Journal of Engineering and Sustainable Development
Vol. 22, No.05, September 2018
ISSN 2520-0917
https://doi.org/10.31272/jeasd.2018.5.18

IMPROVEMENT OF COMPRESSIBLITY CHARCTERISTICSOF NATURAL ORGANIC SOILS

Dr.Adel Hamed Majeed[1], Dr. Abbas Adday Al Zayadi[2], *Jasim Mohammed Abdul Abbas[3]

1) Asst. Prof., Civil Engineering Department, Al-Esraa University College, Baghdad, Iraq.
2) Lec, Civil Engineering Department, Mustansiriyah University, Baghdad, Iraq
3) Student Civil Engineering Department, Mustansiriyah University, Baghdad, Iraq

Abstract: The aim of this paper is to investigate the possible improvement thecompressibility characteristics (copresion index, rebound index, i.e.,)of natural organic soil by using cement dust and fly ash. Natural organic soil with different percentages of organic content (5, 10.15 and 20 %) is used. Three different percentages of cement dust and fly ash (3, 6 and 9 %) are used to improve the compressibility characteristics of the organic soil. The effect of curing time is investigated. The effect of addition of (cement dust and fly ash) on compressibility characteristics of natural organic soil was studied. The results showed that the compressibility characteristics [compression index, rebound index, coefficient of consolidation and coefficient of secondary compression] are increased with increased organic content for all samples. The use of (cement dust and fly ash) has improved the compressibility characteristics of organic soil.

Keywords: *Organic Content, Cement Dust, Fly Ash,Compressibility Characteristics,(Cc), (Cr), (Cv), (Cα).*

تحسين خصائص الانضغاطية للترب العضوية الطبيعية

الخلاصة: الغرض من هذا البحث هو معرفة امكانية تحسين خصائص الانضغاطية للتربة العضوية الطبيعية وذلك بأستخدام غبار الاسمنت والرماد المتطاير. التربة العضوية الطبيعية المستخدمة كانت على نسب مختلفة من المادة العضوية (15,10,5 و 20 %). نسب غبار الاسمنت والرماد المتطاير المستخدم لتحسين الخصائص الانضغاطية للتربة العضوية كانت على ثلاث نسب مختلفة(6,3 و 9 %).تم دراسة تأثير اضافة (غبار الاسمنت و الرماد المتطاير) على معاملات الانضغاط للتربة العضوية الطبيعية. اظهرت النتائج ان خصائص الانضغاطية تزداد مع زيادة المحتوى العضوي لجميع النماذج . استخدام (غبار الاسمنت و الرماد المتطاير) ادى الى تحسين خصائص الانضغاطية للتربة العضوية .

1. Introduction

Organic soil is characterized by low shear strength and high compressibility. This soil causes serious foundation problems and constitutes one of most difficult ground condition for the construction of civil engineering structure. Organic material affects the properties and behavior of soil depending on many factors such as percentage origin, fibrousness, degree of decomposition…..etc.

* Jassim_mohemmed2007@yahoo.com.

of organic material. In general, the maximum dry densityof soil decreases and optimum water content increases with increasing organic content,

which leads to increase in the compressibility characteristic of soil.The compressibility characteristics increase with increasing organic content, while they may increase for fibrous non decomposed low content organic material. Improvement of organic soil is essential to use such soil for civil engineering construction. The highcompressibility and mainly large secondary consolidation Compression characteristic of the Organic soil due tothe settlement characteristicrelated with this soil is very complex.Different chemical materials have been used to improve the characteristics of organic soil.

The maximum dry density and optimum water content increases with increasing organic materials. Similar results were obtained by Abbas et al, [1], when kaolinite was used as clay mineral and (fibrous and powdered) Reed used as the organic material up to 20%.

Rabbee and Rafizul [2],illustrated the geotechnical properties of treated soil prepared in the laboratory by mixing betonies, lime and cement at varying content of (5, 10, 15, 20 and 25) % of dry mass of organic soil. These soils were collected from four selected locations at Khulna region in Bangladesh. They found that, the optimum moisture content decreases, while the maximum dry density increases with the increase in the admixture content.

Adejumo [3], investigated the effect of organic content on consolidation characteristics of organic clayey soils in Ikoyiarea of Lagos and show that the initial void ratio was increasedwith the increase the organic content, It was additional shown that at less stress, high organic content clay samples experienced significant decrease in void ratio with a little increase in pressure. The organic contentwas increasedwith the increase inthe compression index (Cc).

Wardwell and Nelsons, [5] studyied the performance of the coefficient of secondary compression is not constant value, but varies with time, and increases the content of organic substances.Wardwell and Nelson [5] and Al-Saoudi et.al [6]studied the effect of organic materials on the coefficient of secondary compression ($C\alpha$). They illustrated that ($C\alpha$) increases with increasing the organic content which cause a large void ratio in the soil mass. These resemble results were taken by Habbi [4]. The values of compression index increase with the increase of organic materials for two sizes of reed for both cases decomposed and non-decomposed samples. This behavior can be attributed to the fact that the addition of organic material causes an increase of void ratio for both powder and fiber sizes of reed, therefore compressibility is increased Habbi [4].

