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GROUND IMPROVEMENT TECHNIQUES TO ENHANCE THE BEARING CAPACITY OF WEAK SOIL USING BENTONITE

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Abstract

The constructional activities in the coastal areas often demand deep foundations because of the poor engineering properties and the related problems arising from weak soil at shallow depths. The very low bearing capacity of the foundation bed causes shear failure and excessive settlements. Further, the high-water table and limited depth of the top sandy layer in these areas restrict the depth of foundation thereby further reducing the safe bearing capacity. The weak soils such as loose sand with extendable depths requires high precautions and improvement before using as bearing layer. Enhancing the bearing capacity along with reduction of the expected settlement is the main measures for the improvement efficiency. The aim of this study is to investigate the improvement of bearing capacity for loose sandy soil by mixing with different bentonite ratio. Experimental work was conducted for this purpose using a laboratory physical model. The laboratory tests such as compaction, direct shear, and consolidation tests were performed to measure the mechanical characteristics of the stabilized materials. The experimental analysis shown that the addition of 25% of bentonite to the low bearing capacity soil performed as good and increased two times the SBC than the soil sample.

Keyword: Bearing capacity, Bentonite, liquid limit, Plastic limit, Compaction

1.INTRODUCTION

In soil engineering, for any land-based structure, the foundation is very important and has to be strong to support the entire structure. In order for the foundation to be strong, the soil around it plays a very critical role. So, to work with soils, we need to have proper knowledge about their properties and factors that affect their behaviour. The process of soil stabilisation helps to achieve the desired properties in the soil needed for the construction work.

The shortage of petroleum and aggregates, forces the engineers to look at means to enhance soil other than replacing the poor soil at the construction site. Soil stabilisation was used, but due to the use of obsolete methods and the absence of proper technique, soil stabilisation lost favour. In recent times, with the increase in demand for infrastructure, raw materials, and fuel, soil stabilisation has started to take on a new shape. A popular and cost-effective method for soil improvement was identified due to more research work. In this work, soil stabilisation has been done with the help of randomly distributed plastic waste and bitumen material to improve the shear strength parameters, compaction effect, and bearing strength of black cotton soil [1].

The social, economic, cultural, and industrial growth of any country depends heavily on its infrastructure. The only mode that might provide the most service to everyone is transportation by highways and railways. As a result of the development of infrastructure like highways, buildings, railways, and different structures in recent years, the sufficiency of fine-quality land for construction has increased and forces to use poor quality soil for construction. Hence, the ground improvement techniques play a vital role in the construction works. By using ground improvement techniques, the strength of the soil will increase, its compressibility will reduce, and the performance underneath applied loading will be enhanced. Transportation is one of the fields that plays a very important role in the development of a country. There are several suggestions for transportation like roads, railways, airways [2].

Ground improvement is the modification of existing site foundation soils to provide better performance under design and/or operational loading conditions which are increasingly used for new projects to allow the utilisation of sites with poor subsurface conditions. Previously, these poor soils were considered economically unjustifiable or technically not feasible and were often replaced with an engineered fill or the location of the project changed. In short, ground improvement is executed to increase the bearing capacity, reduce the magnitude of settlements and the time in which they occur, retard seepage, accelerate the rate at which drainage occurs, increase the stability of slopes, mitigate liquefaction potential, etc.,[3].

To make use of loose sandy soil as a base course for foundation structures, it must be improved with some suitable admixtures. The bentonite material is widely used for many purposes in relation to civil engineering works improvement materials and stabilisation for weak soil, filler of voids to improve the permeability, strength, density, and filler materials for slurry cutoff walls. Bentonite is an effective material for enhancing the plasticity properties of soil. It increases the liquid limit, the plastic limit, the maximum dry density, and the optimum moisture content [4, 5 6].

Compared to regular sandy soil, grouted soil has a higher bearing ratio, good plastic limit, compaction, and liquid limit. Sodium silicate is less expensive than other grouting materials and has the ability to effectively raise the natural characteristics of soil [7]. Due to shortage of high-quality soil for fills and embankments, employing plastic bottles as a soil stabilizer is a cost-effective and profitable use of them [8]. The strength of the grouted medium is unaffected when admixtures such as aluminium sulphate, tartaric acid, and sodium silicate are used with cement [9,10, 11]. A very efficient method for fortifying the soil and increasing its bearing capacity is soil stabilization with geocell as reinforcement [12].

In this current study the experiments such as moisture content, sieve analysis, plasticity index, liquid limit, specific gravity and compaction properties of soil was carried out. Bentonite was mixed with different proportions to the loose soil and its compaction properties was studied.

