1st International Conference for Geotechnical Engineering and Transportation ICGTE in2415/4/2013

Geotechnical Properties of Compacted Silty Clay Mixed With Different Sludge Contents

Dr. Bushra S. Zbar
College of Engineering, University of Baghdad/ Baghdad
Mohammed A. Khan
College of Engineering, University of Baghdad/ Baghdad
Email:muhammadcivil@yahoo.com
Ahmed S. Jawad
College of Engineering, University of Baghdad/ Baghdad

ABSTRACT

The presence of organic matter in soil may cause different problems depending on many factors such as type and contents of these organic materials. A testing program was carried out to study the geotechnical properties and the behavior of organic matter obtained by the addition of a sludge material brought from a sewerage treatment plant.The tests include classification, chemical, compaction, compressibility and shear strength tests. Based on the results, several conclusions have been obtained. Both liquid and plastic limits increased with increasing organic matter. Regarding compaction test, it can be noticed that both maximum dry density and optimum moisture content slightly decreased with increasing organic contents then tends to increase.Through the observation of shear strength test results, q_u and c_u increased with increasing organic matter contents and then tends to decrease in similar manner to the density water relation of compaction test. Regarding compressibility, organic content, water content, void ratio and arrangement of soil particles are dominant factors controlling this property. The compression behavior of organic soils varies from the compression behavior of other types of soils in two ways, first the compression of organic soils is much larger and second, the creep or secondary compression plays an important role in determining the total settlement as shown in developing a unique relationship for organic soils.

Keywords: Standard Compaction, Optimum Water Content, Maximum Dry Unit Weight, Organic Matter Content, Untrained Shear Strength, Compressibility Parameters.

الخواص الجيوتكنيكية للطين الفرنسي المرصوص المخروج مع نسب مختلفة من مخلفات المياه الثقيلة

الخلاصة

ان وجود المواد العضوية في التربة يسبب مشاكل مختلفة تعتمدعلى عدة عوامل منها نوع ومحتوى هذه المواد. تضمنت الفحوص المختبرية برنامج عملي شامل لدراسة الخصائص الجيوتكنيكية والسلوك الهندسي للتربة تحت الدراسة محضرة عن طريق اضافة مخلفات المياه الثقيلة من محطة معالجة هذا النوع من المياه .

https://doi.org/10.30684/etj.2013.83799
2412-0758/©Publishing rights belongs to University of Technology's Press, Baghdad, Iraq
This is an open access article under the CC BY 4.0 license http://creativecommons.org/licenses/by/4.0

هـذا وقـد اشـتملت الفحـوص فحـوص تصـنيف التربـة والفحـوص الكيميائيـة وخصـائص الـرص وفحوص الانضغاطية وفحوص مقاومة القص . وعلى ضوء النتائج فقد تم الحصـول علـى استنتاجات عديدة . ان دليل السيولة واللدونة تزداد مع زيادة محتوى المواد العضوية. من ملاحظـة فحص الرص ,وحظانـه الكثافـة الجافـة العظمـى والمحتـوى المـائي الامثـل تقلـب قـدرقليل مـع زيـادة محتـوى المـواد العضـوية بعـدها تعـاود الزيـادة.ومـن خـلال ملاحظـة نتـائج فحـوص مقاومـة القص ,تبـين أنـه مقاومـة الانضغاط المحصورومقاومة القص غيرالمبزول تزداد مع زيادة محتوى المواد العضوية لحد معين ثـم تقـل بعـدها بشـكل مشـابه لتصـرف علاقـة فحـص الكثافـة-المحتـوى المـائي مـع الاخـذ بنظرالاعتبـار الانضغاطية, فان محتوى المواد العضوية, المحتوى المائي, نسبة الفراغات وترتيب دقـائق التربـة هـي عوامل مسيطرة لهـا قدرة التحكم فـي هذه الخاصـية. ان تصـرف الانضـغاطية لتربـة المـواد العضـوية تختلـف عـن تصـرف بقيـة انـواع التـرب فـي طـريقين: اولهمـا : الانضـغاط فـي تربـة المـواد العضويةهوالاكبرقيمةً وثانيهمـا: ان الزحـف اوالانضـغاط الثـانوي يلعبـدوراًمهمـاً فـي حسـاب الهبـوط الكلي كماهوملحوظ في تطويرعلاقة فريدة تخص الترب العضوية.

INTRODUCTION

Organic soil is an analogous term for superficial deposit or soil that contains organic matter. Soils with organic matter in it have undergone a change in perception accompanied by a change in terminology. Peat and organic soils both terms used for describing soil with an organic contents, [18].

Organic soils are recognized as a separate soil entity and the Unified Soil Classification System (USCS) which was adopted by the American Society for Testing and Material (ASTM) as a standard classification of soil for engineering purposes and has been described as having been accepted in International Geotechnical Communication, Johnson and Graff, 1988. It has a major division called highly organic soil (P_t) which refers to peat, muck and other highly organic soil.