Thiyyakkandi and Annex [7] and Adejumo [3]showed that the coefficient of consolidation decreases (parabolic) with the increase in organic content.

Sadiq , [8]showed that the increase in organic content causes the increase values of C_α for each percent of lime for both cases, while the values of C_α usually decrease with increasing lime content for all percentage of organic soils in both cases. This is because the void ratio of soil increases with the increase in organic content, which leads to an increase the compressibility. The increase of organic content and increase of consolidation pressure caused the increase value of $c_v$for each percent of lime content and for non-decomposed and decomposed samples. While the values of $c_v$decrease with the increase of lime content for all consolidation stresses and for each percentage of organic content and for non-decomposed and decomposed samples. The increase in organic content causes an increase in the void ratio then an increase in permeability which causes an increase in the values of c_v (Sadiq) [8].

2. Experimental Work

2.1. Materials

1. Soil: Natural organic soil taken from the city of balad north of Baghdad, Iraq is used,the soil containing (10%) of organic material which mainly composed of plant residues and tree roots.
2. Cement dust: Is by products material brought from Lafarge Cement Company in Erbil. Iraq.
3. Fly ash: Is by products material brought from fiery bricks factory in Diyala, Iraq.

2.2. Sample Preparation

Natural soil of organic content equal to (10 %) is used as the source of soil samples of different organic content (5, 10, 15 and 20 %). The organic material was separated and collected from the soil to use it in preparing samples with 15 % and 20 % organic content. While the other samples with 5 % is prepared by sieving the soil to separate the organic material and produce clean soil sample with 0 % organic content.

2.3. Experimental Program

The experimental program adopted in this study includes:

a. Physical and classification tests on the natural soil, the results of these tests are shown in Table b. Chemical tests on the natural soil, cement dust, fly ash and organic material. The results are presented in tables (2), (3), (4) and (5) respectively.

c. Ignition test method is used to determine the actual organic content of prepared samples. The actual organic content of the prepared samples are (4.855 %, 10.24%, 14.75% and 19.96%).

d.Compaction tests: the standard compaction effort is used according to ASTM (2006)[9]. Samples with organic content approximately equal to (5%, 10%, 15% and 20%) are compacted without and with treatment by (3%, 6% and 9%) of cement dust and fly ash separately. The result is presented in Table (6).

e. The one dimensional compression test:this test is conducted according to ASTM D2435-80 [10]. Samples with organic content approximately equal to (5, 10, 15 and 20 %), are tested. Another group of the mentioned sample were prepared and left under applied stress equal to 20 kPa for 6 months to investigate the effect of time on the performance of the treatment. All samples were prepared at maximum dry density and optimum water content.

Table (1) Engineering properties results of nature organic soil

Properties	Value	Standard
Specific Gravity (G_s)	2.825	ASTM D 854-00
Liquid Limit (L.L.)%	54	B.S.1377:1975
Plastic Limit (P.L.)%	25	B.S.1377:1975
Plasticity Index (P.I)%	29	B.S.1377:1975
Standard Compaction Test		
Maximum dry unit weight $\gamma_{d\ max.}$ (kN/m^3)	15.34	ASTM D698-78
Optimum moisture content (%)	22	ASTM D698-78

Table (2) Chemical composition of natural organicsoil

ChemicalCompound	CaO	Na_2O	SO_3	TDS	CO_3	Fe_2O_3	SiO_2	Al_2O_3	L.O.I
Percent (%)	217.	0.62	0.22	0.61	0.23	6.2	24.2	45.37	5.36

Table (3) Chemical composition of cement dust

ChemicalElement	CaO	Na_2O	SO_3	Al_2O_3	K_2O	MgO	SiO_2	Fe_2O_3	L.O.I
Percent (%)	58.49	0.3	2.6	5.87	3.28	4.58	17.4	2.86	4.65

Table (4) Chemical ccomposition of flyash

ChemicalElement	CaO	Na_2O	SO_3	Fe_2O_3	SiO_2	MgO	Al_2O_3	L.O.I	K_2O
Percent (%)	4.99	0.41	0.56	14.68	48.45	3.81	23.17	2.54	1.39

Table (5) Chemical composition of the organic material

Chemical Element	O.M	SO_3	TDS	CO_3	Fe_2O_3	K_2O	Al_2O_3	CaO
Percent (%)	33	0.26	Turbid	0.28	2.5	27	5.96	31

