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Stabilization of Organic Soils using Additives

Dr. R. Chitra[1], Mahabir Dixit [2], Purabi Sen [3], Mukesh [4]

[1 2 3 4] Central Soil and Materials Research Station

New Delhi, India

Abstract— Organic soils are found in many places around the world. Organic soils undergo large secondary settlements depending on the amount of organic matter present in the soil. Due to the problems associated with the organic soils, construction of embankments using the organic soils is avoided. The presence of organic content in a soil acts to the detriment of its engineering properties. Besides, soils with high organic content exhibit inferior properties such as high compressibility, low shear strength, low permeability, and poor compactibility. In order to reduce the secondary settlements caused by organic matter, soil is treated with different stabilizing agents. The difficulties associated with organic soils arise when they are treated with cement or lime stabilizers, as organic matter inhibits cementitious reactions responsible for strength gain. During the geotechnical investigations of a hydroelectric project in the North Eastern region of India, the presence of organics soils in the entire project site where from the soils are to be borrowed for the construction of the embankment was identified. Attempts were made to stabilize the organic soils were made for their use in the construction. The paper focuses on the stabilization of the organic soil from the North Eastern region of India.

Index Terms—Stabilization, Organic Soil, Shear Strength, Permeability, Embankment

INTRODUCTION

Organic soils are generally referred as problematic soil on account of its poor strength and stiffness characteristics and pose significant problems to design engineers. Generally organic soils have high void ratio, high water content, high plasticity and more compressibility when compared to mineral or inorganic soils.

Construction on soft organic soil gives rise to special problems. Most obvious are the large deformations that may occur during and after the construction period, both vertically and horizontally. The settlements often appear very quickly but may also continue for very long time period due to creep. The low strength often causes stability problems, and consequently the load sometimes has to be placed in stages or, alternatively, the soil must be improved through prior treatment.

It is important to realize that organic soil is not a single type of soil but a number of soils with different behaviour. In one case, it may be appropriate to choose preloading, as for fibrous peat, while in another case this solution turns out to be impracticable due to low permeability, as with organic clay where soil stabilization may be the most economical solution. Even for a special soil type, such as peat, the properties may vary immensely, as between fibrous and decomposed states.

Organic soils undergo large secondary settlements depending on the amount of organic matter present in the soil. In order to reduce the secondary settlements caused by organic matter, soil is treated with different stabilizing agents. The difficulties associated with organic soils arise when they are treated with cement or lime stabilizers, as organic matter inhibits cementitious reactions responsible for strength gain. There is a need to understand the fundamentals behind the chemical reactions contributing to the changes in geotechnical properties of stabilized organic soil beds.

ORGANIC SOILS

Organic soils are types of soils from pure organic forms as peat to transition forms as organic clays. In the geotechnical practice, these soils are generally not accepted. Embankments on organic soils are most often constructed for roads or for flood control dikes. When an embankment is constructed on soft organic soil layers, both stability and settlement problems will generally arise.

The engineering properties of organic soils show a great variation depending on the type and amount of organic matter. The organic matter may occur in many forms from small amount of amorphous or colloidal substance embedded in the pores of a mineral soil to fibrous peat with a structure resembling a coarse, loosely woven mat. The effect of organic content on the engineering properties in relation to the properties of a pure mineral soil is mainly confined to a decreased permeability and increased tendency to creep. The organics soils have very low strengths and are extremely compressible and exhibit large creep effects.

Table 1 Guiding values for classification of soils based on organic content

Soil Group	Organic Content in weight % of dry material (< 2 mm)	Examples of Designations
Low Organic Soils	2 - 6	Gyttja – bearing clay Dy-bearing soilt Humus-bearing, clayey sand
Medium Organic Soils	6 - 20	Clayey Gyttja Silty Dy Humus rich sand
High Organic Soils	> 20	Gyttja Dy, Peat Humus rich top soil

Highly fibrous and undecomposed organic soil has a pronounced structural anisotropy. The fibers constitute a horizontal reinforcement and failure surfaces in such materials usually occur as vertical fractures or horizontal shear planes parallel to the fibres. The permeability of the soil is relatively high and is often many times higher horizontally than vertically. The engineering properties of the organic soils depend on the type of organic matter and the organic content. The structural anisotrophy is also equally important for the behaviour of the organic soils. The guiding values for the classification of soils on the basis of organic content is listed in Table 1.

BEHAVIOR OF ORGANIC SOILS

The behavior of the organic soils depends on the amount and type of organic matters present in the soils. Organic matter may be in the form of fully or partly decomposed vegetation. Varying amounts of finely divided vegetable matter are found in sediments and often affect sediment properties sufficiently to influence their classification. The organic silts exhibit no or low plasticity and organic clays exhibit medium to high plasticity. Even small amounts of organic matter in colloidal form in a clay may result in an appreciable increase in liquid limit (and plastic limit) of the material without increasing its plasticity index.

