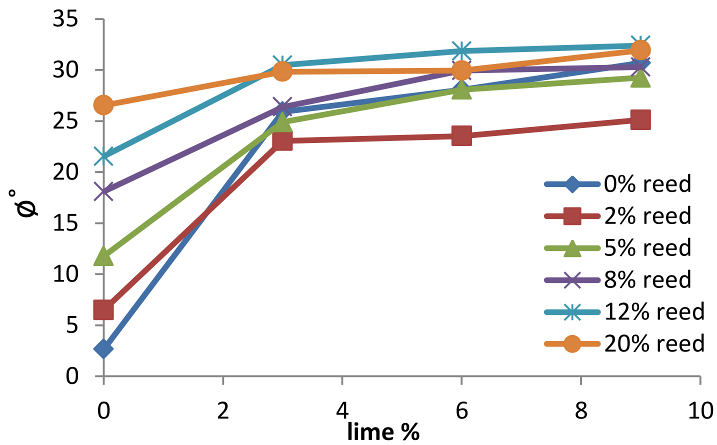

Figure (4) Effect of lime content on angle of internal frictionfor non-decomposed samples with different percentage of organic soils.

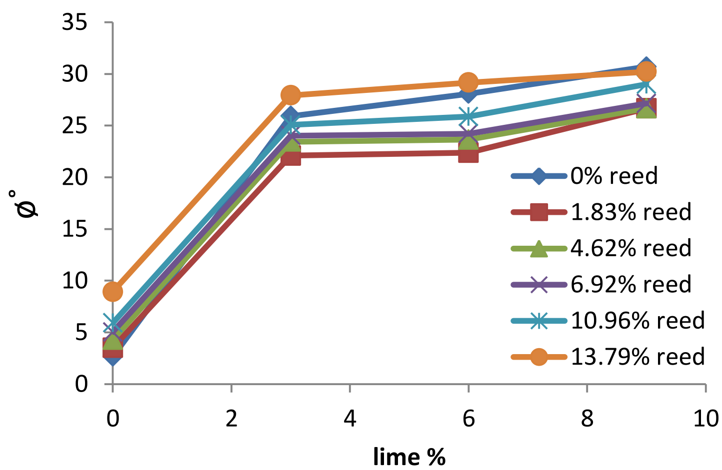

Figure (5) Effect of lime content on angle of internal frictionfor decomposed samples with different percentage of organic soils.

Table (4-7) Summary of direct shear tests results for non-decomposed samples with different percentage of lime and organic content.

	%O.C / % lime	0	2	5	8	12	20
C (kPa)	0	15.401	15.467	17.71	10.698	5.5003	14.125
	3	12.251	15.168	12.24	11.311	13.64	21.084
	6	11.364	14.278	12.969	11.867	14.457	21.558
	9	9.5059	12.33	13.905	12.622	17.322	22.065
ø°	0	2.656	10.78	13.029	20.817	24.887	26.133
	3	25.91	21.67	24.787	30.782	30.464	28.965
	6	28.071	25.16	28.519	32.01	33.197	30.17
	9	30.689	29.71	29.895	32.875	33.477	31.919
w_c %	0	27.486	31.497	29.983	33.41	36.387	40.78
	3	29.39	32.29	32.587	36.65	37.29	43.62
	6	31.28	32.84	36.69	36.721	39.19	44.24
	9	30.08	33.33	37.133	37.343	38.72	44.87
of $\gamma_{d\,max}$*%	0	89.233	89.8	89.94	89.61	89.99	90.22
	3	90.33	89.51	88.368	90.18	90.36	90.28
	6	89.73	89.74	87.98	90.57	91.06	90.9
	9	88.48	89.01	90.78	91.63	89.65	89.92

	σ (kPa)	% lime	0	2	5	8	12	20
τ (kPa)	39.51	0	17.903	22.786	26.855	26.041	24.413	31.534
	66.67		17.496	28.482	33.162	35.603	35.603	49.844
	121.26		21.362	38.451	45.775	56.964	62.051	72.629
	39.51	3	30.72	31.534	29.499	34.992	36.62	41.503
	66.67		45.775	40.689	44.554	50.861	53.302	60.22
	121.26		70.799	63.678	67.747	83.616	84.836	87.481
	39.51	6	32.114	32.755	34.585	36.213	41.096	43.537
	66.67		47.703	45.775	49.03	45.116	56.964	61.847
	121.26		75.885	71.206	78.936	87.481	49.195	91.55
	39.51	9	32.75	34.586	36.213	38.451	34.741	46.792
	66.67		49.437	50.861	52.896	55.337	61.033	63.475
	121.26		81.378	81.378	83.412	91.143	94.653	97.653

*% of $\gamma_{d\,max} = \gamma_{d\,used} / \gamma_{d\,max}$

Table (4-8) Summary of direct shear tests results for decomposed samples with different percentage of lime and organic content.

