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Assessing and Evaluating the Effect of Organic Matters on Clayey and Silty Soil Stiffness Properties

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ABSTRACT

Construction of building and other civil engineering structures on weak or soft soil is highly risky because such soil is susceptible to differential settlements, poor shear strength, and high compressibility.Organic soils are difficult to deal with due to their particular characteristics such as high compressibility and poor strength and, as a consequence, criteria based on common mineral soils may not generally be applied to them. The objective of this research is to investigate and assess adding different percentages of organic matters on soil stiffness, from laboratory experimental work, and to investigate the effectiveness of animal disposals and plants pieces (leaves) ontwo soil types.

Hence, in the present research, mixed organic materials have been used, and it was randomly included in to the soil at four different percentages of organic content, i.e. 5, 10, 15, and 20% by the weight of two main raw, silty soil and clayey soil. The research revealed from the laboratory tests that when organic mattersincreased the stiffness of both clayey and silty soil were reduced, and the reduction were from 16.5% to about 61% with 5 and 20% adding percentage of organic matter respectively. While the liquidity and plasticity increased from the reference soil (without organic materials) as well as the swelling index increasing for the two types of tested soils. Moreover the research indicates the percentage of organic contents played an important role in the development of the vertical displacement of the clayey and silty soil under loading.

Kew words: Organic Matters, Direct Shear, Silty Soil, Clayey Soil, Compression And Rebound Ratio, Compressibility.

تقييم و تحديد تأثير المواد العضوية على خواص مقاومة الترب الطينية و الغرينية

الخلاصة

ان انشاء البنايات و المنشآت المدنية على الترب الضعيفة او الهشة فيه خطورة عالية, لان مثل هذه الترب تكون معرضة الى الهطول التفاضلي و مقاومة قص ضعيفة و انضغاطية عالية. إن الترب العضوية يكون صعب التعامل معها بسبب بعض الخواص المعينة كالانضغاطية العالية و المقاومة الضعيفة و كنتيجة لذلك هناك بعض معايير المقاومة للترب الاعتيادية لا تطبق على الترب العضوية.

ان الغرض من هذا البحث هو معرفة و تعيين مقاومة الترب العضوية و ذلك باضافة نسب مختلفة من المواد العضوية. ومن خلال التجارب العملية و ذلك باضافة مخلفات الحيوانات ممزوجة مع قطع النباتات (الاوراق) الى نوعين من الترب (ترب طينية و غرينية).

تم استعمال في هذا البحث مواد عضوية خلطت بصورة عشوائية ضمن التربة بأربع نسب مختلفة من المواد العضوية (5, 10, 15, 20)%من وزن التربة الجافة الطينية و الغرينية و قد استُنتج في هذا البحث, انه عند زيادة نسبة المواد العضوية تقل قوة الترب الطينية و الغرينية من 16,5% و 61 % عند اضافة 5% و 10% على التوالي. بينما تزداد حد السيولة و اللدونة عنها في الترب الاصلية المرجعية (الترب التي لا تحتوي على مواد عضوية), كما وجدت في هذه الدراسة الحالية ان مؤشر الانتفاخ يزداد لكلا التربتين اضافة الى ذلك بيَن هذا البحث ان وجود المود العضوية يلعب دوراً مهما في تغيير الازاحة العمودية للترب الطينية و الغرينية المعرضة للتحميل.

INTRODUCTION

Organic matter maybe found in the soil in many forms such as sludge, plant residuals pieces, and animal wastes disposal. Sludge or sewage increase the organic content of the soil and may cause some alteration in the engineering properties of the soil.Sludge means any solid, semisolid or liquid waste generated from a municipal, commercial or industrial waste water treatment plant, water supply treatment, air pollution control facility or any other such waste material having similar characteristic and effects (McGhee, 1991).

As sludge seeps through the leakage area of the sewers or may be added to the surface soils in agricultural areas as fertilizer, the interaction of it with the surrounding soil particles may cause significant changes in the properties of the mixture. The effects of fine grained soils may be more obvious (Al-Bayati, 1998).

Organic soils are difficult to deal with due to their particular characteristics such as high compressibility and poor strength and, as a consequence, criteria based on common mineral soils may not generally be applied to them. Compaction of soils with organic content differs appreciably from that of inorganic soil. The organic particles are generally larger than clay particles and have the ability to absorb water. They also attract clay particles which become bound to their surface. The organic particles are still when compressed and act as rigid particles when dry, but when they absorb water they become sponge – like and soft (Franklin et al., 1973). In an early published work by Franklin et al., (1973), it was found that the maximum dry density decreases and the optimum water content increases as organic content increases.

This implies that at low water content much of the water added to the sample becomes in effect a part of the organic matter. This reduces the efficiency of adjusting the water content to optimize the compaction behavior and in soils with very high organic content such as peat, the optimum dry density becomes very hard to define. When the amount of organic matter is relatively small (e.g., in some top soils or organic soils) strength and load – deformation properties as well as the compaction characteristics are influenced. Nevertheless the feasibility of compacting such a soil for engineering purposes still exists as it will, be shown in the present study.

Hendry et al.,(1993), discussed the production of organic CO_2 from organic matters in the soil. They mentioned that the elevated concentration of CO_2 can only be attributed to microbial decomposition of organic matters, and the oxidation of organic carbon will product the CO_2, and the concentration will increase near the water table. So, this phenomenon will produce organic HCO_3 acid, and thus some substructure and foundation will affects.

Many researches were focused on the effect of one type of organic materials such as sludge, plants residual pieces or animal disposal on fixed soil type. While in the present research, mixed of animal wastes disposal and plants residual pieces on two different soil types with different adding percentages have been carried out.

This paper describes a study onsome soil properties –physical and engineering properties by adding different percentage of mixed organic matters on soil with 5,10,15,and 20% from the dry weight. The aim of the present research is to assess and investigate the effects of mixed organic matters of animals,wastes and plant leaves pieceson the engineering properties of two different soil types of clayey and silty soil types.