Jarrett, 1995, [4] stated that the organic soil component of the (USCS) classification is felt to be incomplete; therefore, he gives a classification which can be integrated with (USCS) to bridge the gap between peat and purely inorganic clays and silts.

Table (1) shows the organic content ranges given by Jarrett, 1995, [4].

GEOTECHNICAL PROPERTIES OF ORGANIC SOIL

Geotechnical properties of soils are altered to varying degrees by the presence of organic matter. Organic matter absorbs water and causes clay size particles to aggregate forming an open fabric. This causes unusually high water content and plasticity and exceptionally low wet bulk densities. Some of these deposits show notable increases in shear strength, sensitivity, and degree of apparent over consolidation, [8].

The increase of organic content in soil would influence not only the chemistry of the soil but also alter the geotechnical properties. Therefore the wet bulk density decreases as the organic content increase, [8], and [10].

Atterberg limits refer to water contents correspond to various states of consistency of remolded soil. Liquid limit and plastic limit are the lower most bounds of water content at which a soil behaves as a liquid and a plastic material, respectively. The plasticity index represents the range of water content over which a soil behaves as a plastic material. Liquid and plastic limits provide a measure of the ability of the soil particle to attract and hold water to its surface. Keller, 1982 [8], showed that, with increasing organic content, the liquid and plastic limits were found to increase. Similar results were found by McDonald, 1983, [11], when organic contents range from (1.5 to 5%).

Rashid and Brown, 1975, [16], worked with clay soil and add varying amounts of organic matter to it. There studies showed that shear strength increased as the amount of organic matter increased.

Sobhanet. al. 2007, [20], showed that initial water content and compression index increased with the increase of organic content for most samples of Florida soil.

Zhao et.al 2008, [22], mentioned that organic matter affects the compaction process in at least two ways. First, it increases soil resistance to compaction by enhancing the contact between soil particles and the second, its low particle density compared with soil mineral particles reduces the overall particle density.

Consequently, the organic matter increase water content, liquid limit, sensitivity, compression index, and decrease the specific gravity and bulk density. The organic soils are acidic and the pH values are between (3 and 4.5), [6].

Will The Organic Soil Be a Good Soil for Building and Construction on It?

Organic soil represents the extreme form of soft soil. They are subjected to instability such as localized sinking and slip failure and massive primary and long term settlement when subjected to even moderate load increase. Buildings on peat are usually suspended on piles, but the ground around it may still settle, Mohamed, 2005, [14]. It is, therefore, understandable that constructions and buildings on these types of soil are often avoided whenever possible. On the other hand, this type of soil found in many countries throughout the world, the total world converge is about (30) million hectares, two-third of which are in South East Asia. Since the coverage of these soils is quite extensive, utilization of these problematic soils required in increasing number of instances in the recent years. Hence, suitable geotechnical techniques needed to be found for this type of soil. Therefore, it is necessary to expand our knowledge on the engineeringproperties of organic soils and how to improve its behavior.Now, the question that arises itself is how to improve the behavior of organic soil?

As cited by Mohamed,(2005), [14] andEdil (2003), [3] summaries a number of construction options that can be applied to organic soils, such as excavation–displacement or replacement; ground improvement and reinforcement to enhance soil strength and stiffness such as by stage construction and preloading, stone column, piles , thermal pre-compression and preload piers or by reducing driving forces by light – weight fill, and chemical admixture can be applied either as deep in-situ method (lime-cement columns), or as surface stabilizer.

Another approach of improving organic soil that may be tried is compaction. An extensive study of compaction of organic soil with different organic content would be investigated and performed in this research. Also, the geotechnical properties of compacted organic soil were investigated at different dry densities and corresponding water contents.

MATERIALS USED

To achieve the purpose of this research, a clayey soil was taken from Baghdad city, disturbed samples were taken from a depth of (1.0)m below the natural ground surface, then packed in a double nylon bags and transported to the soil mechanics laboratory, college of Engineering of Baghdad..

Classification tests were performed first. Physical tests include specific gravity, grain size distribution and Atterberg limits. Chemical tests were also performed as shown in Table (2).

Upon completion of the proceeding tests, standard compaction tests were carried out to determine the moisture density relationship.

For engineering tests, Oedometer tests as well as unconfined compression test were carried out on compacted soil at different percentage of organic matter and different water conditions to investigate the effect of organic matter on the engineering properties(compressibility and shear strength characteristics) of compacted clayey soil.

PREPARATION OF COMPACTED SAMPLES

To study the effect of organic matter (sludge) on the behavior of compacted clayey soil, different percentages of organic matter (sludge) were added at (2.5, 5, 7.5 and 10) % to the natural clayey soil. The organic matter was taken from the drying beds of waste water treatment plant of Rustomiyia. The following procedure was adopted in conducting compaction test and preparing the compacted soil specimen for unconfined compression test at different organic matter.A hammer of 1.9cm diameter, (500gm) mass and (30cm) drop was used with split form mold of 38 mm diameter and 89 mm length as shown in Plate (1). Table (3) shows the required number of blows that gives the same comp active effect of the standard comp active effort, [7].