The organic matter consists of entirely of organic material (fibrous peat and fine-grained peat). The highly organic soils are composed of 30 to 75 % organic matter mixed with mineral soil particles (silty peat and sandy peat). The organic soils are composed of 5 to 30 % organic material and are typically classified as organic soils of high plasticity (OH, LL>□50) or low plasticity (OL, LL<50) and have a ratio of liquid limit (oven-dried soil) divided by liquid limit (not dried soil) that is less than 0.75. The slightly organic soils typically have less than 5 % organic matter and the ratio of liquid limit (oven-dried soil) divided by liquid limit (not dried soil) of these soils is greater than 0.75.

Generally, organic soils are dark gray or black in color and usually have a characteristic decaying odor. Organic clays feel spongy in the plastic range when compared to inorganic clays. The tendency for soils high in organic content to form voids through decay or to change the physical characteristics of a soil mass through chemical alteration makes them undesirable for engineering use. Soils containing even moderate amounts of organic matter are significantly more compressible and less stable than inorganic soils; hence, they are less desirable for engineering use.

The presence of organics in soils is, in fact, generally associated with high compressibility, significant secondary compression, often unsatisfactory strength characteristics, and low unit weight. The high compressibility and creep often increase the risks of inadmissible settlements and/or foundation failure. The unsatisfactory strength characteristics associated with the low values of the maximum dry density are a main concern in road construction. As a result of the above, the construction of foundations, embankments, excavations, and other ground works often becomes very difficult in presence of soils with organic matter.

CHARACTERISTICS OF SOIL ORGANIC MATTER

The presence of soil organic matter, a complex mixture of organic compounds, differentiates organic soils from inorganic soils. The amount of soil organic matter significantly affects index, physico-chemical and engineering properties of soils, including specific gravity, water content, liquid limit, plastic limit, density, cation exchange capacity, hydraulic conductivity, compressibility and strength.

Soil organic matter includes "the total organic material in soils, including litter, light fraction, microbial biomass, water-soluble organics, and stabilized organic matter" Given the complexity of soil organic matter, it can be normally classified into two major categories: living organic matter and non-living organic matter. Living organic matter, the minor fraction of soil organic matter, consists of soil biota such as bacteria, fungi, and algae, and fresh and un-decomposed animal or plant debris.

Non-living organic matter, which is the plant or animal debris at different stages of decomposition and transformation, is the major portion of the total organic components in soils. Because of the various chemical components, non-living organic matter is usually divided into humic and non-humic substances

EFFECTS OF ORGANIC MATTER ON GEOTECHNICAL PROPERTIES OF SOIL

The effects of organic matter on soil properties have been extensively investigated in the technical literature, particularly in the soil science and agronomy fields, due to the important role played by organic matter in fertilizers, soil-applied pesticides, and the carbon cycle. In civil engineering, however, organic matter has not received the same attention, even though it is recognized that organic matter plays a critical role in engineering practice. The presence of organic matter in soils is associated with lower specific gravity, higher compressibility, larger creep coefficients, as well as unsatisfactory strength characteristics. These properties are the reason why soils with significant organic matter are perceived by civil engineers as "problem soils".

Water Content: Organic soils usually have very high water content. The fibrous structure of the soils results in large voids and the high cation exchange capacity of organic matter increase the attraction of water molecules; both properties result in high water content.

Gas Content: The gas content of a soil is a very important parameter, which can change with time. The gas content influences permeability, consolidation rate, and pore pressure generation. In organic soils, there are macro and micro pores. The gas in the macro pores is free gas while the gas in the micro voids is entrapped. The macro pores can be reduced by confining pressure but the micro pores cannot. Thus permeability, deformability, and pore pressure generation, are strongly linked with the size of the macro pores and the nature of their fluid.

Bulk Density: Bulk density is defined as the ratio of the dry weight of soil to its total volume and is a function of void ratio, organic content, and specific gravity. Typically, soils with higher organic content have low bulk density, especially when the fiber content is high. The fibers in the organic soil create a more open structure which results in more voids. The reduction of bulk density with fiber content is substantial.

Specific Gravity: The specific gravity of soils with high organic content is generally in the range of 1.0 to 2.0. For soils with high organic content, a typical value is 1.5. The mineral content increases the specific gravity; thus specific gravities greater than 2.0 are an indication of a soil with high mineral content (i.e. low organic content). The specific gravity tends to decrease as the organic content increases.