2. MATERIALS AND METHODOLOGY

The soil at different depth was collected for the experiment and the samples were shown in figure.1

Figure 1. Dry and Wet soil samples

- Bentonite is a type of clay that has the ability to swell and gel when dispersed in water and is used in construction, mainly in excavation and foundation works as shown in fig 2.
- Bentonite is of great commercial importance, possessing innate bleaching properties like Fuller's earth; hence, it is also known as bleaching clay. Containing more than 85% clay mineral, montmorillonite, it is considered to be high-plastic clay.

The safe bearing capacity of the soil samples were found out by conducting the various tests such as moisture content, sieve analysis for coarse grain soil, plastic limit, liquid limit, specific gravity and compaction properties.

Figure 2 Soil samples with Bentonite powder

2.1 Moisture Content of Soil Samples

The moisture content of soil is described as the ratio of the mass of water held in the soil to the dry soil. The difference between the soil moisture content before and after drying is used to determine the water content. Moisture content of the soil was carried out for sample I and II and calculated from its initial weight and final weight after 24 hours it was kept in hot air oven.

2.2 Sieve Analysis for Coarse Grain Soil Samples

The sieve analysis determines the gradation (the distribution of aggregate particles, by size, within a given sample) in order to determine compliance with design, production control requirements, and verification specifications. Sieve analysis is a method that is used to determine the grain size distribution of soils that are greater than 0.075 mm in diameter. It is usually performed for sand and gravel but cannot be used as the sole method for determining the grain size distribution of finer soil. Sieve analysis was carried out by using mechanical sieve shaker.

2.3 Plastic Limit of Soil

The plastic limit of soil is the moisture content at which soil begins to behave as a plastic material. At this water content (plastic limit), the soil will crumble when rolled into threads of 3.2 mm (1/8 in) in diameter. The plastic state is the condition at which the soil can be remoulded into any shape without any development or cracks. Semi-solid is the state at which the soil can be, but only with the development of cracks. In the solid state, the soil cannot be remoulded at all; if it were, the soil specimen would get broken.

2.4 Liquid Limit of Soil

The liquid limit is the water content at which the soil starts to behave as a liquid. The liquid limit is measured by placing a clay sample in a standard cup and making a separation (groove) using a spatula. The cup is dropped until the separation vanishes. The water content of the soil is obtained from this sample. If the natural moisture content of soil is higher than the liquid limit, the soil can be considered soft, and if the moisture content is lower than the liquid limit, the soil is brittle and stiffer. The value of the liquid limit is used in the classification of the soil and gives an idea about the plasticity of the soil. The liquid limit is the water content at which a part of soil, cut by a groove of standard dimensions, will flow together for a distance of 1.25 cm under an impact of 25 blows in a standard liquid limit apparatus.

2.5 Specific Gravity by Pycnometer

The pycnometer is used for the determination of the specific gravity of soil particles in both fine-grained and coarse-grained soils. The determination of the specific gravity of the soil will help in the calculation of the void ratio, degree of saturation, and other different soil properties.

2.6 Compaction Properties by Standard Proctor Test

A compaction test of soil is carried out using Proctor's test to understand the compaction characteristics of different soils with changes in moisture content. Compaction of soil is the optimal moisture content at which a given soil type becomes most dense and achieves its maximum dry density by removing air voids.

2.7 Safe bearing capacity

A safe bearing capacity field test is done to check the capacity of the soil to withstand loads. The maximum load per unit area that the soil can bear without any displacement or settlement is designated as the safe bearing capacity of the soil.

3.RESULTS AND DISCUSSIONS

The safe bearing capacity of the soil samples were found out from the various experimental test results such as moisture content, sieve analysis, plastic limit and liquid limit, specific gravity and compaction test. The Compaction curve was drawn from the maximum dry density and moisture content of the soil samples.
The experimental study shown that the moisture content of the soil samples 1 and 2 were 15.15% and 11.11% respectively. The moisture goes up when the bearing capacity of the soil goes down. This occurs because the soil grains carry less weight when the pores among them are filled with water as water is nearly incompressible.

From the sieve analysis carried out for the samples, cumulative percentage of retained soil and percentage of soil passing were calculated. These values were plotted in the graph and determined the uniformity co-efficient and fineness modulus of the samples.
Fineness modulus of soil sample 1 is 2.44% and the fineness modulus of soil sample 2 is 2.90%. shown in figures 3 and 4.

