Study on Improvement of Problematic Soil with Sand Layer

P. Dayakar*, K. Venkat Raman*, K.V.B. Raju**

*Department of Civil Engineering, Bharath University, Chennai, Tamilnadu, India.

** Director, GITAM University, Bengaluru Campus, Bengaluru, Karnataka, India.

ABSTRACT

Homogeneous soils are very rarely found in nature. In most of the cases, the foundations are located on a natural stratified soil deposits exhibiting varying strength characteristics. A very common kind of such of soil deposit is a soil layer of finite thickness overlying a thick stratum of another soil; of different strength characteristics than overlying soil. In this study the improvement in the load bearing capacity of such soil deposit is examined by conducting a plate load test on the layered soil systems. The Plate load tests are conducted on sand layers of varying thickness of 5cm, 10cm, and 15cm by replacing the problematic soil placed in a tank of size 30cm x 30 cm x 30 cm. It has been observed that when 50% of sand layer is placed over the 50% of clay, the improvement in the load bearing capacity is more under loaded region for 15cm thick sand layer as compared with 5cm, 10cm thick sand layer.

.

1.0 INTRODUCTION

Meyerhof (1963) proposed modified bearing capacity factors to develop a methodology of estimation of ultimate bearing capacity of a stratified soil system with a stronger sand layer overlying a clayey layer. Meyerhof and Hanna (1978) developed a generalized theory to estimate the ultimate bearing capacity of shallow rough continuous foundation supported by a strong soil layer underlain by a weaker soil layer. Madhav and Sharma (1991) studied the bearing capacity of soft-clay deposits overlain by a stiffer layer or crust. Wang and Carter (2001) performed large deformation problem to simulate the penetration of strip and circular footings resting on the surface of two layered clay media, where the overlying layer was considered to be stronger than the underlying one. Shiau, Lyamin and Sloan (2003) developed rigorous plasticity solutions for the ultimate bearing capacity of a strip footing resting on a sand layer over the clay layer by applying advanced upper and lower bound techniques. It has been observed that most of the researches carried out regarding the layered soil system are from the viewpoint of the bearing capacity of the layered soil system. Very few researches have been carried out to study the settlement characteristics of a foundation placed on the layered soil system. The present study has been undertaken to determine the improvement in the load carrying capacity of a plate placed on a layered soil system with granular layers placed on top of the clay soil. The Plate load tests are conducted on sand layers of varying thickness of 5cm, 10cm, and 15cm by replacing the problematic soil placed in a tank of size 30cm x 30 cm x 30 cm.

2. 0 MATERIALS

Soil samples are collected from Mudichur Road, near Tambaram. The organic matter like tree root and pieces of bark are removed from the samples. The index properties of the virgin soils are shown in table 1.

Table 1 Properties of Clay

Description	Values
Specific gravity	2.63
Liquid limit, %	76
Plastic Limit, %	21
Plasticity Index, %	55
Maximum dry density, g/cc	1.39
Optimum moisture content, %	25
IS Classification	CH

Locally available river sand is used to form the layer on the problematic soil. The grain size distribution curve of the same is shown in fig. 1. The properties of the sand are shown in Table 2. The soil sample is prepared in such a way that the coarser particles more than 4.75mm size are removed.