3. Result and Discussion

3.1. Compaction Test

Table (6) presents the result of compaction test on samples of natural soil with different organic content (5, 10, 15 and 20 %). The samples are treated by different percentage (0, 3, 6 and 9 %) of cement dust and fly ash suavely. The result indicated that the maximum dry density decreases with increasing organic content, while the optimum water content increases with increasing organic content. This result agree with previous studies (Abbas,et.al (1985)[1],Tariq (1998)[9], Habbi (2005)[4] and sadiq (2016)[8]). For each percent of organic content, the maximum dry density decreases, while the optimum water content increased with increasing the percent of treated material (cement dust and fly ash). This behavior is due to:

1. The organic material has a specific gravity less than that for soil particle. This lead to decrease the dry density of organic soil,while the organic material has the ability to suck water which causes the increase in optimum water content.
2. Cement dust reacts with water and soil particle. This reaction produced cementing material prevents the soil to compact easily. On the other hand this reaction need more water to complete the reaction.
3. Fly ash has a specific gravity less than that for soil particle. It behaves like organic material in reducing the density and increasing the water content.

Table (6) Value of maximum dry density and optimum water content for organic soil with different percentage of cement dust and fly ash

Organic content (%)	Treated material (%)	Cement dust		Fly ash	
		Maximum dry density (kN/m^2)	Optimum moisture content (%)	Maximum dry density (kN/m^2)	Optimum moisture content (%)
5	0	16	19	16	19
	3	15.43	22.9	15.4	23.28
	6	15.02	26.67	14.4	24.31
	9	14.81	27.64	14.36	28.8
10	0	15.34	22	15.34	22
	3	14.7	26.53	14.9	25.64
	6	14.56	28.5	14.22	28.7
	9	14.29	29.25	14.02	32.92
15	0	13.9	29.54	13.9	29.54
	3	13.3	30.99	12.94	31
	6	13.14	31.51	11.98	32.46
	9	13	32.16	11.02	33.92
20	0	13.1	32	13.1	32
	3	12.43	32.5	12.03	33.24
	6	12.37	35.54	11.06	34.48
	9	12.25	36.28	10.09	35.72

3.2 One Dimensional Compression Tests

3.2.1Compression index (C_c) and rebound index (C_r)

The results showed that compression index (c_c) increases with the increasing in organic content for all percent of cement dust content. , the compression index for organic soil samples decrease with the increase in cement dust content for all samples of different percentages of organic content. On the other hand, cement dust acts as binder between soil particles causing increasing the soil resistance to applied stresses. The value of rebound index (c_r) depends on the percentage of organic material and cement dust content. There is no general trend of variation of these values. It may depend on; the interaction between organic matter and soil particles, the interaction of both materials with cement dusts and the may develop between these materials as shown in figure (1). While the effect of cement dust to the organic soil under working load for time of 6 months on compression index for different samples of organic soil is close to that of working load condition, with slight in cray in the value of compression index as shown in Figure (2).

The fly ash gave similar behavior to that of cement dust in terms of increasing the compression index for different samples of organic soil. The compression index (C_c) decreases with the increases in fly ash percent, for all organic content .organic soil with 20 % organic content showed obvious effect of cement dust as shown in Figure (3).The effect of fly ash to the organic soil under working load of time of 6 months on compression index for different samples of organic soil is the same effect without curing sample, but the fly ash product better improvement in term of reducing the compression index than the cement dust for all organic contents as shown in Figure (4).

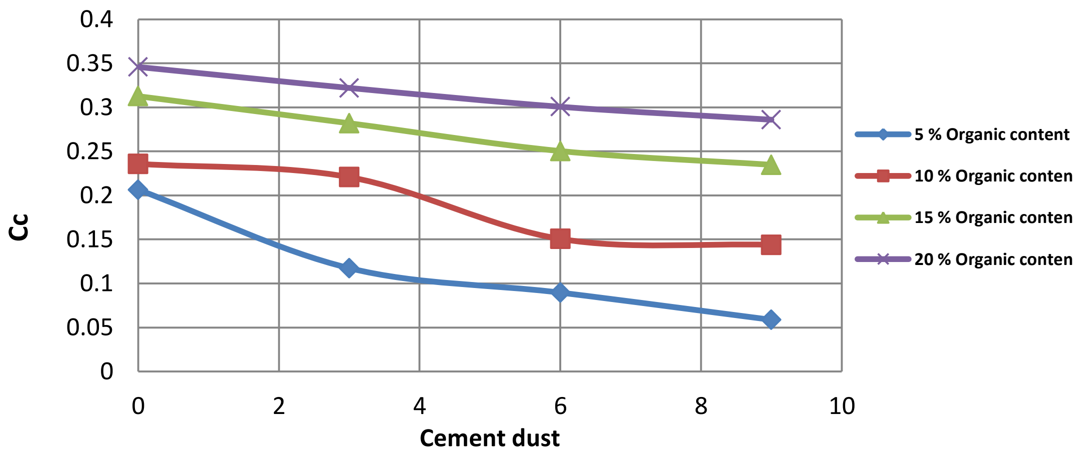

Figure (1) Variation of compression index with cement dust percent for soils of different organic content.

