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Variation in Coefficient of Consolidation and Modulus of Elasticity Values of Clayey Soil Randomly Reinforced with Sand

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Abstract:
In India about one-fifth of the area is covered by clayey soil. This soil behaves like a soft soil under wet/saturated condition. There are a number of methods available to stabilize this type of soft soil such as soil replacement, sand cushion, cohesive non-,swelling layer, mechanical, chemical and thermal stabilization, soil reinforcement, etc. Recently, the use of reinforced soil has been developed to improve the behavior of soil in geotechnical engineering. Reinforced soil can be obtained by either incorporating continuous reinforcement inclusions within the soil mass in a defined pattern or mixing discrete fibers randomly within a soil fill (i.e. randomly reinforced soils). Sand is a common reinforcing material that can be easily applied to the soil. It is a proven fact that geotechnical properties of soil can be improved by adding sand into the soil.
In the current study, the behavior of clayey soil randomly reinforced with sand have been evaluated through laboratory tests. A series of one dimensional laboratory consolidation tests and triaxial shear tests were conducted to study the changes in coefficient of consolidation and modulus of elasticity of clayey soil reinforced with sand. The results indicate improvements in the values of coefficient of consolidation and modulus of elasticity.

Keywords: *Clayey soil, consolidation, coefficient of consolidation, modulus of elasticity, settlement, triaxial shear test*

1. Introduction

In India about one-fifth of the area is covered by clayey soil. The soil behaves like a soft soil under wet/saturated condition. There are a number of methods available to stabilize expansive soil such as soil replacement, sand cushion, cohesive non swelling layer, mechanical, chemical and thermal stabilization, soil reinforcement, etc. In soil replacement, the poor soil is excavated up to certain depth and is replaced by good soil which is not expansive. This is possible only where the non problematic soil is easily and cheaply available nearby. Removal and replacement is generally practical only above ground water table. Earthwork operation is difficult when the soil is wet or submerged. In method sand cushion, the entire depth of the clayey soil stratum or a part thereof is removed and replaced with the sand; compacted to the desired density and thickness, the ill effects of poor soil are minimized. The basic advantage of the sand cushion method is its ability to adapt itself to volume changes in the soil. However, the sand cushion method has several limitations, particularly when it is adopted in deep strata. The high permeability of sand creates conditions conducive to easy ingress and accumulation of water from surface runoff.

Replacement by soils with relatively impervious material may, to a great extent offset the disadvantages of sand cushion method. The method proposed by Katti (1979) uses cohesive non-swelling (CNS) layer to reduce the effects of swelling. The heave of expansive soil underlying a CNS layer reduces exponentially with increase in thickness of the CNS layer and attains a value of no heave around a depth of 1m.The shear strength of the underlying expansive soil at the interface and below increases with the thickness of CNS layer. The method is for construction of canals in clayey soil area. Mechanical stabilization is the process of improving the properties of soil by changing its gradation. Two or more type of natural soils is mixed to obtain composite material which has better strength. Generally coarse grained materials such as sand, crusher dust, moorum (a soil predominantly coarse grained, red in color having fine silt and clay) etc are mixed with fine grained soil. Mixing of lime, cement, fly ash and combination of these in small quantities changes the physicochemical characteristics around and inside of clay particles and the soil gives improved behavior and the process is referred to as chemical stabilization. Reinforcing the soil is usually accomplished by one of the following methods: Soil nailing, Soil anchoring, Micro piles, Stone columns and Fiber reinforcement. Using fibers like jute fabrics, coir ropes, rubber tire chips, waste plastics, synthetic fibres, etc one can stabilize the expansive soils. The soil and its reinforcing elements act in combination and increase the shear strength of the soil mass, reduce its settlement under the load, and improve its resistance to liquefaction. Reinforcement using sand is a commonly used method and it can be effectively applied in places where sand is easily available.

Alappuzha, the place from where the clayey soil for the study was selected, is a district in Kerala, India. Geographically the place is below sea level and the soil collected from the region is of poor load carrying capacity and sand can be easily obtained from the place and the method can be effectively applied at this place.

2. Materials Used

2.1. Clay

Clayey soil for the current study is collected from Kuttanadu region in Alappuzha district, Kerala. The properties of the clay are listed below in table 1.

Moisture content	123.8%
Field density	1.42 g/cm^3
Liquid limit	91%
Plastic limit	40%
Shrinkage limit	20.32
plasticity index	51
Specific gravity	2.49
Maximum dry density	1.31 g/cm^3
Optimum moisture content	25.27%
Modulus of elasticity	753.5 kN/m²
Unconfined compressive strength	18.16kN/m²
Angle of internal friction	3˚
Coefficient of consolidation	1.360 mm²/min
Compression index	0.7
Void ratio	1.98

Table 1: Properties of Clay

2.2. Sand

Locally available sand, passing through 425µ IS sieve was used for conducting the experiment. The properties of the sand are given in table 2.