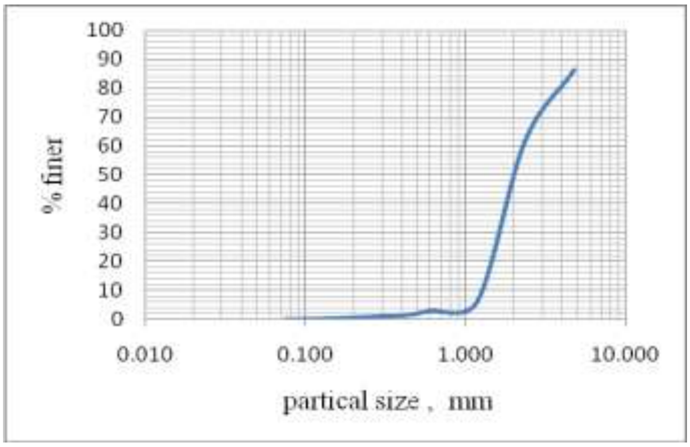

Fig. 1 Grain size distribution of sand

Table 2 Properties of Sand

Description	Values
Specific gravity	2.82
Optimum moisture content (%)	10
Maximum dry density, g/cc	1.62
Coefficient of Curvature, Cc	0.31
Coefficient of Uniformity, Cu	3.2
IS Classification	SP

2.0 METHODOLOGY

Plate load test

The test setup consists of a loading frame, base for placing the soil tank and loading jack as shown in fig. 2. The layered soil system is placed in an acrylic tank (30cm x 30cm x 30cm) is placed in the loading setup and the axial load is applied to the soil system through the center of the plate, via the load cell and the loading frame. The axial displacements are measured by the Linear Variable Displacement Transformer (LVDT), which is mounted on the plate. A steel plate of size 10cm x 10cm is placed on the top of the soil layer at the center. A steel spherical ball is placed over the centre of the loading test plate. A load cell as shown in Fig. 3 is placed over the spherical steel ball, in order to take the readings of the load applied. From this test the load intensity and the corresponding settlement values are recorded using a Data Logger.

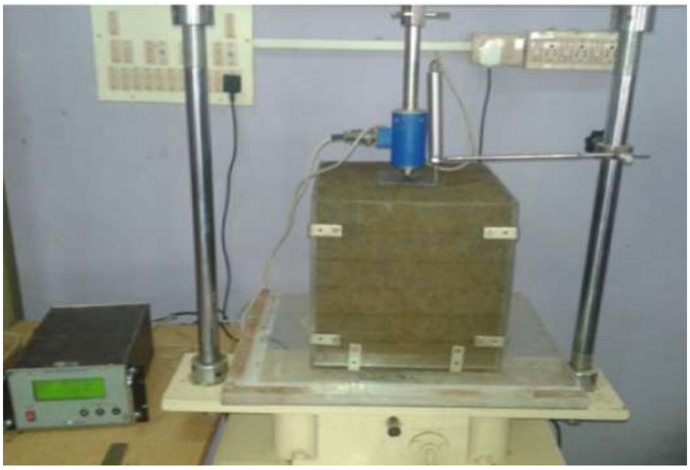

Fig. 2 Plate Load Test setup

Fig. 3 Load cell with LVDT

A series of plate load tests are conducted on different layered soil systems namely, plate load test on clay alone, plate load test on sand alone, plate load test on 5cm sand layer over clay, plate load test on 10cm sand layer over clay and plate load test on 15cm sand layer over clay. The schematic representation of the layered soil system is shown in fig. 4.