Particle Size Distribution: Particle size distribution is an index that represents the state of soil aggregation. Typically 50-80% of organic matter is absorbed on the clay surface; the rest is relatively un-decomposed. Particle size distribution is affected by two mechanisms: aggregation and dispersion.

Atterberg Limits: Atterberg limits comprise liquid limit (LL) and plastic limit (PL). The Atterberg limits of an organic soil depend on two opposing characteristics: higher water adsorption capacity of organic matter, and particle aggregation from organic substances. The higher water adsorption of the organic matter increases the limits, but the tendency of organic matter to aggregate the soil mineral fraction tends to reduce the limits. In general both liquid and plastic limits increase with organic content because the water adsorption capacity of the organic matter usually exceeds the reduction caused by organic matter induced aggregation.

Shrinkage Potential: Shrinkage can be significant in soils with high organic content. For loose high organic soils, the volume change can reach 70% of their initial volume upon drying.

Cation Exchange Capacity and Acidity: The cation exchange capacity of a soil is the ability of the soil to absorb and exchange cations, which are attracted to the surface of the soil particles. The acidity affects the magnitude of cation exchange capacity. In clay minerals, the cation exchange capacity attains its maximum value at pH 8.2. The cation exchange capacity of organic matter increases significantly with pH. The pH of organic soils is typically around 4-7. As the organic content increases the cation exchange capacity increases.

Compaction Behavior: The maximum dry density decreases with organic content and the optimum moisture content increases as the organic content increases.

Strength: The strength of organic soils strongly depends on the organic content. Since the strength of soils is highly dependent on water content and the water content of a soil generally increases with organic content, the strength quickly decreases. In addition, due to the high deformability of organic matter, the maximum strength is reached at higher deformations with increasing organic matter.

Permeability: Permeability is affected by the size and continuity of soil pores. The permeability of organic soils is much higher than that of inorganic soils. The permeability of an organic soil with more than 75% organic content is 100 to 1000 times larger than that of inorganic clay. The degree of decomposition of the organic matter and the degree of aggregation of organic soil particles determine the permeability of organic soils. The organic matter-induced aggregation of soil particles tends to increase the permeability. Because of the deposition process of the soil matter, the permeability in vertical direction is much smaller than in the horizontal direction.

Compressibility: Peats and organic soils exhibit a much higher compressibility than other geotechnical materials. Because of the large water content of organic soils which, given the low specific gravity of organic matter, is associated with large void ratios, their compression index is very high. The secondary consolidation behavior of organic soils is strongly dependent on the nature of the organic matter.

STABILIZATION OF ORGANIC SOILS

Soil stabilization has been successfully applied throughout the world in a variety of soils including granular, soft, expansive and non-organic soils. But organic soil stabilization for the most part has not been researched nor put into practice extensively. Despite the great need for enhancing unsuitable organic soils for foundation materials, organic soil stabilization has been mainly unexplored. The existing ground improvement modification techniques in practice include static compaction, dynamic compaction, dewatering, reclamation of problematic soils, surcharge, soil nailing, stone columns, drain installation and soil stabilization etc. Soil stabilization is a well accepted and effective practice and is done by deep mixing method for foundation stabilization and dry mixing methods using admixtures for embankment constructions.

ORGANIC SOILS FOR EMBANKMENT CONSTRUCTION

During the geotechnical investigations of a hydroelectric project in the North Eastern region of India, the presence of organics soils in the entire project site where from the soils are to be borrowed for the construction of the embankment was identified.

Geotechnical Investigations

A total of ten soil samples were collected from the borrow areas and were subjected to various laboratory tests such as Mechanical Analysis, Atterberg Limits, Standard Proctor Compaction, Specific Gravity, Triaxial Shear Test, One Dimensional Consolidation, Laboratory Permeability, Soil Dispersivity Identification Tests and Chemical Analysis tests. While carrying out the routine laboratory investigations, it was found that the borrow area material possess organic matter in considerable amount and the presence of the organic matter influences the physical & the engineering properties of the soil. Therefore, in addition to the routine tests, additional investigations were carried out to study the influence of organic matter.

The general look of the soils were dark grey/ dark brown material with characteristic odor of decaying organic matter when mixed and rubbed with water. The grain size distribution curves of the tested soil samples are presented in Figure 1.