COMPRESSIBILITY TESTS

Laboratory investigation was conducted using Oedometer to evaluate the compressibility behavior of compacted soil samples at different organic content and different water conditions for evaluating the primary and secondary compression indices.

SHEAR TEST

The purpose of those tests was to investigate the shear strength characteristics of the compacted soil samples in order to study the effect of organic matter on shear strength of the soil tested. Unconfined compression tests, were conducted on specimens (38 mm in diameter and 76 mm in height) compacted at different organic matter content and different water content of the standard compaction curve by means of the manufactured hammer .

RESULTS AND DISCUSSION

Physical tests

Specific gravity

The Specific gravity of the sample was determined according to BS1377: 1990 test No. 6, B., [2] The Specific gravity of the sample was 2.8. Regarding the effect of organic matter on specific gravity of the tested soil, four tests of Gs were conducted as shown in Table (4).

Atterberg limits

The liquid limit was performed according to BS 1377: 1975; test No.2, B, [2] while the plastic limit was determined according to BS 1377: 1990, and test No.3.[2].Four percentage of organic matter were added to the soil to find the effect of organic matter on the plasticity of the soil. Table (4) shows the test results for different percentages of organic matter.The effect of organic matter added to the natural soil on the consistency limits is shown in Figure (1). It is obvious that both of L.L and P.L increased with increasing organic matter.

The increase in L.L could be attributed to the ability of organic matter to absorb water and decomposing of organic matter completely and transform into liquid. The same behavior was noticed by Odell, *et al* (1960), [15] who showed that these two limits and the plasticityindex increase with both increasing clay and organic content.

Grain size distribution test

Grain size distribution of the tested natural soil was determined by sieve and hydrometer test.

Chemical tests

The results of chemical tests carried out according to BS 1377:Part3:1990, [2] are presented in Table (5).

Compaction tests

Moisture**-** density relationship was determined by means of the standard compaction test. This test was performed in accordance with ASTM D698 – 00a, [21] standard as shown in Table (6) and Figure (3).

Organic matter affects the compaction process in at least two ways: (i) it increases soil resistance to compaction by enhancing the contact between soil particles [19]; and (ii) its low particle density [19] compared with soil mineral particles reduces the overall particle density and therefore bulk density, especially when organic matter content is high.

Also the maximum dry densities and optimum moisture contents are plotted against the organic matter content in Figures (4 and5) respectively. It can be noticed that both maximum dry density and optimum moisture content slightly decreased with increasing organic contents then tends to increase.

This behavior of decreasing maximum dry density with increasing organic matter due to decreasing of specific gravity. The decreasing in optimum water content as the organic matter increased.

Effect of organic matter on shear strength

The results of UCS tests are listed in Table (6). The plots of q_u and $\varepsilon_f$versus organic matter contents are shown in Figures (6 and 7) respectively. From Table(6), it is clear that q_u and c_u increased with increasing organic matter contents and then tends to decrease in similar manner to the density water relation of compaction test .This behavior could be attributed to the reinforcing effect of the fibrous material in the first 3 percent then tends to decrease. Also, this behavior reflects the increasing of shear strength with decreasing water content. A similar finding was obtained by Huttunen et al. (1996), [5] and (Al-Bayati 1998), [1] which showed the compressive strength increase decrease with increase in the peat organic content.

Effect of organic content on compressibility

According to ASTM D 2435-96a, [21] a series of consolidation tests were carried out on prepared soil specimens at different water content, densities and different organic contents to determine their compressibility characteristics. The results are presented as void ratio, e, versus logarithm of vertical pressure, P, as shown in Figures (8), (9), (10), (11) and (12) for all the specimens tested and the Compression Indices are determined as shown in Table (7), which shows the variation of C_c with natural water contents and dry unit weight of compacted soil samples for different organic contents.

Secondary Compression Behavior

Secondary compression tests were conducted on specimens using the Incremental Load Ratio. The variation of e with log time is approximately linear. The slope of the curve is called the Secondary Compression Index, C_a, and is defined as follows:

$$= \frac{\Delta e}{\_} = \Delta e \;/\; \Delta l$$

Where t_p is the time to End-of-Primary consolidation and t is any time $t>t_p$. In this study, C_α was calculated during the first log cycle after the End-of-Primary consolidation

Time-Stress-Compressibility Relationships (C_α/C_c Concept)

Mesri and Godlewski (1977), [12] postulated that for any given soil, there is a unique relationship between ($C_\alpha = \Delta e / \Delta log\ t$) and ($C_c = \Delta e / \Delta log\ \sigma'$), that holds true at all combinations of time (t), effective stress (σ'), and void ratio (e). At any given effective stress, the value of C_α from the first log cycle of secondary compression and the corresponding Cc value computed from the ***e-log***σ'curve are used to define the relationship between $C_\alpha$and C_c. These values were plotted to develop the unique C_α/C_c relationship for Florida organic soils. It was found from that the C_α/Cc ratio for Florida organic soils range from 0.028 to 0.051. Compilation of worldwide existing data for peat, fibrous peat, and amorphous to fibrous peat from the literature shows that the value for the C_α/C_cratio varies within the range 0.035 – 0.1 **(**Mesri et al. 1997), [13]; these values are consistent with the values obtained in the current investigation as shown in Table (7).