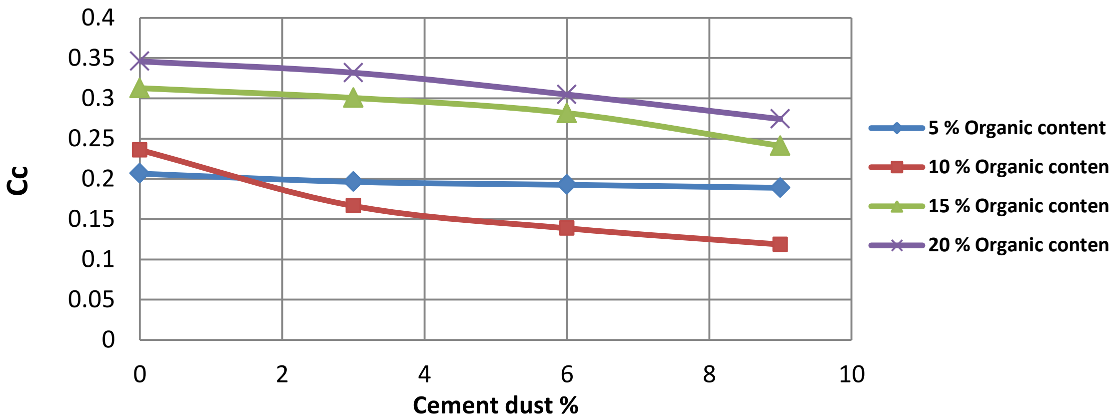

Figure (2) Effect of cement dust content on compression index for different organic soil samples under working load for time of 6 months.

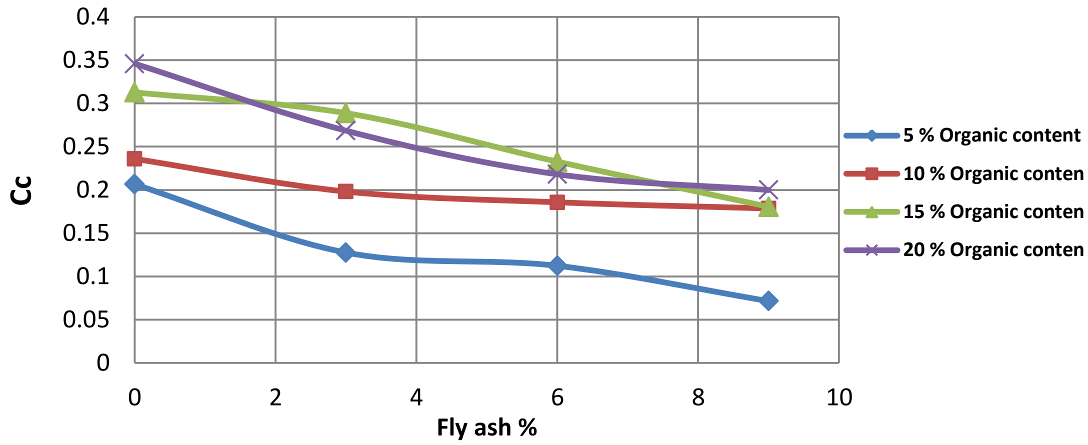

Figure (3) Effect of fly ash content on compression index for different organic soil samples.

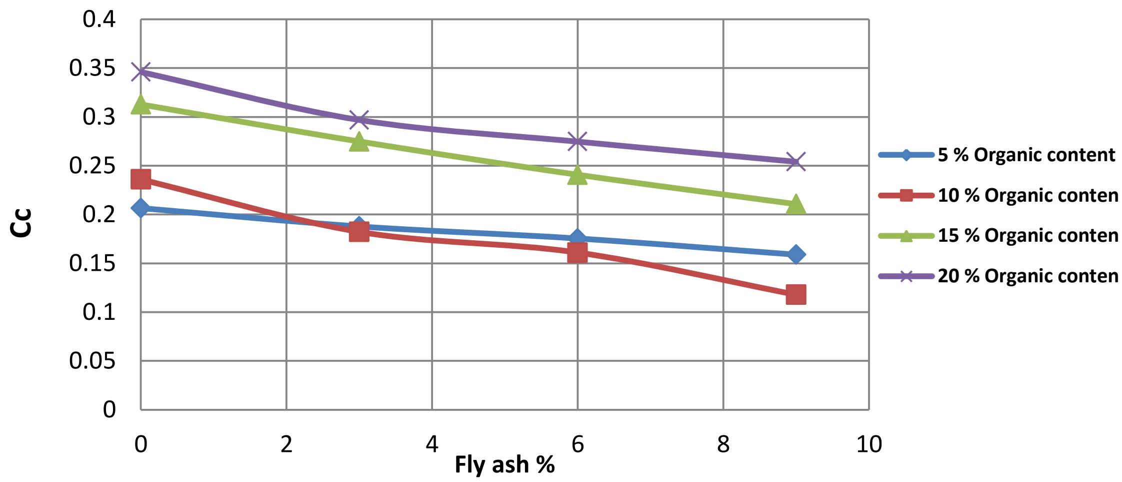

Figure (4) Effect of fly ash content on compression index for different organic soil samples under working load for time 6 months.