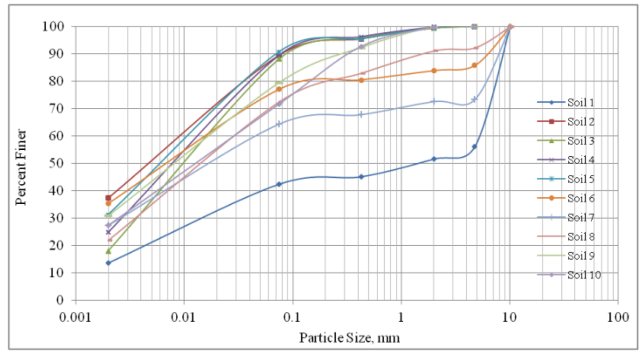


Figure 1 Grain Size Distribution Curves of the Organic soils

The test results indicate that the presence of organic content influences the geotechnical properties of the tested soil samples by increase in the atterberg limits, decrease in the proctor density and increase in the optimum moisture content and decrease in the strength characteristics. It was observed from relatively high liquid limits, lower compaction density and high OMC of the borrow area materials might be due to presence of considerable amount of organic matter. In order to confirm, organic content of the soil samples are determined through chemical methods and the results are presented in Table 1.

Table 1 Results of Loss on Ignition of Soil Samples

Soil No	Loss on ignition of air dried sample at 80°C (%)	Loss on ignition of air dried sample at 110°C (%)	% Loss on ignition % of air dried sample at 550°C (%)	% Organic matter determined by chemical method (%)
1	2.85	4.46	6.85	2.5
2	5.76	7.59	14.26	6.0
3	8.45	13.4	22.95	17.7
4	6.34	9.01	16.84	8.4
5	5.11	7.93	13.01	7.7
6	5.02	6.48	12.72	5.4
7	3.72	5.43	11.82	2.1
8	4.22	6.41	11.82	4.1
9	9.53	12.0	20.13	8.9
10	2.45	4.34	6.75	2.7

The proctor compaction test was carried out on the air dried and the oven dried soil sample and the results are presented in Figure 2.

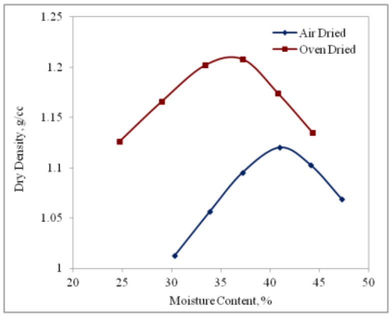


Figure 2 Compaction Curve–Air dried and oven dried soils

All the test results confirms the presence of organic matter in the borrow area materials. As per the guideline given in the IS:1498 and IS:12169, the organic soils are not recommended as construction materials for the construction of the embankments. Therefore attempts were made to stabilize the organic soils were made for their use in the construction.

Methodology

In order to improve the characteristics of the organics soil, the commercially available quick lime and the river sand collected from the project site were used for blending the borrow area materials. A total of two soil samples, collected from two different borrow areas were subjected to various laboratory tests with and without additives.

River sand collected from the project site was added to the borrow area materials in proportions of 10%, 20 % and 30 % by dry weight and the blended materials were subjected to various laboratory tests.

The quick lime was added in proportions of 5%, 10%, and 20 % by dry weight and the blended materials were kept in humid chambers. The blended materials were subjected to various laboratory tests after 7 and 28 days of mixing in order to study the effect of lime blended with the borrow area materials after 7 days and 28 days on the geotechnical characteristics of the borrow area materials.

In addition, an attempt was also made to mix 10 % of lime and 10% of river sand to the soil samples order to the effect on the behaviour of the blended material.

Geotechnical Properties of Materials

The grain size analysis of the borrow area materials indicate that the tested soil samples possess predominantly silt sizes followed by clay sizes and fine sand sizes with high compressibility and plasticity characteristics. Figure 3 presents the grain size distribution curves of the soil used for the experiments.

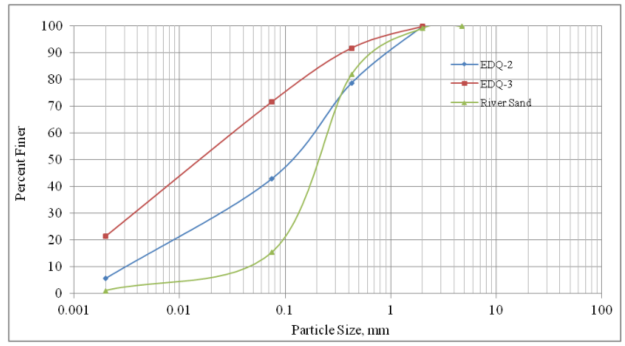


Figure 3 Grain Size Distribution Curves of the Soil under study

The organic silt and clays are usually distinguished from inorganic silts which have the same position on the plasticity chart, by odour and colour. However when the organic content is doubtful, the material can be oven dried, remixed with water and retested for liquid limit. A reduction on liquid limit after oven drying to a value less than three fourth of the liquid limit before oven drying is positive indication of organic soils. Therefore Atterberg Limit tests were carried out on the oven dried soil samples and the results are presented in Table 2.