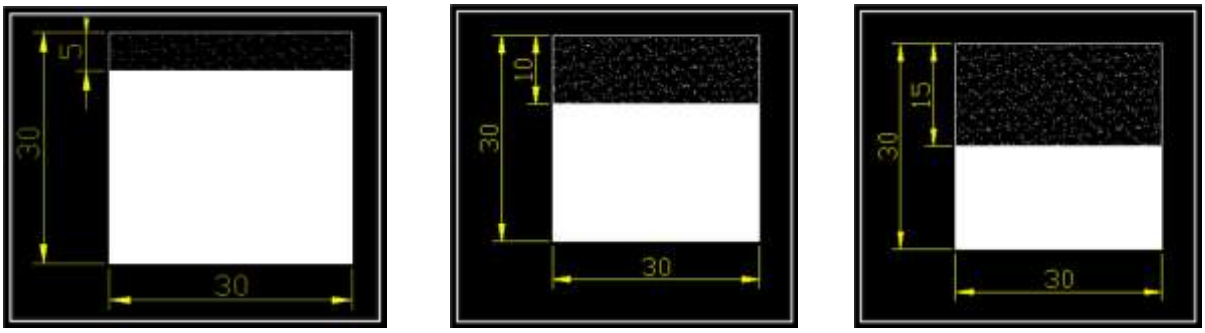

Fig. 4 Schematic representation of the layered soil system

Load test on clay alone

As a first case the tank is filled with full clay alone in layers of thickness 2.5cm and compacted to achieve the required relative density. This procedure is continued to reach to a total thickness of 30 cm, by compacting manually in layers so as to achieve a dry density of 95% of the maximum dry density (1.39 g/cc) using manual wooden hammer having 50 mm diameter. Care is taken to maintain the moisture content of the soil system less than the optimum moisture content (25%). Then the prepared soil system is placed in the loading frame and the load is applied in small increments until failure is reached.

Load test on Sand alone

To compare the increase in the load carrying capacity of the layered soil system, in the second case sand alone is placed fully in the tank in layers where each has a thickness of 2.5cm and compacted to achieve the required relative density. The sand is compacted so as to reach 95% of the maximum dry density (1.62 g/cc) at a moisture content less than optimum moisture content (10%). Care is taken to place the prepared soil system in the loading frame without any disturbance. The load is applied in small increments until failure is reached.

Load test on clay with 5cm thick sand layer

In this case to improve the load carrying capacity of the problematic soil, clay is filled in the tank for a depth of 25cm only. The same procedure is followed as in the first case while filling the clay soil. Over this layer sand is placed for a thickness of 5cm, compacting the same to maintain the maximum dry density of 1.62 g/cc at an optimum moisture content of 10%, using manual wooden hammer. Compaction was carried out very carefully so that the prepared clay did not get disturbed. The load is then applied in small increments until the failure.

Load test on clay with 10cm thick sand layer

In continuation with the previous case, a sand layer of 10cm placed over the clay layer of 20cm. Care is taken to maintain the respective maximum dry densities in the two layers namely sand and clay by following the same procedure as in the previous cases. Fig. 5 shows the typical plate load test setup for the layered soil system.

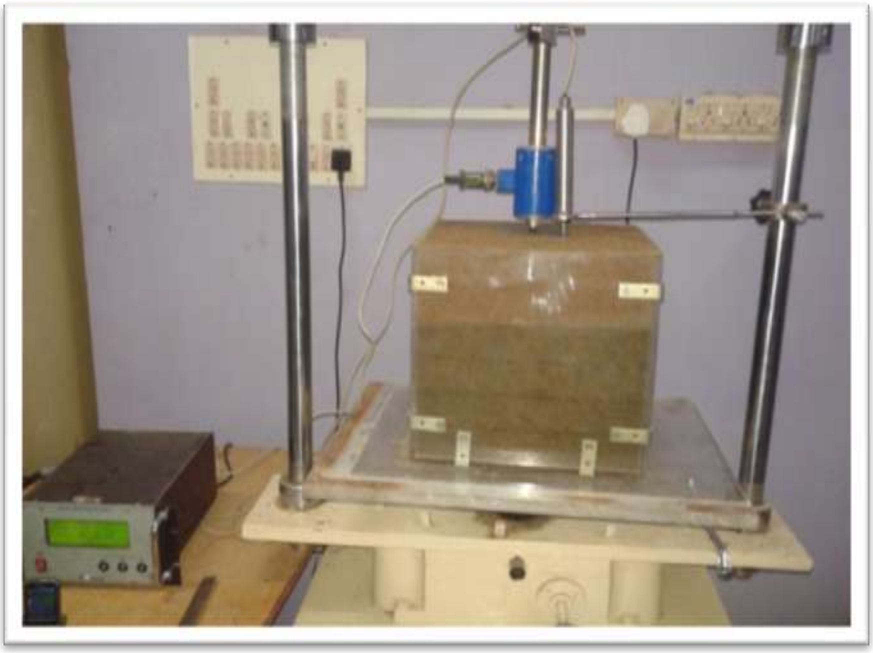

Fig 5 Test setup on Layer soil system with 10 cm thick sand layer on clay

Load test on clay with 15cm thick sand layer

As a last case 50% of the clay is replaced by sand layer and load test is conducted on this soil system. i.e. 15cm sand layer is placed over 15cm clay layer. In this case also care is taken to maintain the respective maximum dry densities, by following the same procedure as mentioned in the previous cases. Then the load settlement test is conducted by applying the load gradually until the failure.