3.2.2 Coefficient of consolidation (c_v)

The Square root time method is used to determine the coefficients of consolidation for samples. The results of organic soil samples for different cement dust contents are summarized in Tables (7). The values of c_v range from (1.46 – 8.996) m^2/yr. The general trend of variation of c_v is that, the value of $c_v$increases with the increase in organic content and with increase consolidation pressure for each percent of cement dust content. The increase in organic content causes an increase in the void ratio then an increase in permeability which causes an increase in the values of c_v. While the effect of add the cement dust to the organic soil under working load for time 6 months on the coefficients of consolidation for different samples of organic soil is the same effect without curing sample ,but the value of the coefficients of consolidation increase after duration time of 6 months. Summary of the results obtained from these tests is given in Table (8).

The effect of adding fly ash is like behavior with adding cement dust on coefficient of consolidation for different samples of organic soil. The coefficient of consolidation (c_v) increase with the increase in organic content for each percent of fly ash content, Table (9) shows the summary of compression tests results. The effect of adding the fly ash to the organic soil under working load for time6 months on coefficients of consolidation for different samples of organic soil is the similar effect without working load sample, Summary of the results obtained from these tests is given in Table (10).

Table (7) Values of $C_v(m^2/yr)$ for organic soil samples with different percentage of cement dust

P (kPa)	Cement dust (%)	O.C % 5	10	15	20
	0	2.47	2.747	2.989	3.061
25	3	2.133	2.405	2.585	2.867
	6	1.796	2.063	2.272	2.673
	9	1.46	1.722	1.959	2.479
	0	3.06	3.238	3.643	3.874
50	3	2.614	2.784	3.215	3.523
	6	2.168	2.33	2.787	3.172
	9	1.722	1.875	2.36	2.821
	0	3.874	4.408	4.717	5.06
100	3	3.235	3.688	4.036	4.517
	6	2.596	2.968	3.355	3.974
	9	1.959	2.249	2.676	3.432
	0	4.717	5.44	5.868	6.327
200	3	3.895	4.542	4.932	5.523
	6	3.073	3.644	3.996	4.699
	9	2.25	2.747	3.061	3.874
	0	5.06	6.887	7.499	8.197
400	3	4.289	5.671	6.213	6.934
	6	3.518	4.455	4.927	5.671
	9	2.747	3.238	3.643	4.408
	0	5.868	8.197	8.996	9.918
800	3	5.056	6.841	7.467	8.426
	6	4.244	5.485	5.938	6.934
	9	3.432	4.128	4.41	5.442
	0	6.887	9.918	10.99	12.245
1600	3	6.164	8.426	9.622	11.162
	6	5.441	6.934	8.254	10.079
	9	4.717	5.442	6.887	8.996

Table (8) Values of $C_v(m^2/yr)$ for organic soil samples with different percentage of cement dust under working load for time 6 months

P (kPa)	Cement dust (%)	O.C % 5	10	15	20
	0	2.47	2.747	2.989	3.061
25	3	2.163	2.372	2.639	2.796
	6	1.856	1.997	2.381	2.531
	9	1.55	1.623	2.123	2.268
	0	3.06	3.238	3.643	3.874
50	3	2.68	2.717	3.235	3.489
	6	2.3	2.196	2.827	3.105
	9	1.921	1.675	2.421	2.721
	0	3.874	4.408	4.717	5.06
100	3	3.362	3.653	4.05	4.454
	6	2.851	2.898	3.383	3.848
	9	2.34	2.145	2.717	3.242
	0	4.717	5.44	5.868	6.327
200	3	3.904	4.509	4.967	5.422

	6	3.091	3.578	4.066	4.497
	9	2.28	2.647	3.167	3.573
400	0	5.06	6.887	7.499	8.197
	3	4.367	5.673	6.289	6.87
	6	3.674	4.459	5.079	5.543
	9	2.983	3.247	3.871	4.217
800	0	5.868	8.197	8.996	9.918
	3	5.136	6.87	7.474	8.357
	6	4.404	5.543	5.952	6.796
	9	3.672	4.217	4.43	5.236
1600	0	6.887	9.918	10.99	12.245
	3	6.197	8.432	9.587	10.721
	6	5.507	6.946	8.184	9.196
	9	4.817	5.462	6.721	7.672

Table (9) Values of C_v (m^2/yr) for organic soil samples with different percentage of fly ash