LITERATURES REVIEW

The previous studies on the effects of organic matters on soil properties were made by adding different percentage of some kind of plants, and some researches on organic soil improvements.However, Al-Bayati,(1998), studied the effect of low content of organic sludge on the engineering properties of clay soil. The study reviled that the low content had decreasing the shear strength and increasing compressibility. Deboucha,etal., (2008), made thierstudy on peat soil stabilization to improve its physical and engineering properties. It investigates the effect of additives (binder amount 5%, 10% and 15% (85%cement, 15% bentonite) and range of sand 5% to 25% on the index properties as well as, pH, compaction, California Bearing Ratio and unconfined compressive strength of tropical peat soils. The amount of additives added to the peat soil sample was investigated in terms of the percentage of the dry soil mass.The results showed that of the additive admixtures altered the engineering properties of tropical peat soils. The soil liquid limit was found to decrease with increase of the additive content. The maximum dry density was found to increase while the optimum moisture content was found to decrease with the increase of the additive content. The California Bearing Ratio of the soil was found to increase significantly with increase in the additives.

Abd Al-Nafea, (2010) studied the effect of organic matter's content on the engineering properties of expansivesoils by resemblance to the organic soils, dry leaves of the wide spread trees all over Iraq (Youkaliptous). The crushed dry leaves, passing sieves No.40 was mixed with the soil, with the amount (5, 10, and 15) % from dry weight of soil. The study concluded that the presence of organic matters can cause instability in soil properties generally, so that its decrease the plasticity(more than 35%), shrinkage(25% decreasing at 15% organic content), and cause decrease in shear strength(more than 50%).

Ali,(2010) investigated the effect of adding organic material by using (animal fertilizers) and the chemical material by using (compound of mixed fertilizer) on the physical properties of the soil by studying , Atterberglimits, maximum dry unit weight, and mechanical properties , unconfined compressive strength, cohesion force, angle of internal friction and consolidation.

The study includes preparation of a number of disturbed samples, where the soil was mixed with different percentages of organic and chemical materials (0,2%,4%,6%) with water content equal to the optimum water content of the origin soil used in order to study the effect of different percentages of adding materials on the maximum unit weight . The study also includes the effect of time factor where the tests are done in ages (0,1,7,30) days for organic and chemical soil.It was noticed that for different times of the test (0,1,7,30) days and for different percentage of organic material (2-6%) increasing in the liquid limit, Plastic limit, angle of internal friction and compression index(3-25%),(5-47%),(15-75%), and (38-85%) respectively.

Moreover, Martinez (2006), done his study on ground Improvement of organic soils using Wet Deep Soil Mixing Method WSMM, the objective of his research was to assess the use of the WSMM in organic soils, from laboratory experimental work, and to investigate the effectiveness of specific cementations binders and the effect of temperature, carbon dioxide concentration and relative humidity on the stabilization of organic soils. This was achieved by conducting a series of unconfined compression tests in wet-soil mixed specimens prepared both mechanically and using laboratory-scale auger-mixing equipment.

Other researches were made to improve the organic soil by applying different procedures.Moayedi et al.,(2012), involved a number of experiments using composition of alkaline earth metals grout to treat organic soils, in order to provide a better understanding of the engineering behavior of this soil after stabilization. Besides, it provides a series of the laboratory mix design and testing which in turn provide an essential guide regarding the choice, dosage and economical amount of chemical binders. While, Tastan, et al.,(2011), were studied the effectiveness of fly ash use in the stabilization of organic soils and the factors that are likely to affect the degree of stabilization. Unconfined compression and resilient modulus tests were conducted on organic soil–fly ash mixtures and untreated soil specimens.

MATERIALS PROPERTIES AND EXPERIMENTAL STUDY

Soil type

The soil which used in this study has been chosen from two different locations, it can be classified as sandy clayey siltfrom Nasryah, and clayey soil from Dialya. The physical properties are given in Table (1), and soil classification illustrated in Figure (1) for clayey soil and Figure (2) for silty soil.

Organic matters

The organic matters which used in this research were collected from dry plant leaves and animal wastes disposal, by mixing both the cutting of the leaves with animal wastes and after drying, the organic matters added to the soil under investigation with different percentages of 5, 10, 15, and 20% from the dry weight of the soil samples.

Physical properties of the organic soil

The two types of soil with different percentages of organic materials were investigated for the physical properties such as liquidity, plasticity, specific gravity, dry unit weight, porosity, and optimum moisture contents for all percentages of organic added to the soil. Table (2) and Table (3), shows the results of the physical properties of organic soil as well as the soil without organic (reference soil) for comparing the new behavior of soil under examination.

Direct shear test

The experimental study involved performing a series of direct shear tests. The tests were conducted in a shear box of the size 60 mm by 60 mm. The tests were performed as consolidated and drained tests at normal stresses of σ_n= 27.7, 55.5 and 111.11 kPa in order to completely define the shear strength parameters (i.e. the effective angle of shear strength (φ°) and cohesion (C)) for both reference soil(without organic) and organic soil specimens. The loading rate was 0.002 mm/s in the tests. Shear stresses were recorded as a function of horizontal displacement up to a total displacement of 10mm. A shear rate of 0.05 mm / min was applied according to the ASTM D3080-72 with duplicated specimens to observe the post-failure behavior as well.

Consolidation and Displacement

Oedometer tests were performed according to ASTM D 2435. The apparatuses with a diameter of 7.5 cm and height 1.9 cm were put in the consolidation cells. The soil was mixed with different organic contents as 5, 10, 15 and 20%. The soil samples were enclosed in a metal ring and placed into the consolidometer. The sample was sandwiched between two porous stone allowing a two-way drainage of the sample. Water was added into the cell around the sample, so the sample remained saturated during the test. Seven vertical static load increments were applied. The changes in the displacement of the sample against time were recorded during each loading increment.

RESULTS AND DISCUSSIONS

Effect of organic content on physical properties

The effect of organic contents on liquidity and plasticity are presented in Figures (3 and 4) respectively. The results showed that with increasing organic contents leads to the increasing in plasticity index and liquid limit, but the clayey soil shows more increasing than silty soil as results of the fact that the organic particles are generally larger than clay particles and have the ability to absorb water (Franklin,et al.,1979), and the porosity of clay is more than silt, and the high retention ability of the water within clay is more than other types of soil.