3.0 RESULTS AND DISCUSSIONS

From the plate load test conducted on various cases of layered soil systems, the settlement corresponding to the load intensity are tabulated in table 3. The load–settlement relationship for the clay alone and sand alone are shown in fig 6. From the graph it may be understood that the clay is able to take more for when compared to the sand. But the ultimate load is 365 kPa for sand as compared to 325 kPa of the Clay.

Table 3 Comparison of Load Intensity of the Layered Soil system

Load Intensity kPa					Displacement in mm				
Full clay	**Full sand**	**5 cm Sand layer**	**10 cm Sand layer**	**15 cm Sand layer**	**Full clay**	**Full sand**	**5 cm Sand layer**	**10 cm Sand layer**	**15 cm Sand layer**
0	0	0	0	0	0	0	0	0	0
30	75	20	30	100	0.07	1.25	0.17	0.15	0.89
60	150	40	60	200	0.13	1.42	0.69	0.29	1.15
90	175	60	90	300	0.22	1.46	0.81	0.53	1.46
120	200	80	120	350	0.32	1.48	0.9	0.96	7.12
150	275	100	150	376	0.78	1.42	0.99	1.55	12.93
180	325	120	180		1.35	8.81	1.09	2.05	
210	350	140	210		1.55	12.93	1.21	3.27	
240	365	160	240		1.81	13.55	1.34	4.03	
270		180	278		1.93		1.52	6.02	
310		200			3.45		1.77		
317		217			4.53		2.41		
320					5.17				
325					5.95				

From the values tabulated in table 3, a plot between load intensity and settlement is made for the three cases namely 5cm sand layer over clay, 10cm sand layer over clay and 15cm sand layer over clay as shown in fig. 7.

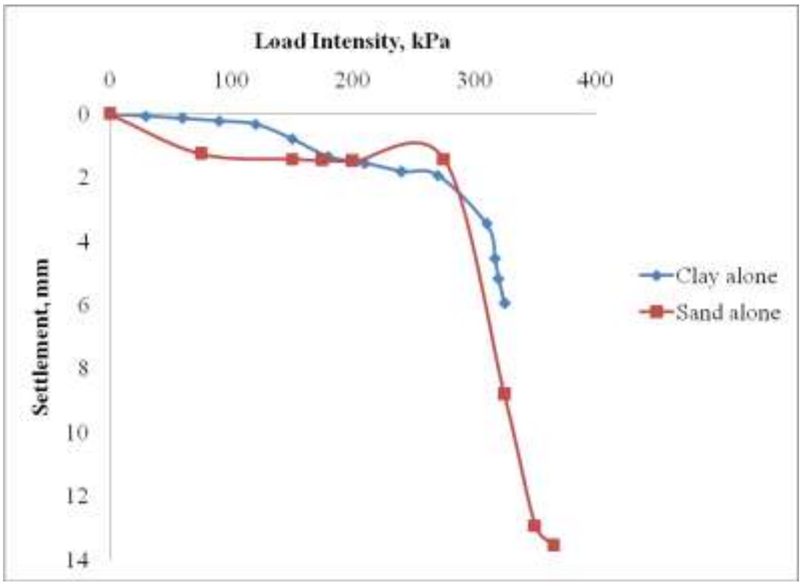

Fig 6 Plot between Load intensity and settlement for Clay and Sand alone

It is observed that the 15cm sand layer over the clay soil system is able to take more loads, when compared to the other two systems of layered soil.