P (kPa)	Fly ash (%)	O.C %			
		5	10	15	20
25	0	2.47	2.747	2.989	3.061
	3	2.299	2.514	2.647	2.956
	6	2.128	2.281	2.396	2.851
	9	1.959	2.049	2.145	2.747
50	0	3.06	3.238	3.643	3.874
	3	2.723	2.908	3.298	3.662
	6	2.386	2.578	2.953	3.45
	9	2.049	2.249	2.608	3.238
100	0	3.874	4.408	4.717	5.06
	3	3.452	3.854	4.165	4.749
	6	3.03	3.3	3.613	4.438
	9	2.608	2.747	3.061	4.128
200	0	4.717	5.44	5.868	6.327
	3	4.11	4.647	5.203	5.918
	6	3.503	3.854	4.538	5.489
	9	2.898	3.061	3.874	5.06
400	0	5.06	6.887	7.499	8.197
	3	4.393	5.805	6.468	7.421
	6	3.726	4.723	5.437	6.644
	9	3.061	3.643	4.408	5.868
800	0	5.868	8.197	8.996	9.918
	3	5.126	7.151	7.811	9.112
	6	4.384	6.105	6.626	8.305
	9	3.643	5.06	5.442	7.499
1600	0	6.887	9.918	10.99	12.245
	3	6.278	9.111	10.325	11.469
	6	5.669	8.304	9.66	10.693
	9	5.06	7.499	8.996	9.918

Table (10) Values of C_v (m^2/yr) for organic soil samples with different percentage of fly ash under working load for time 6 months.

P (kPa)	Fly ash (%)	O.C % 5	10	15	20
25	0	2.47	2.747	2.989	3.061
	3	2.393	2.648	2.747	3.026
	6	2.316	2.549	2.596	2.991
	9	2.241	2.451	2.445	2.956
50	0	3.06	3.238	3.643	3.874
	3	2.859	3.041	3.303	3.733
	6	2.658	2.844	2.963	3.592
	9	2.459	2.649	2.624	3.452
100	0	3.874	4.408	4.717	5.06
	3	3.519	3.924	4.332	4.819
	6	3.164	3.44	3.947	4.578
	9	2.809	2.957	3.562	4.338
200	0	4.717	5.44	5.868	6.327
	3	4.216	4.78	5.24	6.018
	6	3.715	4.12	4.612	5.689
	9	3.214	3.461	3.984	5.36
400	0	5.06	6.887	7.499	8.197
	3	4.527	5.872	6.605	7.506
	6	3.994	4.857	5.711	6.8156
	9	3.451	3.843	4.817	6.126
800	0	5.868	8.197	8.996	9.918
	3	5.226	7.251	7.878	9.206
	6	4.584	6.305	6.76	8.494
	9	3.943	5.36	5.642	7.783
1600	0	6.887	9.918	10.99	12.245
	3	6.36	9.201	10.405	11.537
	6	5.833	8.483	9.82	10.829
	9	5.306	7.766	9.235	10.123

3.2.3 Coefficient of secondary compression (C_α)

C_α represends the slope of axial strain versus logarithm of time curve for time period between passing 24 hours (1440 min) to become asymptotic after the dial gage reading becomes stable under a consolidation pressure (1600) kPa.

The values of C_α increase with the increase in organic content for each percent of cement dust, while the values of C_α generally decrease with increasing cement dust content for all percentage of organic soils as shown in Figure (5). This is because the void ratio of soil increases with the increase in organic content, which leads to an increase the compressibility.

on the other hand, the addition of cement dust causes reaction taking place within the soil which in turn changes the soil matrix. It led to reduce void ratio in organic soil and therefore decrease the amount of the secondary compressionfor samples. While the effect of add the cement dust to the organic soil under working load for time 6 months on the secondary compression for different samples of organic soil is the same effect without working load samples as shown in Figure (6).

The effect of fly ash is similar behavior with adding cement dust on the secondary compression for different samples of organic soil. The secondary compression (C_α)

increase with the increase in organic content for all percent of fly ash content as shown in Figure (7) While the effect of fly ash on organic soil under working load for time 6 months on coefficients of consolidation for different samples of organic soil is the same effect without working load sample as shown in Figure (8).