The effect of organic contents onspecific gravityand dry unit weight are presented in Figure (5 and 6). For any particular organic contents, an increase in organic content causes a reduction in specific gravity and dry density for both clayey and silty soil. As already explained in some researches, this is due to the reduction of average unit weight of the solids in the soil mixture due to lowdensity and specific gravity of the organic which is the specifc gravity is less than 2.0 (Bowels,1997).However, the value of the dry densitydepends on the specific gravity and the void ratio. It is observed from Fig.6 that the plot of variation of dry density with respect to organic contents is a linear reverse relationship. This result is matching with the research ofDuraisamy et al.,(2007) andAbd Al-Nafia, (2009).The reduction of specific gravity and dry density for clayey soil are from 3.5 to 18% and 6 to 11% respectively, while from 4.5 to 19% and 2.5 to 12% respectively for silty soil.

As the result revealed in this study,and as an early published work by (Franklin et al., 1973), the optimum moisture content increase with increasing the mixing of organic contents Figure (7) due to increasing the voids of soil skeleton when increasing the organic materials (Al-Adili,1998, Abd Al-Nafia, 2009) and the increasing of retention rate of water in both soil types.

Shear strength

The variation of cohesion (C) and friction angle (φ°) is given in Table-4 and Figures(8 and 9). The variation of cohesion and friction angle with organic contents shows linear variation. The result has shown that the cohesion of the reinforced soil has decreased with increasing the percentage of added organic percentages for both soil types, with regard to the reference soil (zero% organic matters). In contrast, the internal friction of the organic soil increasing with increasing the percentage of the organic contents in thesame trends for the two soil types. These results could be attributing to play the organic matters good role as weakened agents in the soil skeleton and produce poor locking texture.

Based on the direct shear test results, the study indicated that organic matters inclusions decreased the peak shear strength and limited post-peak reductions in shear resistance for both clayey and silty soils, but the silty soil showed more percentages of reduction from about 31 to 76.5%Figure (8), with significant decrease in stiffness of the organic–soil composite was observed. While , the internal friction angle increase for both soil types with increasing the percentages of organic matters from 16 to 60% and from 10 to 60% for clayey and silt soils respectively(1) as in Figure (9).

Consolidation test

The addition of random organic matters into the soil on consolidation shows that the compression decreases with increases the organic for the two types of soils with 5 and 10% percentages of added organic for clayey and silty soils respectively. The odometer test are shown in Tables-5 and 6. However, the relation between compression and compression index is not a direct relation, and the compression index (Cc) dose not represents the compressibility of the soil. Wesly, (1988) mentioned that the compression ratio (CR) is more realistic to find out the compressibility value, which it is;

$$CR= Cc / (1+e_o) \qquad \dots (1)$$

In contrast, the Rebound (Swelling) ratio (RR) is more accurate than the swelling index (Cr), Where:

$$RR= Cr/ (1+ e_o) \qquad \dots (2)$$

Moreover, Al-Adili (1998) concluded that the compressibility and rebound ratios could be increases while the compressibility and rebound indices decrease. The results showed the compression ratios of the organic clayey and silty soils were reduced with increasing the percentages of added organic in generalFigure

(10). This results is matching with the previous studies and attributes to the fact the organic matters play significant role in reducing the interlocking of the soil skeleton and increasing the voids as well as the moisture content withlow specific gravity and unit weight of the organic. Also, the organic matters increase significantly the rebound ratio and swelling ratio linearly, as shown in Figure (11).

Modules of Elasticity (E)

The modules of elasticity is one of the best parameters to determine the soil stiffness and elasticity (Dunn et.al., 1980), because this modules (modulus of deformation or, more commonly (but incorrectly), the modulus of elasticity Bowles, 1997) represents the relationship between stresses and strains for the soil.The stress-strain modulus ***(E)*** used here is not a simple parameter to obtain for any soil, forit varies with soil type, state,confinement, and depth (Bowles,1997). In this study the modules of deformation for the silty soil and clayey soilwere reduced significantly due to increasing the organic matters Figure (12). The reduction in the Modules of deformation are 9.5 to 50% for increasing organic from 5 to 20% respectively for clayey soil, and from 20.5 to 48.5% for increasing organic from 5 to 20% respectively for silty soil. This result leads to the fact the organic matter (animal wastes disposal and plant residual pieces) within soil strata reduce the stiffness and increasing the settlement especially immediate settlement due to lacking of internal locking with increasing organic percentage and increasing voids and pores with low specific gravity and unit weight of the organic, and need to make soil improvement and stabilization as well.

Displacement

Figure (13) shows the vertical displacement of the two types of the soil with increasing the organic matters. The percentage of organic contents played an important role in the development of the displacement of the clayey soil and silty soil under loading. The vertical displacement test of the soil showed that the organic matters weaken the soil structure at the adding percentage of organic from 5 to 20% linearly,(1) see Figure (13). This result is matching with the results of the other tests on this research like shear and consolidation. However, Sobhan, et al.,(2007) concluded that the soft compressible organic soils and peaty soil will cause secondary settlement at long-term and may cause of recurring pavement distresses in the form of cracking, rutting, and subsidence below roadway.

Nevertheless, the initial void ratio and porosity increasing with increasing the organic content in the soil, as well as the reduction in the dry unit weight, so this aspects conduct weak soil structures and increasing the liquid limit and plasticity, and leads to increasing the displacement of the soil under loading for both clayey and silty soil. As expected, the organic clayey soil shows more rate of displacement than the organic silty soil.

CONCLUSIONS

The study presents comprehensive experimental results on the strength and stiffness response of organic clayey soil and silty soil. Based on the test results and discussions, the following conclusions can be made;

1. Based on the experiments conducted to study the influence of mixed animal waste disposal and plant residual (random inclusion) as added material on the strength behavior of two types of soil, clayey and silty soils, it reduces the dry density and specific gravity of the soil due to a low specific gravity and low density

of organic matters. While increasing liquid limit and plasticity by increasing the organic matters percentages for the clayey and silty soils.