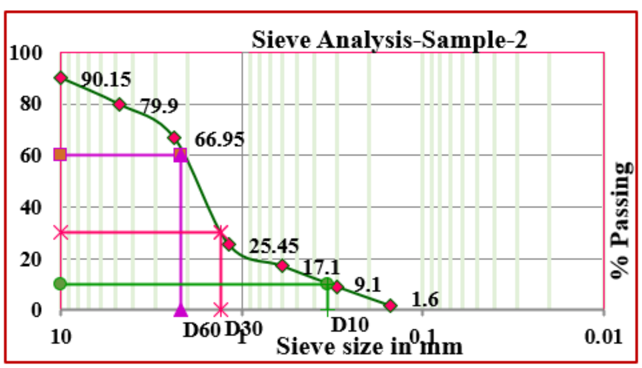

Figure 3 Sieve analysis of the sample 1

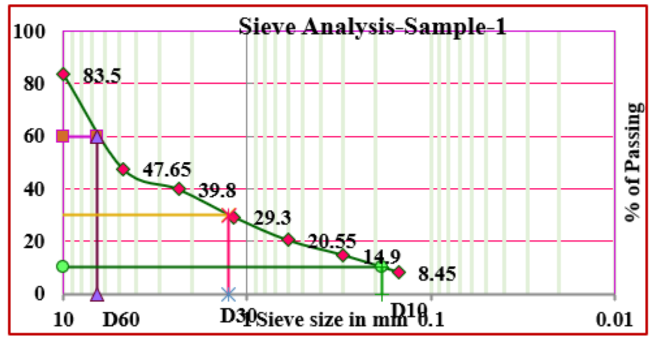

Figure 4 Sieve analysis of the sample 1

The plastic limit test can be conducted to determine the cohesion of the soil. According to the cohesion, the soil type is determined whether it is clayey soil or not. From the experimental results the Plastic limit of soil samples was calculated and the values were 57.1% and zero for the Sample 1 and 2. Liquid limit of the soil sample is done with three trials and the values noted were used to calculate the liquid limits and the values were 17.05% and 15.23% for sample 1 and 2. Number of blows and percentage of water content were plotted in the graph and shown in figures 5 and 6.

The percentage of specific gravity can be used to deduce soil strength. From the experimental results, the specific gravity of the soil sample-1 is 1.73 and sample-2 is 2.04.

Maximum dry density of soil sample 1is 1.75g/cc and optimum moisture content of the soil sample 1 is 10%. For soil sample 2, Maximum dry density is 1.2 g/cc and optimum moisture content is 9.8% shown in figure 7 and 8.