Table 2 Results of Atterberg Limits and Soil Type

Field No	Liquid Limit of Soil Dried at 100°C-110°C	Liquid Limit of Air Dried Soil	Plastic Limit of Soil Dried at 100°C-110°C	Plastic Limit of Air Dried Soil	LL (Oven dried) / LL (Air Dried)	Soil Type
EDQ-2	62.8	76.2	50.0	58.3	0.82	SM
EDQ-3	47.1	68.8	35.5	46.7	0.68	OH

The Liquid limit values of the air dried and oven dried soil samples indicate that the liquid limit after oven drying is less than the three forth of the liquid limit of the air dried sample. Based on the results of grain size distribution and Atterberg limits tests, the soil samples fall under OH (Organic Soil with High Compressibility) group of Bureau of Indian Standard soil classification system. The soil of OH group are capable of achieving very poor compaction characteristics, are likely to exhibit very high compressibility and poor shear strength when compacted and saturated and have poor workability as construction material. The OH group soils are least desirable for use as core materials and embankment materials (IS: 1498 and other relevant books on Embankment Dam Design).

The Specific gravity values of the tested soil samples vary from 2.56 to 2.77. Figure 4 presents the results of the standard proctor compaction tests carried out on the borrow area materials under study. The values of Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of the tested soil samples vary from 1.23 g/cc to 1.32 g/cc and 35.0 % to 33.1% respectively. From the Standard Proctor compaction test results, it is inferred that the soil samples are capable of achieving low compaction densities and higher OMC. The Unconfined Compressive Strength of the soil samples is 0.40 kg/cm^2 and 0.52 kg/cm^2 respectively.

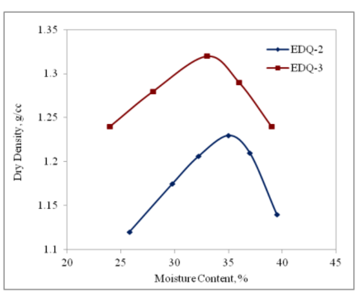
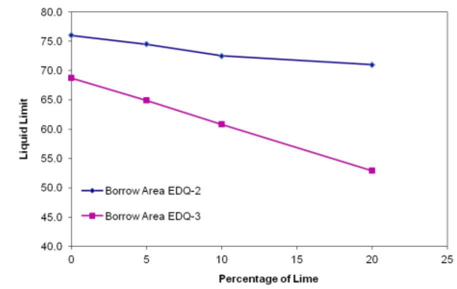


Figure 4 Results of Proctor Compaction Test

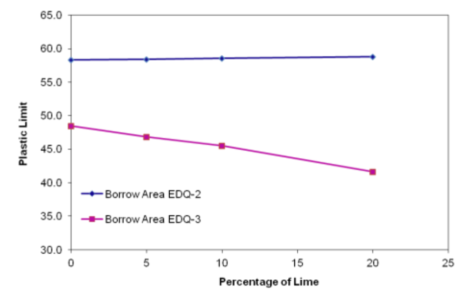
The grain size analysis of the river sand indicates that the tested soil sample possesses predominantly fine sand sizes followed by coarse sand sizes and silt sizes and non plasticity characteristics and falls under SM (Silty Sand) group of Bureau of Indian Standard soil classification system.

Tests on soils with additives

Atterberg Limits: The graphical representation of the percentage of lime added to the borrow area materials and the liquid limit and plastic limit values are presented in Figure 5.



Liquid Limit



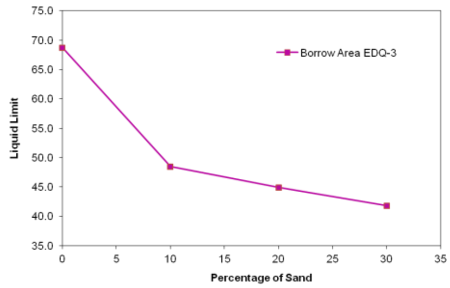
Plastic Limit

Figure 5 Borrow Area Materials with Lime

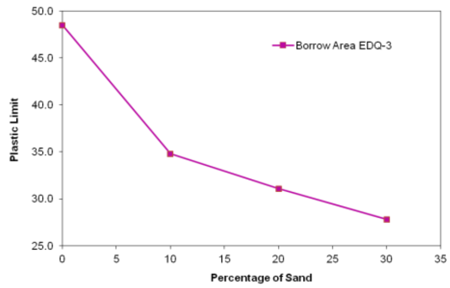
It is observed from Figure 5 that the addition of lime to the borrow area material EDQ-2 has very little effect only on the limit values of the tested soil sample. Whereas, the addition of lime to the borrow area material EDQ-3 has significant effect on the limit values of the tested soil sample. As the percentage of lime content increases, the liquid limit values of the soil sample decreases.