2. The shear stress of organic clayey and silty soil was weakened due to the addition of the organic with adding percentage of 5 to 20% especially for silty soil type. The cohesion was reduced the soil skeleton by adding organic matters.

3. Moreover, this research concludes that the modules of deformation for the silty and clayey soils reduced significantly due to increasing the organic matters. The reduction in the Modules of deformation are 9.5 to 50% for increasing organic from 5 to 20% respectively for clayey soil, and from 20.5 to 48.5% for increasing organic from 5 to 20% respectively for silty soil. The reduction on elasticity and increasing the displacement is due to the higher liquidity of the organic matters, as well as the action of the organic matters as weakened agent for the cohesion and the bonds and increasing the total strain.

4. The present research concluded and emphasized that compression ratio (CR) is more realistic to find out the compressibility value, and the rebound (swelling) ratio (RR) is more accurate fromswelling index (Cr) in such researches.

5.Stiffness of soil decreases considerably due to organic inclusion which it appears significantly by increasing displacements for the both soil types, however, the immediate settlement of soil can be reduced by incorporating some of improvement inclusion to the soil.

6. Hence, it is recommended to improve and make some treatments for such organic soil if using infrastructures in such environment with respect of the percentages of organic matters.

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Table (1) Properties of the soil used in the test.

Soil properties	Silty soil	Clayey soil
LL %	35	43.5
PI %	16	26
Specific gravity	2.65	2.7
Sand %	21	3.5
Silt %	41	31.5
Clay %	38	65
Porosity (n)%	34	39
Dry unit weight (kN/m^3)	17.25	16.92
Void ratio (e)	0.513	0.637
Elasticity (kPa)	2171	2000

Table (2) the physical properties of the organic clayey soil.

Properties	Clayey soil 0% organic	Clayey soil with 5% organic	Clayey soil with 10% organic	Clayey soil with 15% organic	Clayey soil with 20% organic
L.L.	43.5	47.95	52.47	55.30	58.73
P.I.	26.3	28.1	30.6	31.9	33.1
GS	2.7	2.61	2.41	2.33	2.21
γdry (kN/m^3)	16.92	15.91	15.51	15.39	15.02
O.M.C.	17.75	20.1	21.82	23.3	24.5
Porosity(n) %	39	41	41.1	39,7	37.7

Table (3) the physical properties of the organic silty soil.

Properties	Silty soil 0% organic	Silty soil with 5% organic	Silty soil with 10% organic	Siltysoil with 15% organic	Silty soil with 20% organic
L.L.	35.0	41.0	47.0	48.0	54.5
P.I.	16	20	25	25.5	30
GS	2.68	2.56	2.45	2.28	2.17
γdry (kN/m^3)	17.25	16.83	16.23	15.46	15.2
O.M.C.	16.2	18.2	20.2	21.6	24.6
Porosity(n) %	33.9	34.6	37.8	38.3	39.1

Table (4) Results of shear strength of organic clayey and sandy soil.

Soil samples	C (kPa) of clayey soil	φ° of Clayey soil	C (kPa) of Silty soil	φ° of silty soil
Reference soil 0% organic	76.5	25	157.4	30
5% organic	63.9	29	108.7	33
10% organic	50.6	34	74.23	36
15% organic	42.41	37	66.06	40
20% organic	29.91	40	37.33	45

Table (5) Consolidation parameters for silty soil with adding organic matters.

Soil sample	Initial void ratio (e_o)	P_c	CR	RR
Clay only (0% Organic)	0.637	185.7	0.0737	0.0178
5% Organic	0.696	250.0	0.0772	0.0204
10% Organic	0.668	275.0	0.0614	0.0230
15% Organic	0.658	283.4	0.0596	0.0229
20% Organic	0.605	277.3	0.0614	0.0263

Table (6) Consolidation parameters for silty soil with adding organic matters.

Soil sample	Initial void ratio (e_o)	P_c	CR	RR
Clay only (0% Organic)	0.513	217.0	0.0689	0.0136
5% Organic	0.529	192.9	0.0743	0.0155
10% Organic	0.608	170.0	0.0710	0.0170
15% Organic	0.522	174.0	0.0635	0.0153
20% Organic	0.643	191.7	0.0589	0.0195

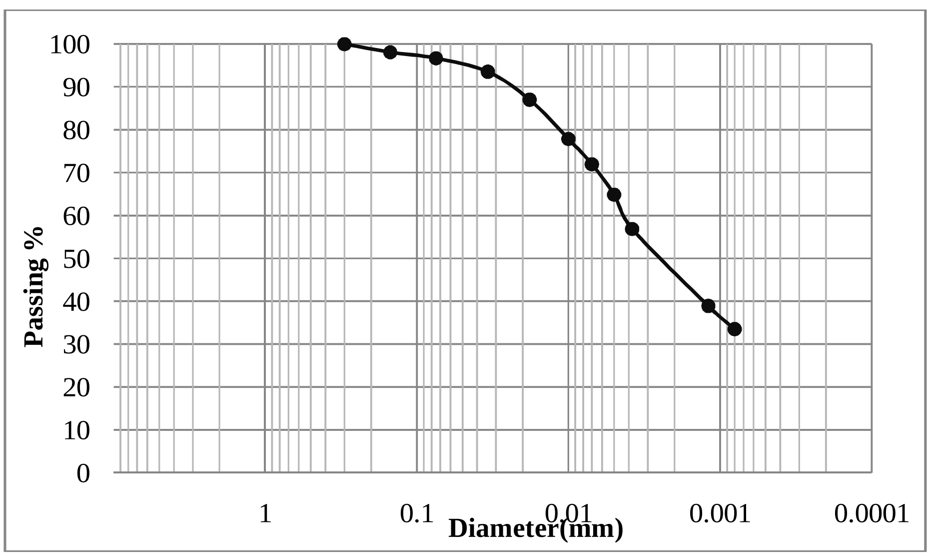


Figure (1) Grain size distribution of the clayey soil from first location (Nasryah).