CONCLUSIONS

Based on the results, several conclusions have been obtained:

1. The organic sludge material acts as reinforcement to the soil due to the existence of the fibrous material within it.
2. Both liquid and plastic limits increased with increasing organic matter.
3. Regarding compaction test, it can be noticed that both maximum dry density and optimum moisture content slightly decreased with increasing organic contents then tends to increase. This behavior of decreasing maximum dry density with increasing organic matter due to decreasing of specific gravity. The decreasing in optimum water content as the organic matter increased.
4. Optimum water content generally decreased as the percentage of organic matter increased up to 9.2 % then increased beyond this percentage.
5. The unconfined compressive strength, $q_u$increased with increasing organic matter till 9.7% then decreased.
6. Apparently, axial strain decreased with increasing organic matter.
7. The C_α/C_cratio varies within the range 0.00452-0.10769 which is within the ranges found in the literature.
8. After the performance of the tests in this research and studying the available researches in literature, it is highly recommended to study the geotechnical properties of organic soil in this work at higher percentages other than in this research. Beyond this limit the behavior of organic soil became more obvious and clearest.

REFERENCES

[1]. Al-Bayati, D.T., "Effect of organic sludge on the Engineering Properties of clay soil", 1998.

[2]. British Standard Methods of test for Soils for civil engineering purposes, 1990.

[3]. Edil, T.B.,“Recent advances in geotechnical characterization and construction over peat and organic soils”, Proceedings 2nd International Conference on Advances in Soft Soil Engineering and Technology. (Eds). Huat et al. Malaysia: Putrajaya, pp: 3-25, 2003.

[4]. Jarrett, P.M., 1995, “Geoguide 6. Site investigation for organic soils and peat”, JKR Document 20709-0341-95, Public Works Department Malaysia, Malaysia, 1995.

[5]. Huttunen, E., K. Kujala and H. Vesa,“Assessment of the quality of stabilized peat and clay” ,Symposium Grouting and Deep Mixing. Leiden: Balkema, pp: 607-612, 1996.

[6]. Kazemian, s., Huat, B.B.K, Prasad, A. and Barghchi, M., " States of art review of peat: Geotechnical engineering Perspective". International Journal of the Physical Sciences Vol. 6(8), pp. 1974-1981, 18 April, 2011.

[7]. Khan, M.A.J., "Effect of compaction on the behavior of kirkukgypsious soil", 2005.

[8]. Keller, G.H., “Organic matter and the geotechnical properties of submarine sediments”, Geo-Marine Letters Vol. 2, 191-198. A. M. Dowden, Inc., 1982.

[9]. Keller, G. H., Lamberg, D. N., and Bennett, R, H., “Geotechnical properties of continental slope deposits-Cape Hatteras to Hydrographer Canyon”., In: L. J. Doyle and O. H. Pilkey (eds.). Geology of Continental Slopes.Society of Economic Paleontologists and Mineralogists.Special Publication No. 27, p. 131-151, 1979.

[10]. Krzic, M., C.E. Bulmer, F. Teste, L. Dampier, and S. Rahman, “Soil properties influencing compactability of forest soils in British Columbia”, Can. J. Soil Sci. 84:219–226, 2004.

[11]. McDonald, W., “Influence of organic matter on the geotechnical properties and consolidation characteristics of Northern Oregon continental slope sediments”, M.S. Thesis, Oregon State University, 69 p, 1983.

[12].Mesri, G. and Godlewski, P. M., “Time-Stress-Compressibility Interrelationship”,Journal of the Geotechnical Engineering Division, ASCE, Vol. 103, No. GT5, pp. 417-430, 1977.

[13]. Mesri, G., Stark, T. D., Ajlouni, M. A., and Chen, C. S., “Secondary Compression of Peat With or Without Surcharging,”, Journal of Geotechnical and Geo-environmental Engineering, ASCE, Vol. 123, No. 5, pp. 411-421, 1997.

[14]. Mohamed, Thamer Ahmed, Maail, Shukri and Huat, Bujang B.K., “Effect of chemical admixtures on the engineering properties of tropical peat soils". American Journal of Applied Sciences, 2005.

[15]. Odell, R. T., Thornburn, T. H., and McKenzie, L. T., “Relationship of Atterberg Limits to some other properties of Illinois soils”, Proceedings Soil Science of America, v. 24, p. 297-300, 1960.

[16]. Rashid, M.A. and Brown, J. D., “Influence of marine organic compounds on the engineering properties of a remoulded sediment”, Engineering Geology, v. 9, p. 141-154, 1975.

[17]. Redding, T.E., and K.J. Devito, “Particle densities of wetland soils in northern Alberta”, Canada. Can. J. Soil Sci. 86:57–60, 2006.