The borrow area materials from the Borrow Area EDQ-3 was blended with river sand collected from the project site and the graphical representation of the percentage of sand added to the borrow area materials and the liquid limit and plastic limit values are presented in Figure 6.

From Figure 6, it is noted that the addition of 10% sand to the soil samples from Borrow Area EDQ-3 has significant effect on the Atterberg Limits and the values decreases remarkably. But further increase of sand to 20% and 30%, do not have much effect on the plasticity index.



Liquid Limit



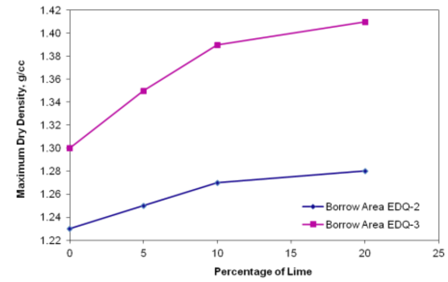
Plastic Limit

Figure 6 Borrow Area Materials with Sand

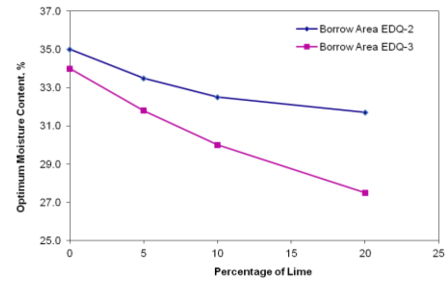
An attempt was made to mix 10 % of lime and 10% of river sand to the soil samples from Borrow Area EDQ-3 in order to the effect on the behaviour of the blended material. The mixture has significant effect on the Liquid Limit, Plastic Limit and Plasticity Index of the tested material and the values decreased from 68.7 to 49.8, 48.5 to 38.8 and 20.2 to 11.0 respectively.

Standard Proctor Compaction: The graphical representation of the percentage of lime added to the borrow area materials and the maximum dry density and optimum moisture content values are presented in Figure 7.

It is observed that the addition of lime to the borrow area material EDQ-2 do not have any significant effect on the maximum dry density and optimum moisture content values of the tested soil samples. Whereas, the addition of lime to the borrow area material EDQ-3 has significant effect on the maximum dry density and optimum moisture content values of the tested soil samples. As the percentage of lime content increases, the maximum dry density values of the soil samples increases and the optimum moisture content values decreases.



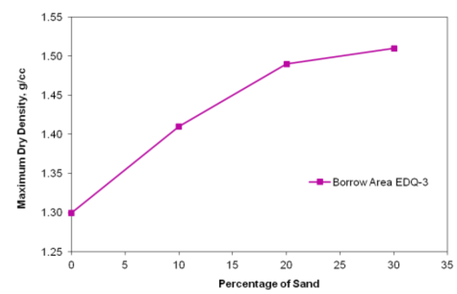
Maximum Dry Density



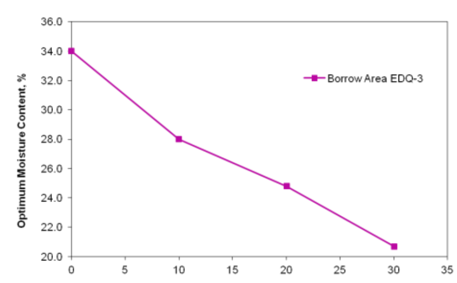
Optimum Moisture Content

Figure 7 Borrow Area Materials with Lime

The borrow area materials from the Borrow Area EDQ-3 was blended with river sand collected from the project site and the graphical representation of the percentage of sand added to the borrow area materials and the maximum dry density and optimum moisture content values are presented in Figure 8.



Maximum Dry Density



Optimum Moisture Content

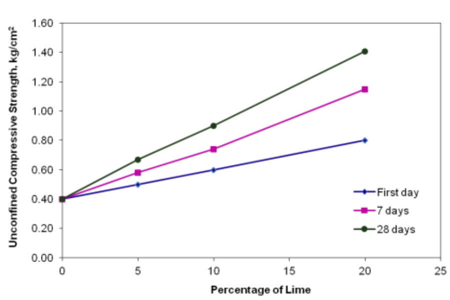
Figure 8 Borrow Area Materials with Sand

It is observed that the addition of sand to the soil samples from Borrow Area EDQ-3 has significant effect on the maximum dry density and the values increases remarkably. The maximum dry density values increases from 1.30 g/cc to 1.41 g/cc, 1.49 g/cc and 1.51 g/cc with the addition of 10%, 20% and 30% sand to the soil samples from Borrow Area EDQ-3.