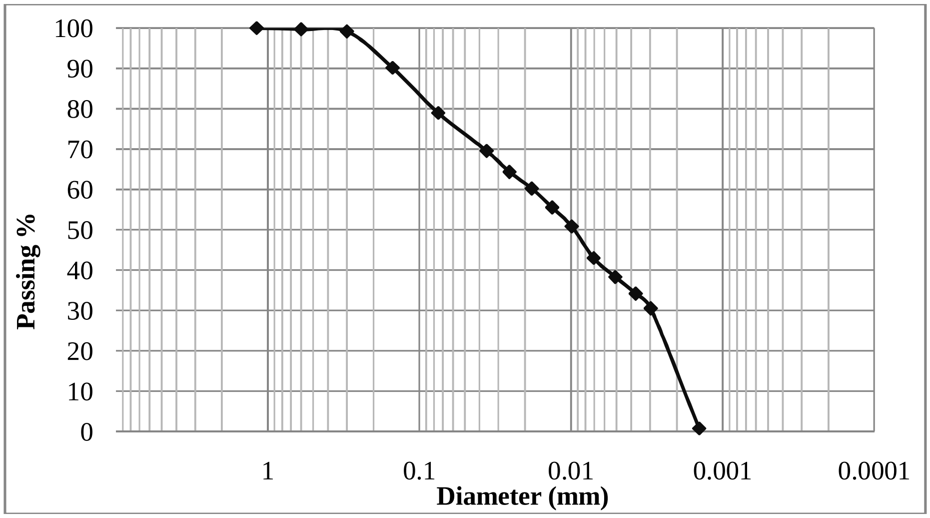


Figure (2) Grain size distribution of the silty soil from Second location (Diyala).

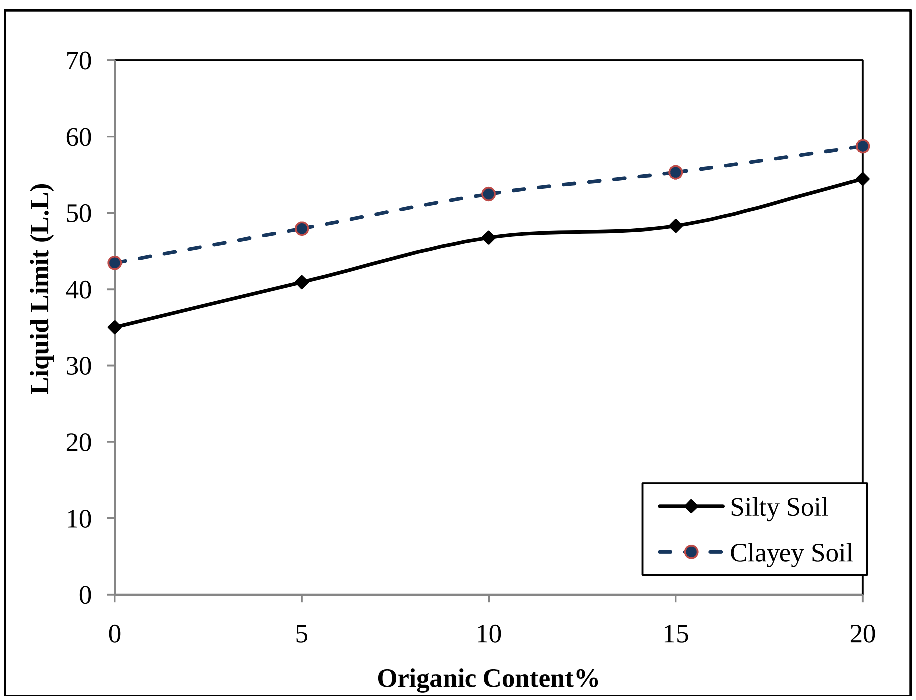


Figure (3) Liquid limits behavior of clayey and silty soil with increasing organic matters.

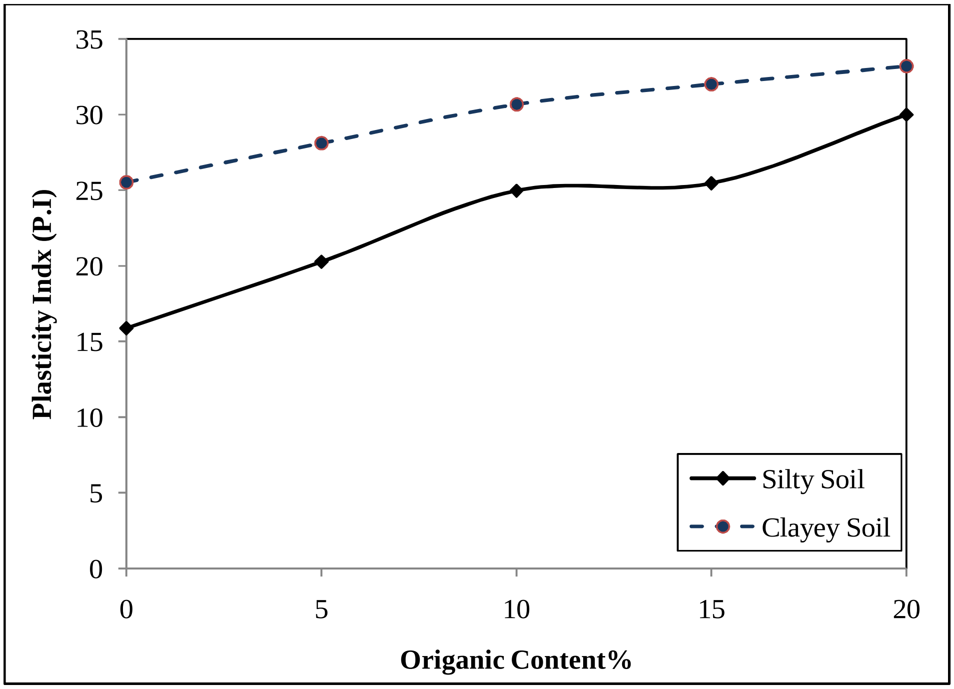


Figure (4) Plasticity behavior of clayey and silty soil with increasing organic matters.