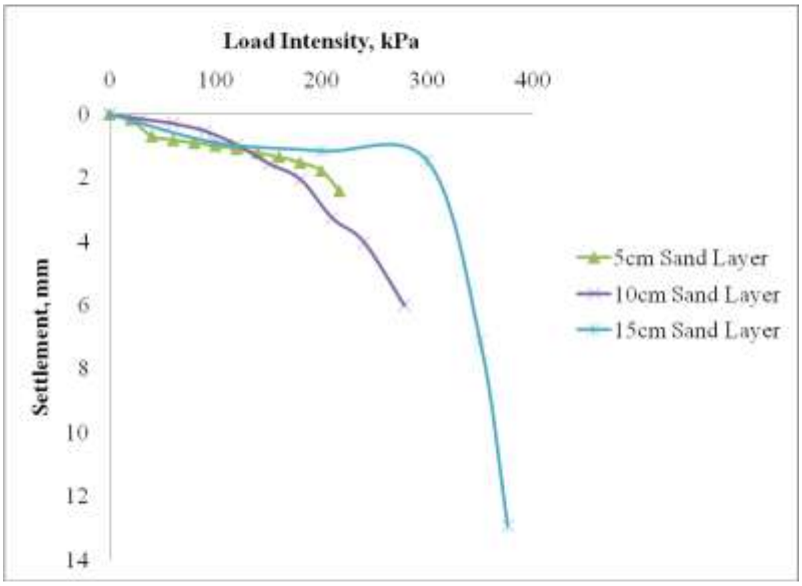

Fig 7 Plot between Load intensity and settlement for Layered soil system

The comparison of load intensity and settlement for all the cases of layered soil systems are shown in fig 8. From the graph it can be seen that the sand layer of 5cm and 10cm do not improve the load carrying capacity, when compared to the virgin clay. Whereas the 50% replacement, i.e. 15cm sand layer over the clay has markedly improved the load carrying capacity of the layered soil system.

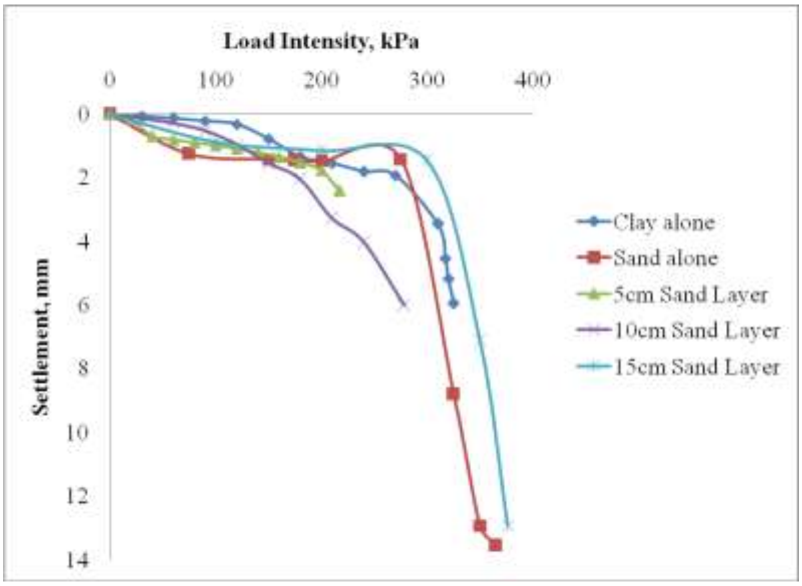

Fig 8 Comparison of Load intensity and settlement for all the cases

Comparison of Ultimate Bearing Capacity

The Ultimate Bearing capacity of the layered soil system is determined for the various cases by the method of tangents. Using that method the determined values are tabulated in table 4.