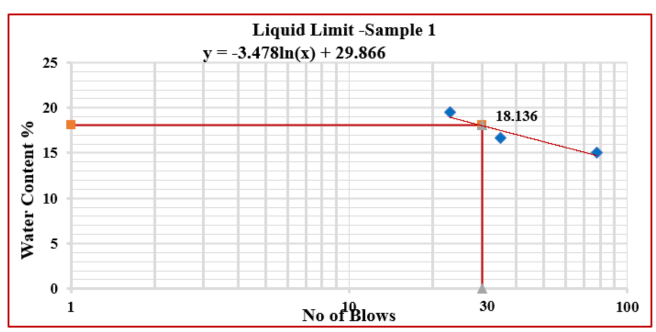

Figure 5 Liquid Limit of the sample 1

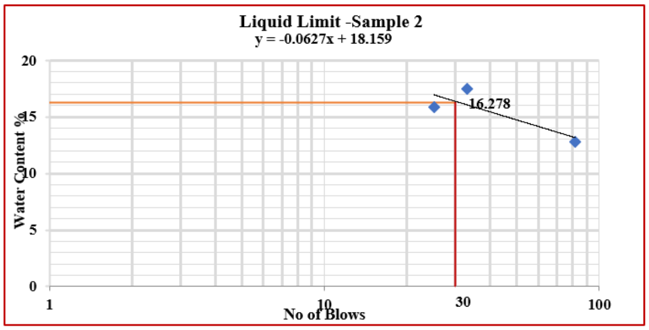

Figure 6 Liquid Limit of the sample 2

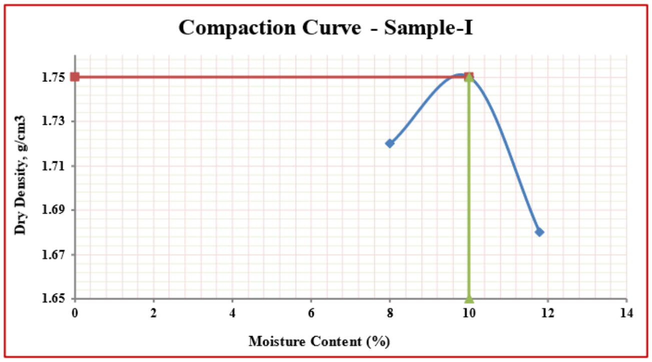

Figure 7 Compaction curve of sample 1

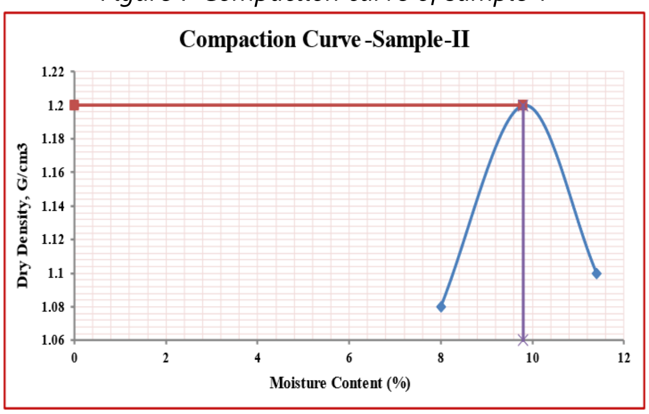

Figure 8 Compaction curve of sample 2

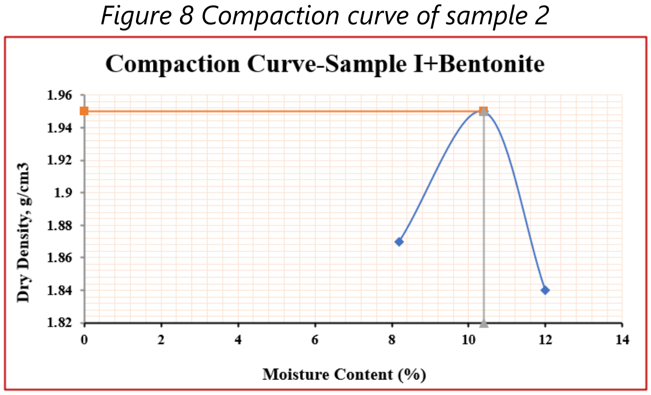

Figure 9 Compaction curve + bentonite sample 1

The SBC of soil sample 1and II is 11.96 kN/m2 and 5.74 kN/m2.and classified as loose soil according to SBC value. Safe bearing capacity of the samples I and II are low.

Proctor compaction test (using bentonite powder)

After using bentonite, Maximum dry density of soil sample 1 is 1.95g/cc and optimum moisture content of the soil sample 1 is 10.4%. For soil sample 2, Maximum dry density is 1.83 g/cc and optimum moisture content is 10.4% shown in figures 9 and 10. The Safe Bearing Capacity of the soil is 24.37 KN/M2 according to the table, it is considered as loose sand.

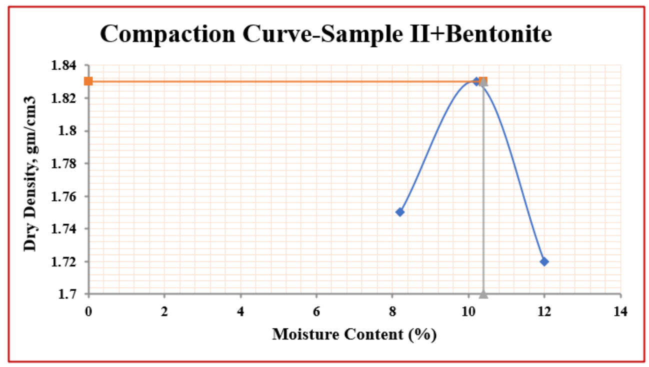

Figure 10 Compaction curve + bentonite sample 2

4. CONCLUSIONS

This study concluded that there is an essential need to study the technique of removal, addition and replacement for improving soil behaviour taking into consideration of geotechnical requirements, cost to achieve the optimum replacement layer thickness and the most suitable material corresponding to minimum total cost of foundation works.

The density or unit weight of the soil can be increased by the rearrangement of the soil particles by the mechanical effort using the compaction and fine soil particles such as Bentonite to fill the voids in the poorly graded loose soil. The cohesion of the loose soil can be improved by using the Bentonite as a percentage of soil mass. The plasticity of the soil can be improved by using the Bentonites. The increasing in the percent of Bentonite, the cohesion (C) of soil increases Compared to other ratios employed in this study, adding 25% of

Bentonite to the loose, poorly graded soil produces superior outcomes. Therefore, the addition of 25% of bentonite improves the safe
bearing capacity of loose soil for improving its strength.

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