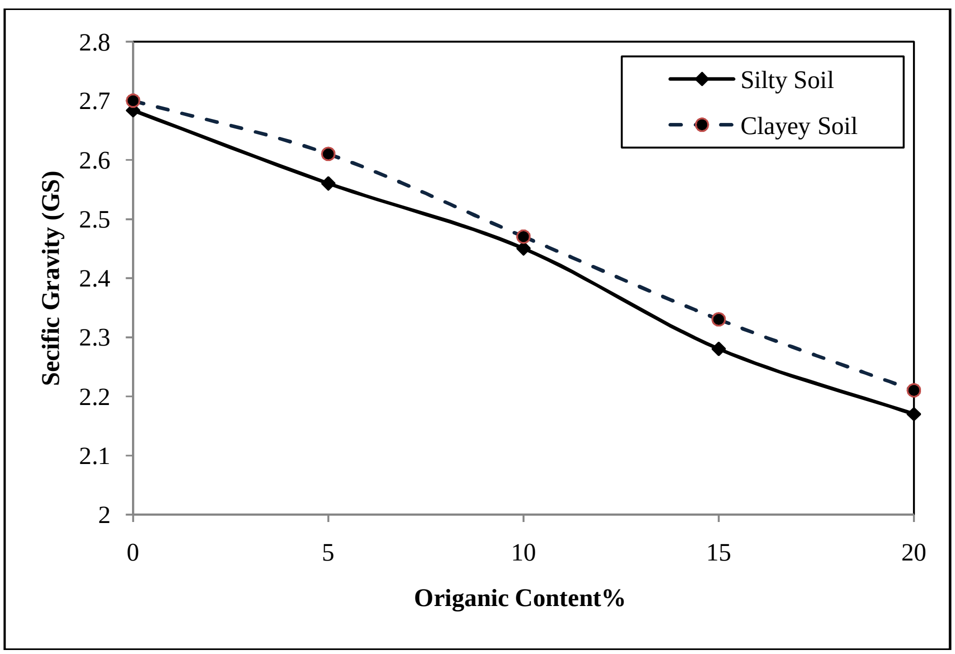


Figure (5) Specific gravity of clayey and silty soil with increasing organic matters.

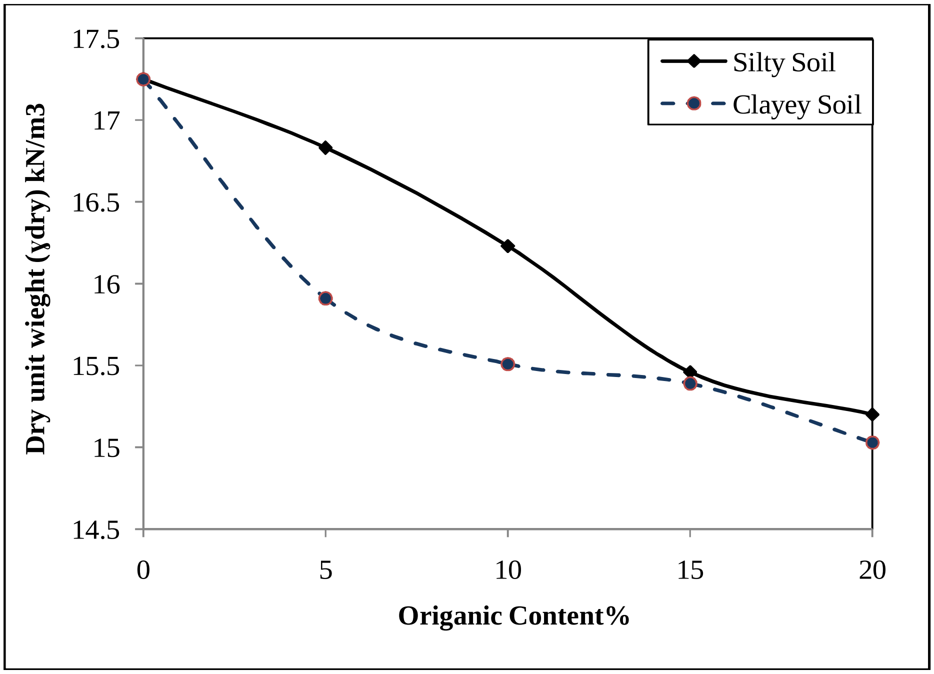


Figure (6) Dry density of clayey and silty soil with increasing organic matters.

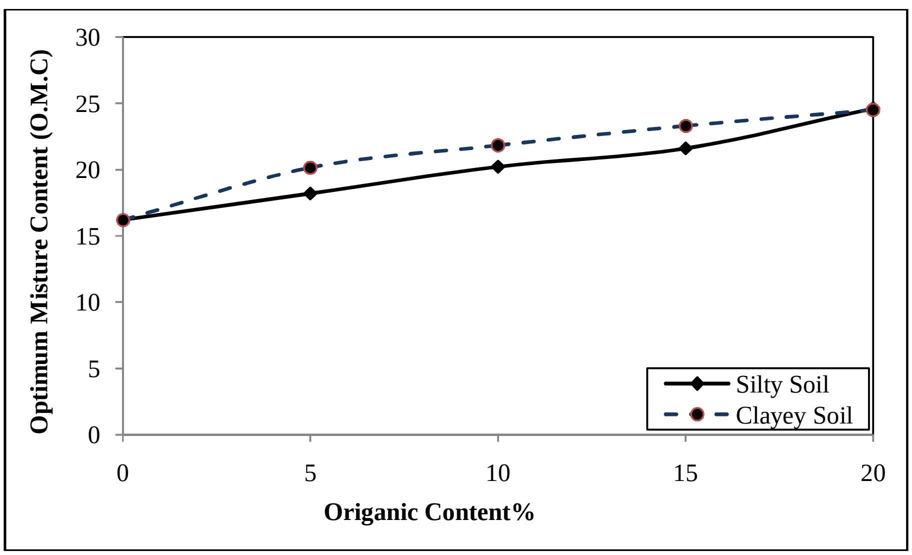


Figure (7) Optimum moisture content of clayey and silty soil with increasing organic matters.