[18]. Singh, H. &Huat, B.B.K., "Tropical Peat and Its Geotechnic", Proceedings of 2nd International Conference on Advances in Soft Soil Engineering and Technology. (eds). Huat et al. Putrajaya, Malaysia.pp. 203 – 220, 2003.
[19]. Soane, B.D., "The role of organic matter in soil compatibility: A review of some practical aspects", Soil Tillage Res. 16:179–201, 1990.
[20]. Subhan, K. Ali, H., Riedy, K., and Huynh, H., "Evaluating the compressibility behavior of organic soils using laboratory characterization and rapid on-site piezocone penetration testing", International Journal of Geotechnical Engineering, 1(1), 9-18, 2007.
[21]. "Standard Test Method for Rocks and Soils", ASTM Standards 4.08, (2003).
[22]. Zhao,Y., Krzic,M., Bulmer,C.E. and Schmidt, M.G., "Maximum Bulk Density of British Columbia Forest Soils from the Proctor Test: Relationships with Selected Physical and Chemical Properties", Soil Science Society of America Journal: Volume 72: Number 2, March–April , 2008.

Table (1) Organic Content Ranges (after Jarrett, 1995).

Basic Soil Type	Clay or Silt or Sand	Organic Soil	Peat
Descriptor	Slightly organic	-	-
Organic Content,%	3-20	20-75	>75

Table (2) Summary of physical and chemical properties of soil used.

Organic Content,%	SO_3,%	G_s	LL,%	PI,%	w_{opt}, %	γ_{opt}, kN/m^3
2.2	1.94	2.80	44	19	25.1	15.9

Table (3) Corresponding Compactive Efforts in the Manufactured Hammer.

Type of compaction	No. of blows / layer in the compaction mould	Compactive effort, (CE) in compaction mould (kN.m/m^3)	No. of blows / layer in manufactured mould*	Compactive effort, (CE) in manufactured mould (kN.m/m^3)**
Standard compaction	25 blows (3 layers)	593.7	3 layers (2 of them compacted at 12 blows and the other at 11 blows)	597.525

* Compaction Mould of (101.6) mm diameter.
**Split mould of (38) mm diameter.

Table (4) Tests results of consistency limits.

Organic matter content,%	**Specific gravity, G_s**	**Consistency limits,%**			**USCS**
		L.L.	**P.L**	**P.I**	
2.2*	2.800	44	25	19	CL
4.5	2.731	48	28	20	CL
7.2	2.726	47	27	20	CL
9.5	2.662	49	35	14	ML
12.2	2.603	49	43	6	ML

*: Natural soil sample with 2.2% organic matter content.

Table (5) Chemical tests results.

Chemical test	**Results,%**
Sulphate Content	1.94
Organic Content	2.2

Table (6) Compaction tests results.

Organic matter,%	**Compaction characteristics**	
	$\gamma_{dry\ max}$, kN/m^3	w_{opt}, %
Natural Soil	15.9	25.10
4.5	15.82	24.80
7.2	15.50	23.00
9.5	15.30	21.00
12.2	15.42	23.60

Table (6) Effect of organic content on shear strength.

Organic content,%	Water content condition	Water content,%	Shear Strength		
			Failure strain, ε_f, %	Unconfined compressive strength, q_u, kPa	Undrained strength, c_u, kPa
2.2 (Natural Soil)	Dry	23.10	11.80	62.48	31.24
	Optimum	25.10	9.69	78.14	39.07
	Wet	27.10	10.21	37.33	18.66
4.7	Dry	22.80	12.00	71.54	35.77
	Optimum	24.80	8.67	103.45	51.725
	Wet	26.80	18.42	37.83	18.91
7.2	Dry	21.00	8.92	80.27	40.13
	Optimum	23.00	4.54	116.29	58.145
	Wet	25.00	12.16	38.93	19.46
9.7	Dry	19.00	7.89	90.64	45.32

	Optimum	21.00	5.90	132.36	66.18
	Wet	23.00	5.60	68.98	34.49
12.2	Dry	21.60	11.84	72.12	36.06
	Optimum	23.60	4.41	106.22	53.11
	Wet	25.60	11.05	45.51	22.75

Table (7) The Results of the Consolidation Tests.