Density	1.24 g/cc
Cohesion	0
Friction	26˚
Specific gravity	2.66
Uniformity coefficient	2.41
Coefficient of curvature	1.33
Percentage of coarse fraction	98.434

Table 2: Properties of Sand

3. Experimental Program

Sand is randomly reinforced with clayey soil to improve the bearing capacity and to reduce settlement. The behavior of clayey soils after reinforcing with sand have to be analyzed for ensuring the stability and safe functioning of clayey soil. In the present work, the behavior of clayey soil reinforced using sand has been evaluated through laboratory tests. Here a series of laboratory tests are to be conducted to understand the variation in coefficient of consolidation and modulus of elasticity values. Clayey soil samples were reinforced with 4%, 8%, 12%, 16% and 20% of sand content and each sample is taken for study.

3.1. Laboratory Test Procedure: Consolidation Test

After reinforcing the clayey soil with sand, the variation in coefficient of consolidation was determined by conducting the one dimensional consolidation test in the laboratory. Procedure for test is as per IS 2720 Part 15. The tests were performed in the consolidation test apparatus by means of a loading frame. The pressures applied were varied by varying the weights used for the tests. Standard pressures were 0.125 kg/cm^2, 0.25 kg/cm^2, 0.5 kg/cm^2, 1kg/cm^2, 2 kg/cm^2 etc. Pressure applied depends on the area of the specimen. For different pressures, dial gauge readings were noted for different time intervals (0, 0.25, 1, 2.25, 4, 6.25, 9, 12.25, 16, 20.25, 25, 36, 49, 64, 81, 100, 121, 144, 169, 196, 225 etc minutes). Graph for dial gauge reading vs. time is plotted. From this graph coefficient of consolidation is determined by root time method.

3.2. Laboratory Test Procedure: Triaxial Shear Test

The shear parameters on reinforced soft clay specimens compacted to their corresponding field density were determined as per IS 2720 Part 13- 1986[13]. Test specimens were prepared corresponding to their field density. These specimens were of size 37.5 mm in diameter and sheared at a rate of 1.25 mm/minute. From stress-strain curve. The modulus of elasticity of clay was determined and the variation of value was studied.

4. Results and Discussions

The values of coefficient of consolidation (c_v) and modulus of elasticity were obtained from one dimensional laboratory consolidation test and triaxial shear test respectively. Variation in coefficient of consolidation with percentage of sand in clay specimen for each normal stress values are shown in the Figure 1, Figure 2 and Figure 3.

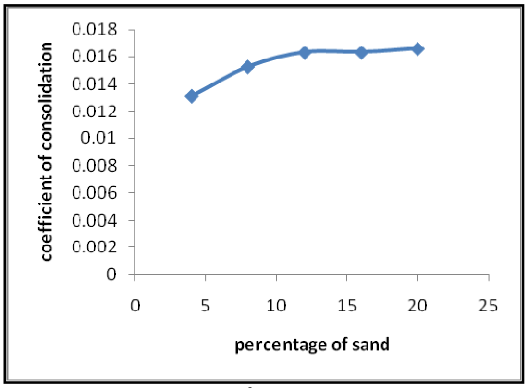

Figure 1: variation of coefficient of consolidation (cm^2/min) with percentage sand for normal stress 0.5 kg/cm^2.

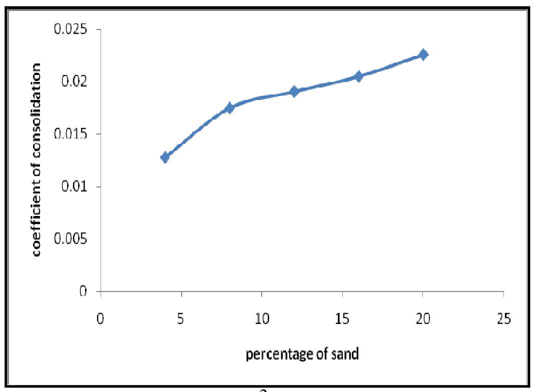

Figure 2: variation of coefficient of consolidation (cm^2/min) with percentage sand for normal stress 1 kg/cm^2.