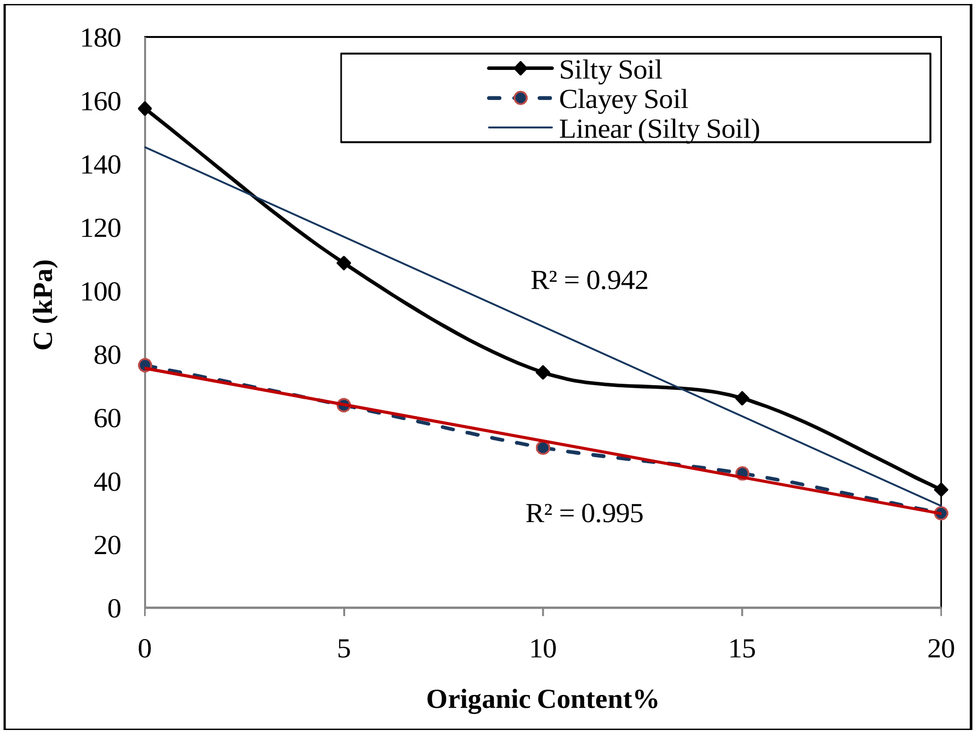


Figure (8) Effect of organic matters on cohesion of clayey and silty soil.

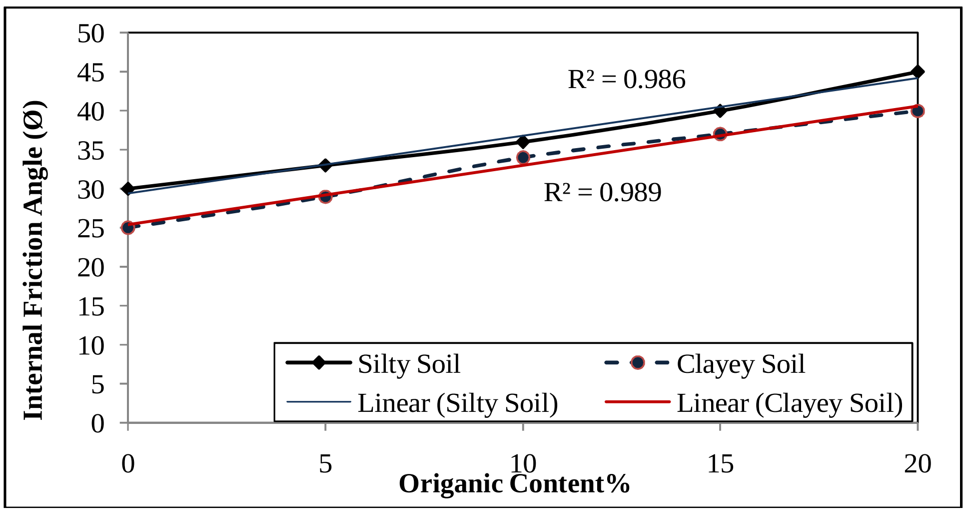
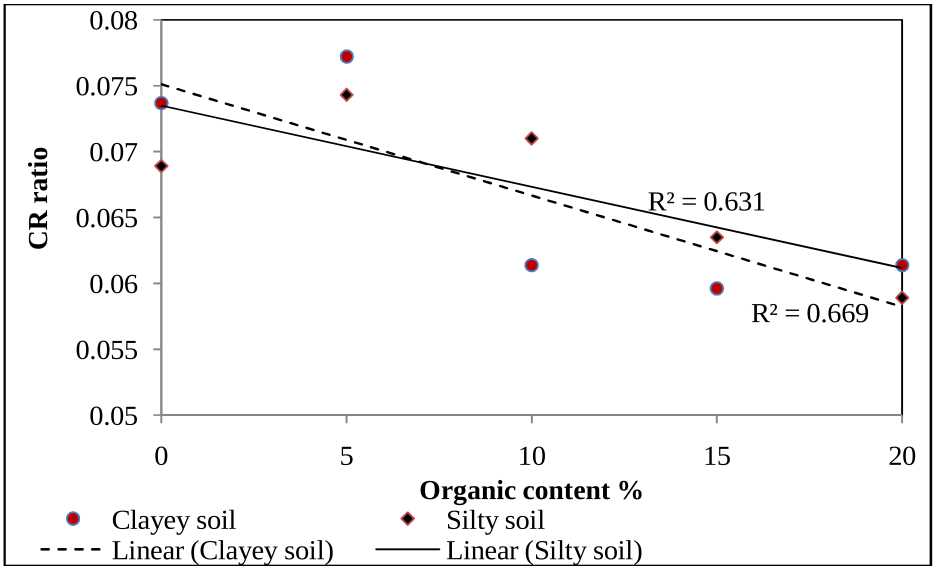


Figure (9) Effect of organic matters on Internal friction angle for both soil types.