Organic content, %	γ_d	w_c,%	Water content condition	Void ratio, e	Stress level ,kPa	C_C	C_S	C_a	C_a/C_c	m_v, m^2/MN
2.2 (Natural Soil)	1.58	23.10	Dry side	0.73291	50	0.16573	0.02189	0.00775	0.04676	0.356602
					100			0.01185	0.07150	0.324179
					200			0.01550	0.09353	0.2172
					400			0.01640	0.09896	0.136696
					800			0.01094	0.06601	0.079424
	1.59	25.10	Optimum	0.72201	50	0.187058	0.02635	0.01593	0.08515	0.821998
					100			0.00732	0.03912	0.380002
					200			0.00861	0.04603	0.242001
					400			0.00861	0.04603	0.153501
					800			0.00861	0.04603	0.08675
	1.58	27.10	Wet side	0.73291	50	0.19184	0.02054	0.01256	0.06549	0.544087
					100			0.00563	0.02935	0.398309
					200			0.00866	0.04514	0.25151
					400			0.00650	0.03387	0.164765
					800			0.00433	0.02257	0.08867
4.7	1.5675	22.80	Dry side	0.74227	50	0.18271	0.027683	0.00367	0.02009	0.293332
					100			0.00367	0.02007	0.256397
					200			0.00458	0.02507	0.112988
					400			0.00275	0.01505	0.049432
					800			0.00092	0.00503	0.019284
	1.582	24.80	Optimum	0.72630	50	0.16872	0.028802	0.01817	0.10769	0.743158
					100			0.01360	0.08061	0.368422
					200			0.01590	0.09424	0.224211
					400			0.01227	0.07269	0.129474
					800			0.01363	0.08077	0.082369
	1.5675	26.80	Wet side	0.74227	50	0.208066	0.02413	0.00392	0.01884	0.362265
					100			0.00696	0.03345	0.306535
					200			0.00871	0.04187	0.285893
					400			0.00871	0.04187	0.178296
					800			0.00958	0.04604	0.096373
7.2	1.545	21	Dry side	0.76440	50	0.217744	0.027059	0.00221	0.01013	0.340745
					100			0.00221	0.01013	0.218451
					200			0.00573	0.02633	0.287958
					400			0.01323	0.06076	0.1803
					800			0.01059	0.04862	0.103999
	1.55	23	Optimum	0.75871	50	0.202143	0.025511	0.00440	0.02175	0.375994
					100			0.00659	0.03260	0.277998

ABBREVIATIONS AND NOTATIONS.

Symbol	Abbreviations
ASTM	American Society of Testing Material
BS	British Standards
CE	Compactive effort, in compaction mould ($kN.m/m^3$)
Cu	Coefficient of uniformity
c	Cohesion(kPa)
EOP	End-of-Primary
e	void ratio
G_s	Specific gravity
LL	Liquid limit, ,%
PI	Plasticity Index, %
w_{opt}	Optimum water content, %
P	vertical pressure, kPa
q_u	Unconfined compressive strength, kPa
m_v	Modulus of volume change , m^2/MN
$\gamma_{dry\ max.}$	Maximum dry unit weight, , kN/m^3
σ'	Effective stress, kPa
ε_f	Failure strain,%
SO_3,%	Sulphate content, %
t	Time of any consolidation, minute
tp	Time at the end of consolidation, minute
UCS	Unconfined Compressive Strength

Plate (1) Manufactured Hammer.

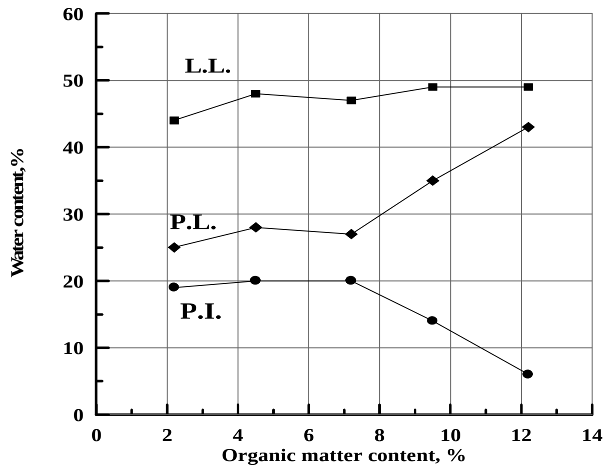


Figure (1) Effect of organic content on water content indices.

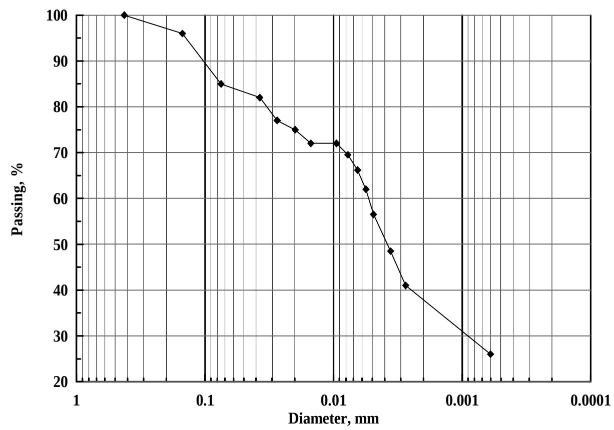


Figure (2) Grain size distribution curve.

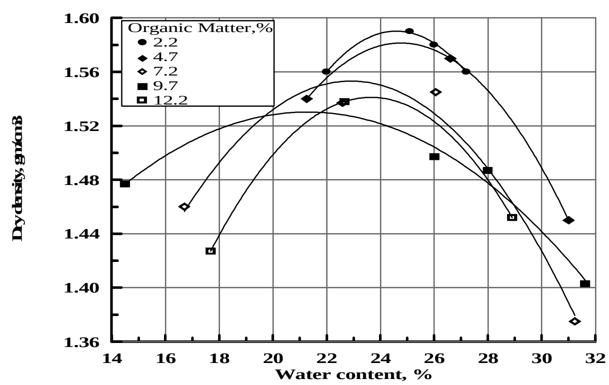


Figure (3) Moisture- density relationships of different organic matter contents.