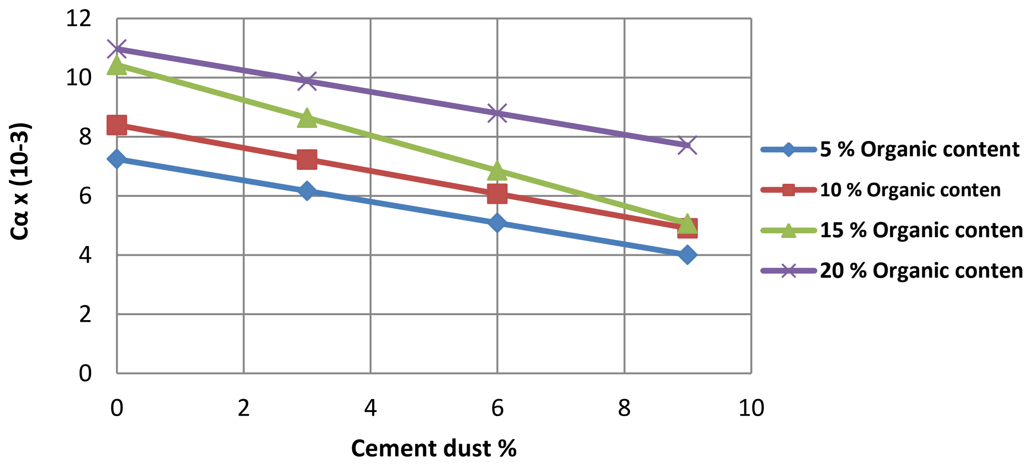

Figure (5) Effect of cement dust content on coefficients of secondary compression for different consolidation pressures for organic soil samples.

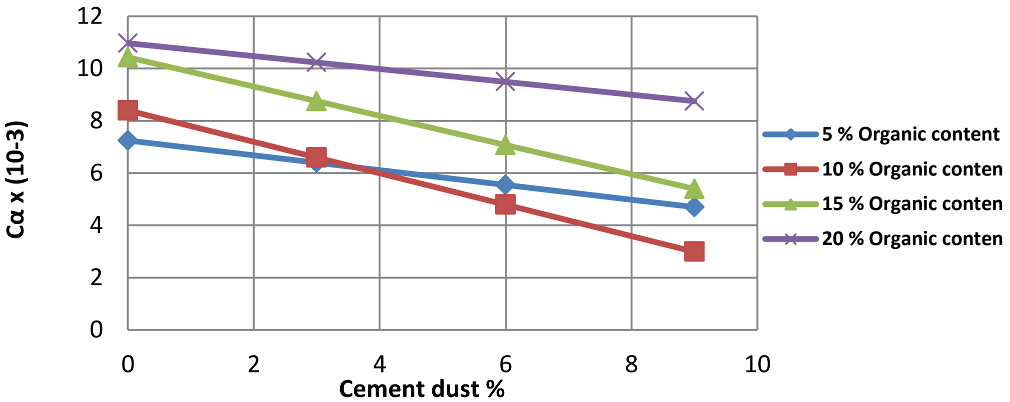

Figure (6) Effect of cement dust content on coefficients of secondary compression for different consolidation pressures for organic soil samples under working load for time 6 months.

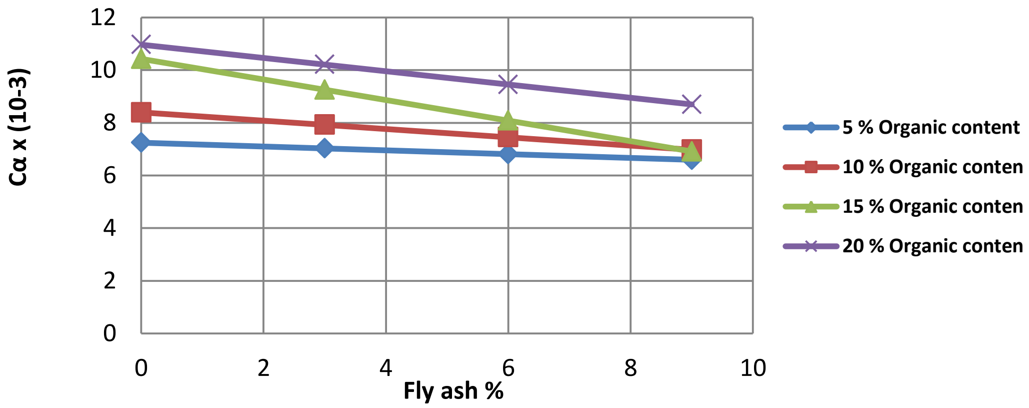

Figure (7) Effect of fly ash content on coefficients of secondary compression for different consolidation pressures for organic soil samples.