The addition of 10% sand to the soil samples from Borrow Area EDQ-3 has significant effect on optimum moisture content and the values decreases remarkably. But further increase in the percentage of sand to 20% and 30%, do not have much effect. The optimum moisture content values decreases from 34.0% to 28.0% when 10% of sand is added and further the values decreases to 24.8% and 20.7% when 20% and 30% of sand is added to the borrow area material from the Borrow Area EDQ-3.

An attempt was made to mix 10 % of lime and 10% of river sand to the soil samples from Borrow Area EDQ-3 in order to the effect on the behaviour of the blended material. The mixture has significant effect on the Maximum Dry Density and Optimum Moisture Content of the tested material. The Maximum Dry Density values increased from decreased from 1.30 g/cc to 1.44 g/cc and the Optimum Moisture Content values decreased from 34.0% to 26.0% respectively.

Unconfined *Compressive Strength Test:* The graphical representation of the percentage of lime added to the borrow area materials from Borrow Area EDQ-2 and Borrow Area EDQ-3 and the unconfined compressive strength values are presented in Figure 9.



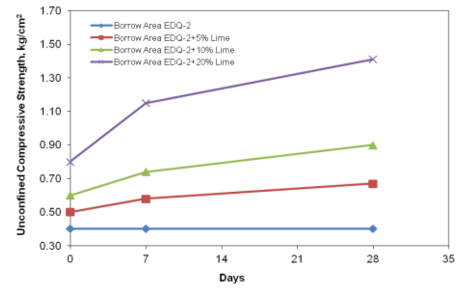


Figure 9 UCS (Borrow Area EDQ-2 with Lime)

It may be seen that as the percentage of lime content increases, the unconfined compressive strength of the soil samples linearly increases and the percentage of improvement is higher when 20% of lime is added.

It may be seen from the Figure 10 that the addition of lime to the borrow area material EDQ-3 has significant effect on the unconfined compressive strength of the tested soil samples. As the percentage of lime content increases, the unconfined compressive strength of the soil samples increases and the percentage of improvement is higher when 5% of lime is added. Further addition of quick lime to the soil samples from Borrow Area EDQ-3 has very little improvement in the strength of the blended soil.

It may be seen from the Figure 11 that the addition of sand to the borrow area material EDQ-3 has significant effect on the unconfined compressive strength of the tested soil samples. As the percentage of sand increases, the unconfined compressive strength of the soil samples increases linearly upto 20% of sand is added. Further addition of 30% sand to the borrow area material increases the unconfined compressive strength but less comparatively.

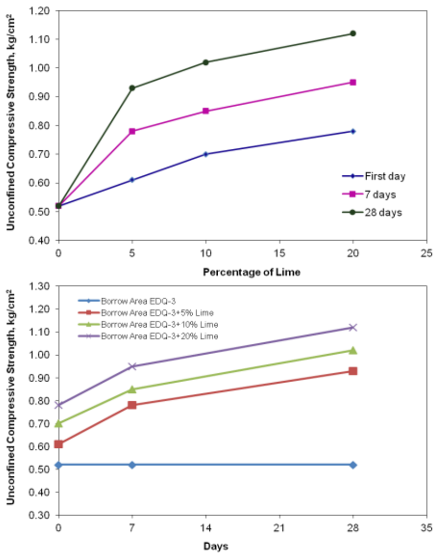


Figure 10 UCS (Borrow Area EDQ-3 with Lime)

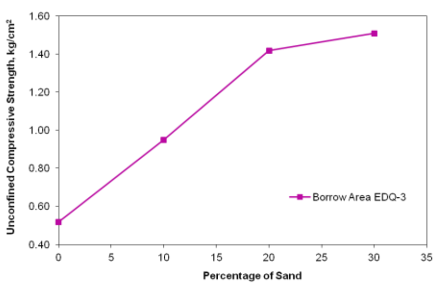


Figure 11 UCS (Borrow Area EDQ-3 with Sand)

An attempt was made to mix 10 % of lime and 10% of river sand to the soil samples from Borrow Area EDQ-3 in order to the effect on the behaviour of the blended material. The mixture has significant effect on the unconfined compressive strength of the tested material. The 7 days unconfined compressive strength increased from 0.52 kg/cm^2 to 0.96 kg/cm^2 and the 28 days unconfined compressive strength is 1.06 kg/cm^2.

Laboratory Permeability Test: The borrow area soil samples from Borrow Area EDQ-3 and the blended borrow area materials with this borrow area and sand were subjected to the laboratory permeability test using falling head method. The coefficient of permeability, k values of the tested blended borrow area materials from Borrow area EDQ-3 and various proportions of river sand vary from no flow to 2.53×10^{-6} cm/sec. The results of laboratory permeability test indicate that all the tested soil samples possess impervious drainage characteristics. It is observed that the increase in the percentage of river sand added to the borrow area materials increases the drainage characteristics of the material.