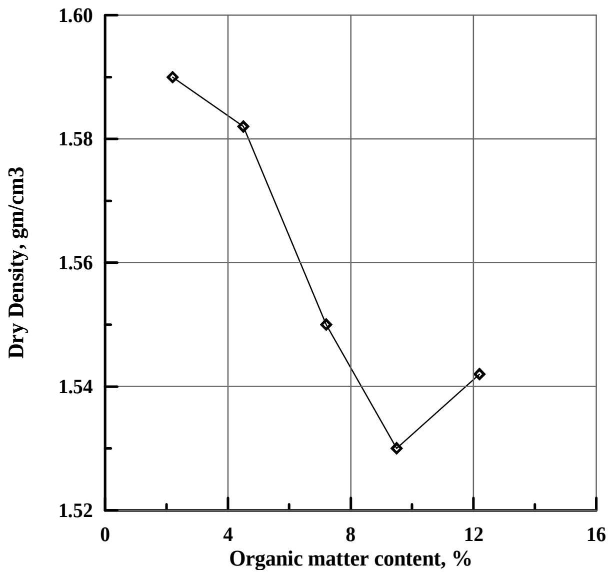


Figure (4) Effect of organic content on maximum dry density.

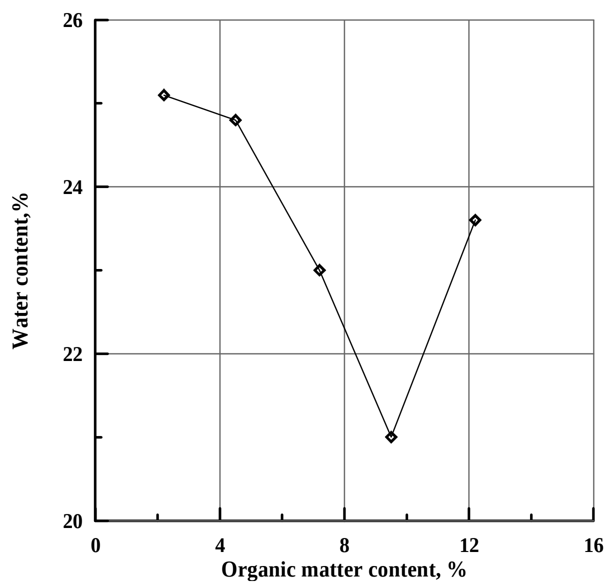


Figure (5) Effect of organic content on optimum water content.

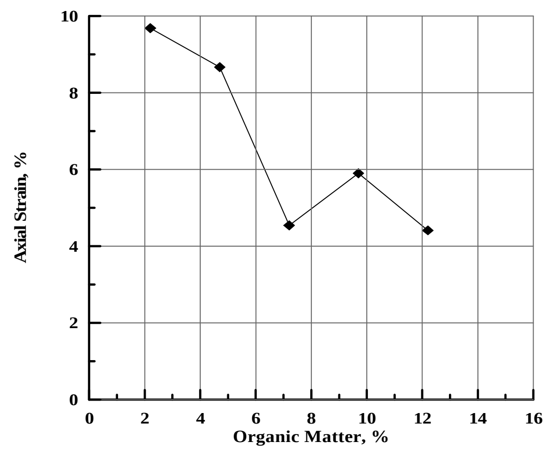


Figure (6) effect of organic content on axial strain.

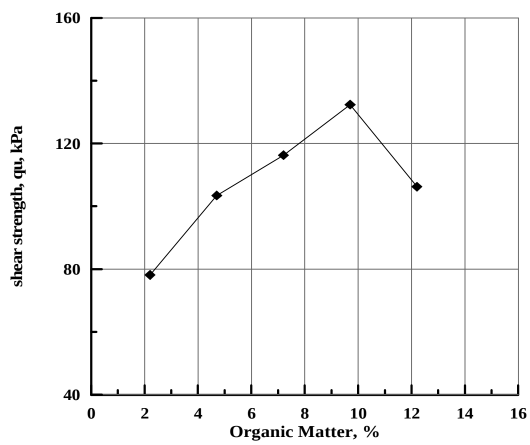
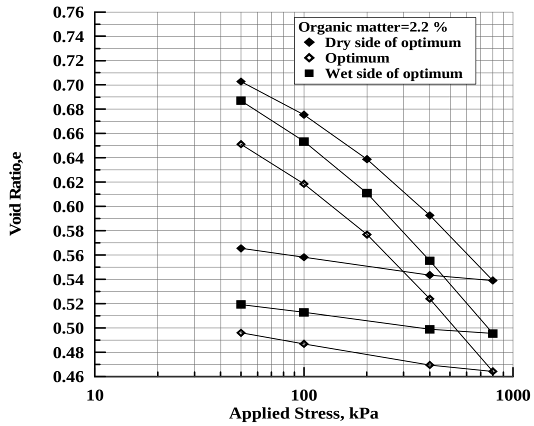


Figure (7) effect of organic content on unconfinedCompressive strength.