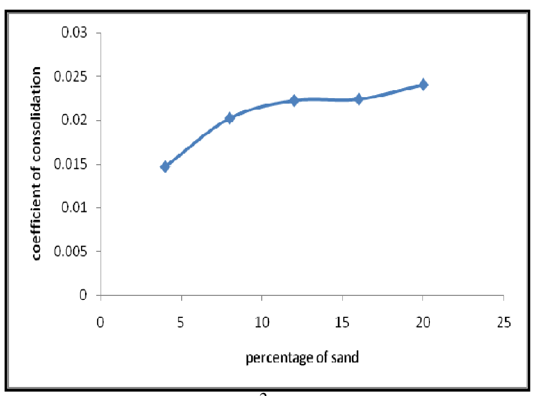

Figure 3: variation of coefficient of consolidation (cm^2/min) with percentage sand for normal stress 2 kg/cm^2.

Variation in coefficient of consolidation with different normal stress values is shown in Figure 4.

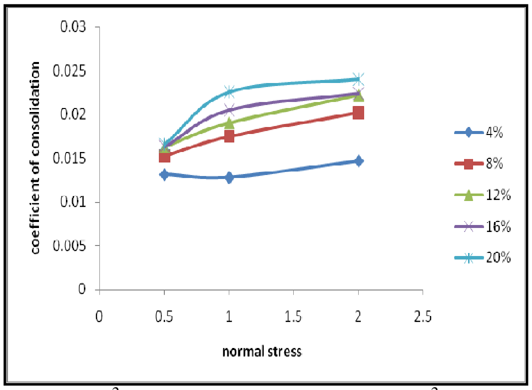

Figure 4: variation of coefficient of consolidation (cm^2/min) with normal stress (kg/ cm^2) for varying percentages of sand in clayey samples.

Change in t_{90} values with normal stress for different percentages of sand in clayey sample is given in Figure 5.

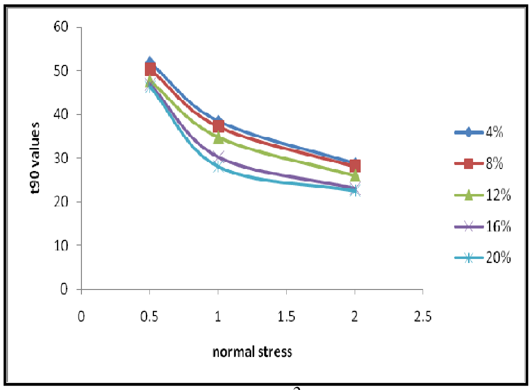

Figure 5: variation of t_{90} (min) with normal stress (kg/ cm^2) for varying percentages of sand in clayey samples.

Triaxial shear tests are conducted on clayey samples with varying percentages of sand. Stress strain curves are drawn for each clayey sample and modulus of elasticity was calculated from the graph. Variation in the value of modullus of elasticity with the percentage increase of sand content in clay is shown in the Figure 6.

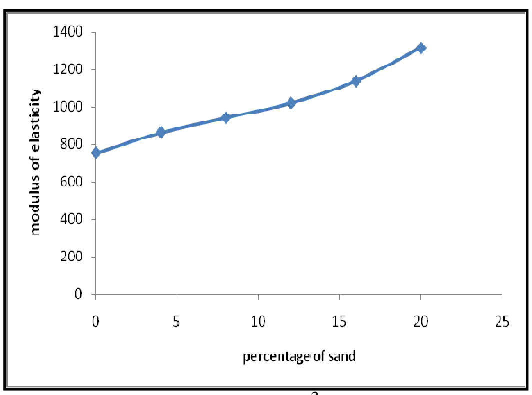

Figure 6: Variation of modulus of elasticity (kN/m^2) with percentage of sand in clay sample.

5. Conclusions

Consolidation tests and triaxial shear tests were conducted on clayey soil collected from Kuttanadu, a local region in Kerala, after they are reinforcing with sand which is also a locally available material. Sand content was varied as 4%, 8%, 12%, 16%, 20% in each sample. C_v (coefficient of consolidation) and t_{90} values were calculated from consolidation test data. It is observed that c_v values increased with the increase in the normal stress value as well as with the percentage of sand reinforcement in clayey samples taken for study. Time required for the completion of consolidation settlement of clayey soil diminishes when the percentage of sand reinforcement in the sample increases. In the study, t_{90} values of soil samples decreased with increase in percentage of sand as well as with the increase in normal stress. From this we can conclude, the provision of sand reinforcement can accelerate the settlement process and the time required for consolidation is reduced. The triaxial shear test results indicates increase in the modulus of elasticity values. From this it is well understood that, the stiffness of the soil can be increased by introducing sand as a reinforcing material into the clayey sample. Because of the above reasons, it can be conclude that sand can be effectively used for improving the settlement and strength characteristics of clay where sand is easily available and the clayey soli with higher percentages of sand can be improved faster by using other ground improvement techniques like preloading, sand compaction piles, stone columns etc. The presence of sand content causes reduction in settlement and increases the strength.

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