Figure(10) The Compression ratio for both clayey and silty soil with increasing organic matters.

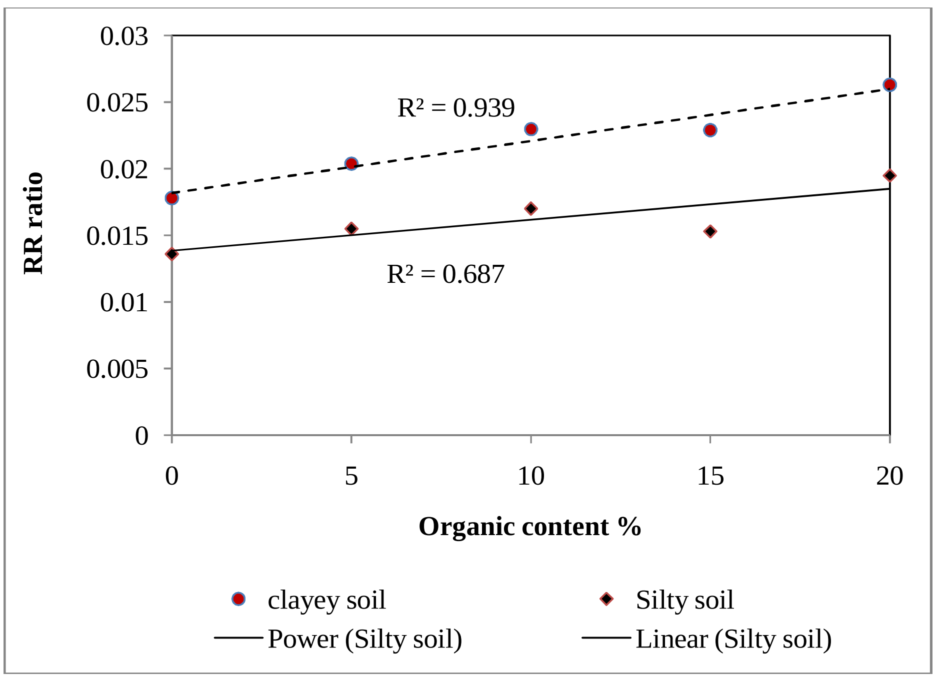


Figure (11) The rebound ratio for both clayey and silty soil with Increasing organic matters.

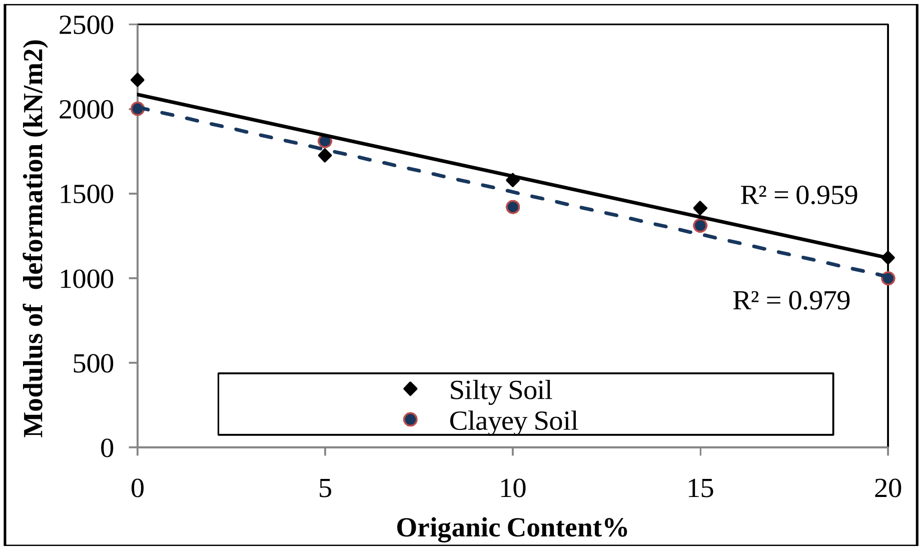


Figure (12) Modules of deformation with increasing organic matters for soil under consideration.

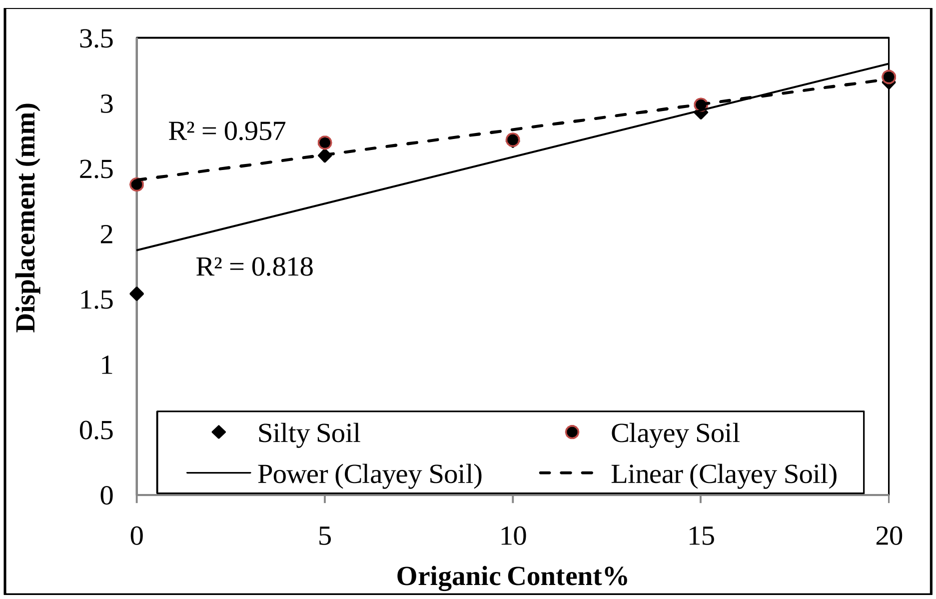


Figure (13) the vertical displacement due to increasing organic Matters for two soil types.