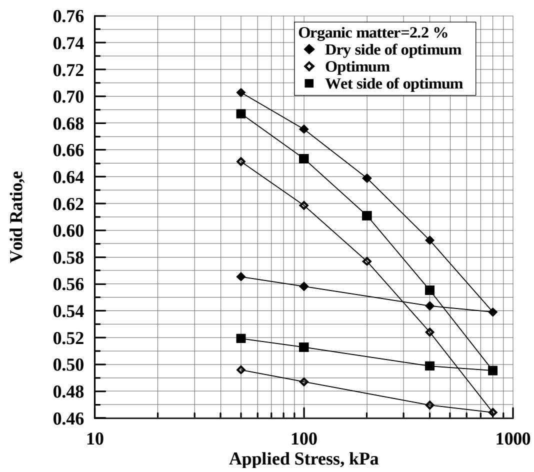


Figure (8) typical e-log p plot for natural soil.

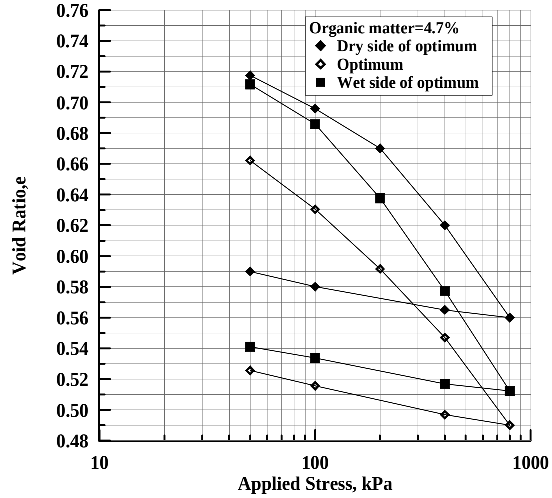


Figure (9) typical e-log p plot for soil containing Organic content=4.7%.

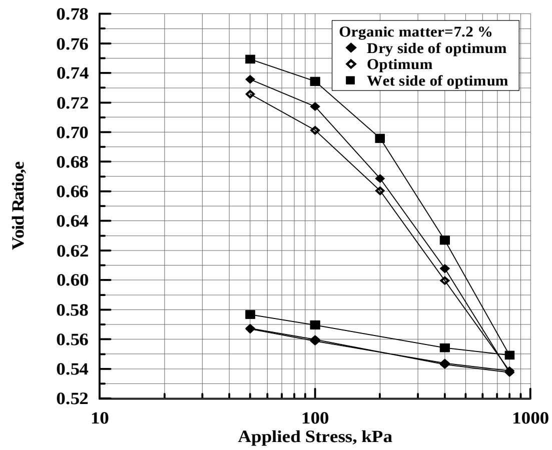


Figure (10) typical e-log p plot for soil containing Organic content=7.2%.

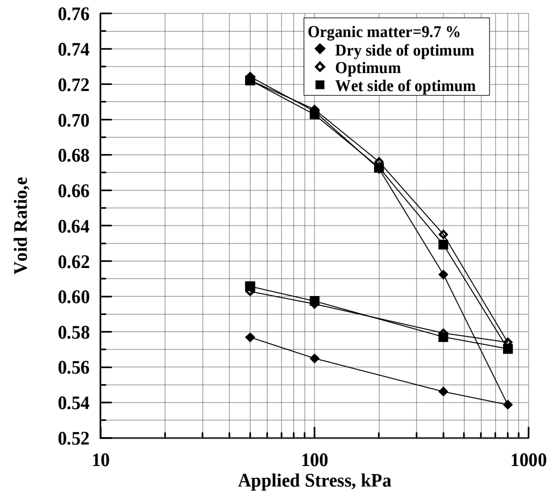


Figure (11) typical e-log p plot for soil containing Organic content=9.7 %.

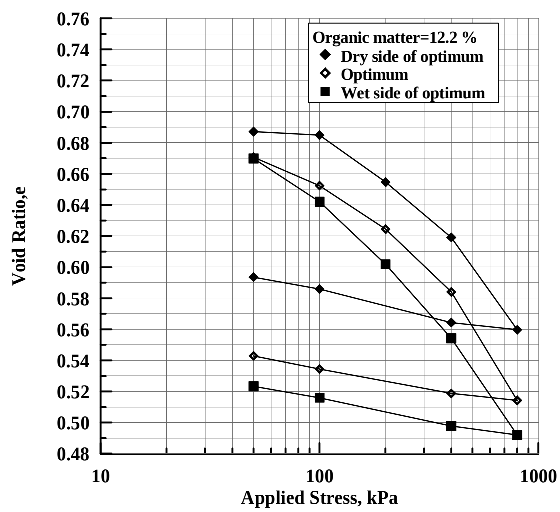


Figure (12) typical e-log p plot for soil containing Organic content=12.2%.