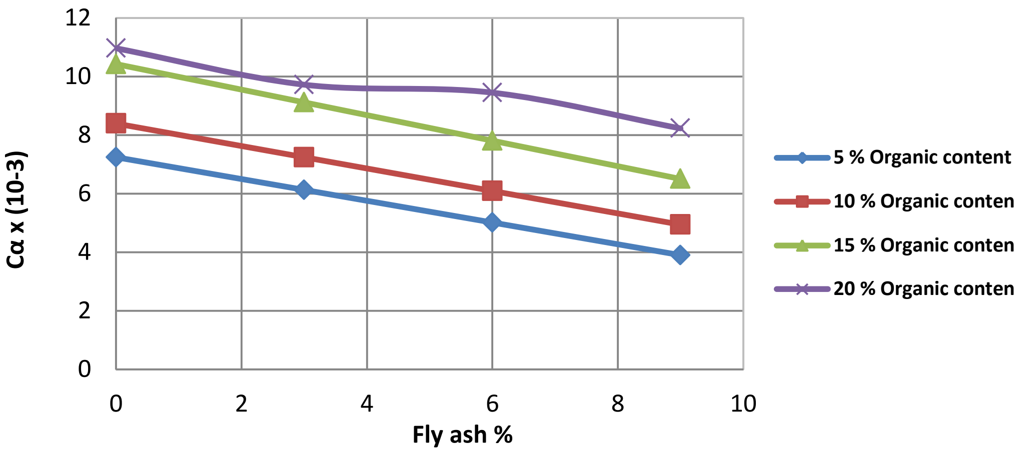

Figure (8) Effect of fly ash content on coefficients of secondary compression for different consolidation pressures for organic soil samples under working load for time 6 months.

4. Conclusions

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

1. The maximum dry density decreased with the increase in organic content for all percentage of cement dust and fly ash, while the optimum moisture content increased with increase of organic content for all percentage of cement dustand fly ash.
2. Increasing the organic content of soil leads to increase in the compressibility characteristics (c_c, c_r,c_v and C_α)for each percent of cement dust and fly ash content.
3. The compressibility characteristics (c_c, c_r, c_v and C_α) for organic soil samples decreased with the increase of cement dust and fly ash content for all samples of different percentages of organic content. But the value for samples under working load for time 6 months was greater than that for samples tested after preparation.
4. Using cement dust in organic soil improvement better than fly ash when samples tested after preparation, while leaving the treated sampled for 6 months under working load provided an enough time for fly ash to show better results than cement dust especially for organic soil with organic content more than 15%.

Abbreviations

ɣd	Dry unit weight (kN/m^3)
ɣdmax.	Maximum dry unit weight (kN/m^3)
ɣ d	Dry unit weight of sample(kN/m^3)
O.W.C	Optimum water content for sample (%)

5. References

1. Abbas, A., Majeed, A. H., and Hassan, I. M., 1985, *"Compaction and Strength of Slightly Organic Soil"*, Journal of Building Research Center, Vol.4, No.1, Iraq, PP. 1-19, May.
2. Rabbee T., Rafizul I. M., 2012, *"Strength and Compressibility Characteristics of Reconstituted Organic Soil at Khulna Region of Bangladesh"*, International Journal of Engineering and Technology Volume 2, No.10, October, pp.1672-1681.
3. Taiye Elisha Adejumo ," *Effect of Organic Content on Compaction and Consolidation Characteristics of Lagos Organic Clay "* Department of Geotechnics and Ecology in Civil Engineering, Faculty of Civil Engineering; Belorussian National Technical University, Minsk, Belarus, 2012 .
4. Habbi, Z. M., 2005, *"Compressibility and shear strength characteristics of model organic soils"*, M.S.c Thesis, college of Engineering, Mustansiriyah University.
5. Wardwell, R., and Nelson, J.D., 1981, *"Settlement of Sludge Landfills with Fiber Decomposition,"* Proceeding of the Tenth InternationalConferenceonSoilMechanicsandFoundationEngineering, Vol.2, PP 397-401.
6. Al-Saoudi, N.K.S., Hassan, I.M., Majeed, A.H. and Khalel, A.H.,1985, *"Compressibility Characteristics of Model Organic Clays,"* Journal of Building Research Center, Vol.4, No.2, Iraq, PP. 19-41, November.
7. Thiyyakkandi S., Annex S., 2011, *"Effect of Organic Content on Geotechnical Properties of Kuttanad Clay"*, Vol. 16, Bund.U., pp.1653-1663.
8. Sadiq, Z, H (2016), Improvement of Engineering Properties of Model Organic Soils M.S.c Thesis, college of Engineering, Mustansiriyah University.
9. ASTM D 698-78., (2006), *"Test Method for Laboratory Compaction Characteristics of Soils"* Annual Book of ASTM Standards, ASTM, Philadelphia, USA. vol. 04.08, pp. 69-76.
10. ASTM D 2435 – 96. (2006), *"Standard Test Method for One-Dimensional Consolidation Properties of Soils1"* American Society for Testing and Matterials , 100 Barr Harbor Dr., West Conshohocken, PA 19428.
11. ASTM D 854-00 (2006), "*Standard Test Method for Specific Gravity of Soils"* Annual Book of ASTM Standards, ASTM, Philadelphia, USA. vol. 04.08; pp. 80-83
12. Tariq, D., 1998, *"Effect of organic sludge on the Engineering properties of clay soil,"* M.S.c. Thesis , Baghdad University/College of Engineerining .
13. ASTM D 2487-06, (2006) *"Standard practice for classification of soils for engineering purposes (unified soil classification system).*" Annual Book of ASTM Standards, West Conshohocken, PA, pp. 1-12.