DISCUSSIONS

Effect of lime blended to the borrow area materials:

- The Liquid Limit, Plastic Limit and Plasticity Index decrease with increase in percentage of lime.
- The Maximum Dry Density increases with increase in percentage of lime.
- The Optimum Moisture Content decreases with increase in percentage of lime.
- The Unconfined Compressive Strength increases with increase in percentage of lime.
- The addition of lime to the borrow area material EDQ-2 has significant effect on the unconfined compressive strength of the tested soil samples.
- As the percentage of lime content increases, the unconfined compressive strength of the soil samples linearly increases and the percentage of improvement is higher when 20% of lime is added.
- The addition of lime to the borrow area material EDQ-3 has significant effect on the unconfined compressive strength of the tested soil samples.
- As the percentage of lime content increases, the unconfined compressive strength of the soil samples increases and the percentage of improvement is higher when 5% of lime is added. Further addition of quick lime to the soil samples from Borrow Area EDQ-3 has very little improvement in the strength of the blended soil.

Effect of river sand blended to the borrow area materials:

- The addition of 10% sand to the soil samples from Borrow Area EDQ-3 has significant effect on the Atterberg Limits and the values decreases remarkably. But further increase of sand to 20% and 30%, do not have much effect on the plasticity index.

- The addition of sand to the soil samples from Borrow Area EDQ-3 has significant effect on the maximum dry density and the values increases remarkably.
- The maximum dry density values increases from 1.30 g/cc to 1.41 g/cc, 1.49 g/cc and 1.51 g/cc with the addition of 10%, 20% and 30% sand to the soil samples from Borrow Area EDQ-3.
- The addition of 10% sand to the soil samples from Borrow Area EDQ-3 has significant effect on optimum moisture content and the values decreases remarkably. But further increase in the percentage of sand to 20% and 30%, do not have much effect.
- The optimum moisture content values decreases from 34.0% to 28.0% when 10% of sand is added and further the values decreases to 24.8% and 20.7% when 20% and 30% of sand is added to the borrow area material from the Borrow Area EDQ-3.
- The addition of sand to the borrow area material EDQ-3 has significant effect on the unconfined compressive strength of the tested soil samples. As the percentage of sand increases, the unconfined compressive strength of the soil samples increases linearly upto 20% of sand is added. Further addition of 30% sand to the borrow area material increases the unconfined compressive strength but less comparatively.
- The coefficient of permeability, k values of the tested blended borrow area materials from Borrow area EDQ-3 and various proportions of river sand vary from no flow to 2.53×10^{-6} cm/sec.
- The results of laboratory permeability test indicate that all the tested soil samples possess impervious drainage characteristics.
- The increase in the percentage of river sand added to the borrow area materials increases the drainage characteristics of the material.

Addition of 20% quick lime to the borrow area materials decreases the plasticity index by 30 - 45%. Further addition of lime may decrease the plasticity index of the soil samples and the value may be found to be less than 10 also which is not desirable.

Addition of 20% quick lime to the borrow area materials increases the Maximum Dry Density by 4 – 9% and decreases Optimum Moisture Content by 9 – 20% only.

Addition of 10 – 30% sand to the borrow area materials from Borrow Area EDQ-3 decreases plasticity index by 30 - 35%. Further addition of sand may decrease the plasticity index of the soil samples and the value may be found to be less than 10 also which is not desirable.

Addition of 30% sand to the borrow area materials from Borrow Area EDQ-3 increases the Maximum Dry Density by 16% and decreases Optimum Moisture Content by 40%.

CONCLUSIONS

The organic soils are capable of achieving poor compaction characteristics and are likely to exhibit high compressibility and poor shear strength characteristics when compacted and saturated. Organic soils have poor workability as construction material and are least desirable for use as core materials and embankment materials.

From the geotechnical investigations carried out on the blended borrow area materials it is revealed that:

- Addition of quick lime is not effective for improving the compaction characteristics of the borrow area materials from Borrow Area EDQ-2 and Borrow Area EDQ-3.
- Addition of river sand is very effective for improving the compaction characteristics of the borrow area materials from the Borrow Area EDQ-3.

- Mixing of sand and coarser fraction up to 30% by dry weight is likely to be beneficial and will provide strength and stability to the structure.
- Sands and coarser fractions are used for improving the density of the borrow area materials even up to 40% to provide stability and strength to the structures provided plasticity, permeability and other desired parameters are not compromised.

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