	%O.C %lime	0	1.83	4.62	6.92	10.96	13.79
C (kPa)	0	15.401	16.846	21.463	22.012	21.924	20.456
	3	12.251	11.604	11.264	11.012	12.473	10.386
	6	11.364	13.89	14.467	14.527	13.281	8.4182
	9	9.5059	12.869	13.778	13.552	11.211	10.559
ø°	0	2.656	3.508	4.272	5.029	5.909	8.911
	3	25.91	22.087	23.442	24.027	25.065	27.928
	6	28.071	22.377	23.644	24.209	25.859	29.153
	9	30.689	26.647	26.67	27.135	28.991	30.212
w_c %	0	27.486	33.56	39.25	36.4	34.55	41.55
	3	29.39	35.52	38.55	38.46	37.32	39.2
	6	31.28	38.51	36.49	35.89	38.28	38.32
	9	30.08	36.65	38.12	39.51	37.44	39.52
of $\gamma_{d\,max}$*%	0	89.233	88.12	90.49	89.47	89.9	90.31
	3	90.33	90.73	88.45	89.03	90.74	90.74
	6	89.73	88.96	90.2	90.07	90.49	89.17
	9	88.48	89.1	89.41	89.27	91.34	89.62
σ (kPa)							
τ (kPa) 39.51	0	17.903	18.717	24.413	25.227	26.244	27.058
66.67		17.496	21.769	26.448	28.279	28.482	30.313
121.26		21.362	24.006	30.517	32.551	34.586	39.672
39.51	3	30.72	28.075	28.482	28.686	30.924	30.517
66.67		45.775	38.044	40.079	40.689	34.741	46.996
121.26		70.799	61.033	63.882	65.102	69.171	74.257
39.51	6	32.114	29.703	30.11	30.517	31.941	30.924
66.67		47.703	44.554	46.182	47.199	46.385	44.961
121.26		75.885	64.085	66.73	68.154	71.816	76.292
39.51	9	32.75	32.144	32.755	32.958	32.958	33.975
66.67		49.437	47.199	48.623	49.03	48.42	48.827
121.26		81.378	73.443	47.257	75.274	78.326	81.378

*% of $\gamma_{d\,max} = \gamma_{d\,used} / \gamma_{d\,max}$

5. Conclusions

Based on the results from the experimental works, the following conclusions can be drawn. It was emphasized that these conclusions were limited to the variables studied:

1. The maximum dry unit weight decreases and the optimum moisture content increases with increasing the organic content for both samples (decomposed and non-decomposed).
2. The max. dry density is decreased with increases of organic content for each percent of lime for both samples, while no significant effect on the maximum dry density noticed with increased lime content for each percent of organic content for non-decomposed and decomposed samples except 12% and 20% organic content for non-decomposed samples, where the max. dry density is increased with increased lime content.
3. The values of cohesion for non-decomposed samples are decreased with increasing organic content up to 8% of organic content then increased, while the values of cohesion for decomposed samples are increased with increasing the organic content up to 6.92% then decreased for each percent of lime content.
4. The cohesion of soil is decreased with increased lime content for small present of organic content (0, 2)% and increased for other percent (5, 8, 12, and 20%) for non-decomposed samples. For decomposed samples the cohesion is decreased with increased lime content for all percentage of organic content.
5. Angle of internal friction (Ø˚) increases with the increase of organic content for both decomposed and non-decomposed samples for each percent of lime content.
6. For both samples, the angle of friction is increased with increasing lime content for all percentage of organic material.
7. Using lime will improve the shear strength parameter of organic soil.

Abbreviations

G	Specific gravity of soil
Gp	Specific gravity of added material
Gs	Specific gravity of soil particles
p	Proportion of added material by dry mass
w	Required weight(gm)
ɣd	Dry unit weight (kN/m^3)
ɣdmax.	Maximum dry unit weight (kN/m^3)
ɣ d used	Dry unit weight of sample(kN/m^3)
O.W.C	Optimum water content for sample (%)
UCS	Unconfined Compressive Strength (kPa)
τ max	Maximum shear stress (kPa)
σ	Maximum normal stress (kPa)
Ø˚	Angle of internal friction (degree)
c	Cohesion (kPa)

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