Table 4 Ultimate Bearing Capacity

	Full clay	5 cm Sand layer	10 cm Sand layer	15 cm Sand layer
Ultimate Bearing Capacity	308	191	205	320
Increase / Decrease ,%		-37.99	-33.44	3.90

The increase or decrease in the Ultimate Bearing Capacity when compared with load intensity of clay alone is determined and shown as percentage in the table 4. Fig 9 shows the graphical representation of the comparison of the ultimate bearing capacity.

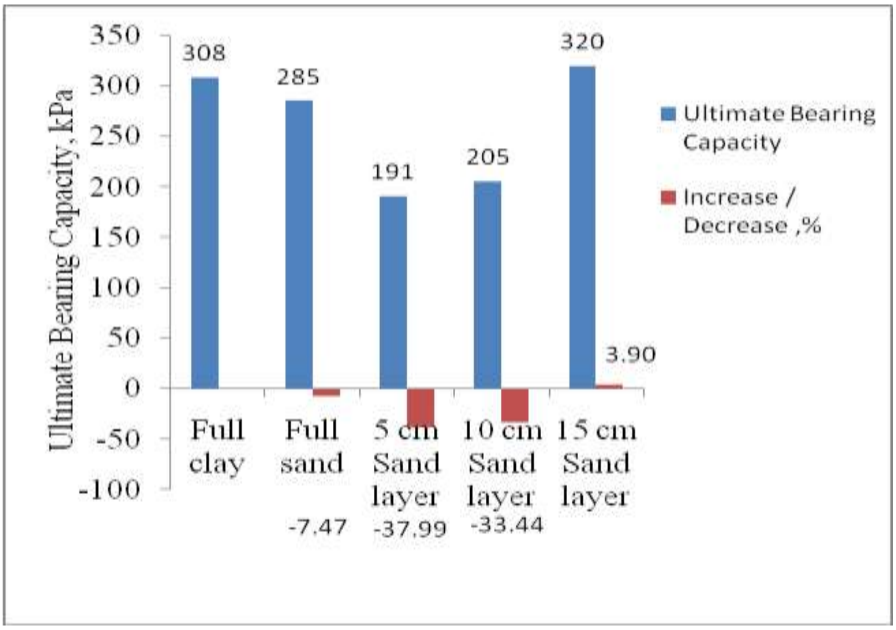

Fig 9 Comparison of Ultimate Bearing Capacity

From the results it can be seen that there is a decrease of 7.47% in the case of full sand and decrease of 37.99% in the case of 5cm sand layer over the clay layer. Whereas there is a decrement of 33.44% in the case of 10cm sand layer. Finally 3.90% increase in the case of 15 cm sand layer over the clay layer. The reason for decrease in load intensity in the case of 5cm and 10 cm sand layer may be attributed to the thickness of the sand layer when compared to thickness of the clay layer.

5.0 CONCLUSION

A comparison of the Load intensity of various cases of layered soil system is made, to understand the behaviour of improvement in the load carrying capacity of problematic soil with a sand layer on the problematic soil. From the results and discussions it may be concluded that 50% replacement of problematic soil with granular soil will improve the load carrying capacity.

ACKNOWLEDGEMENTS

The authors acknowledge the Under graduate students, Kumar Abhishek, Md Nausad Alam, Tabish Ahmed and the technical staff of the Soil Mechanics Laboratory, Department of Civil Engineering for their support in testing of this research project.

REFERENCE

1. Ullagaddi P.B. & Nagaraj T.K : "Experimental study on load settlement Behavior of sand Foundation" , Indian Geotecnnical Conférence -2010, Geotrendz. December 16-18, (2010), IGS Mumbai Chapter & IIT Bombay.

2. Meyerhof, G. G. and Hanna, A. M. (1978). Ultimate Bearing capacity of foundations on layered soils under inclined loads. Canadian Geotechnical journal, 15(4), pp. 565-572.

3. Sona Vasudev & Unikrishnan. N: "Behaviour of raft foundation in homogeneous and layered sand "College of Engineering Thiruvananthapuram, Kerala.

4. Nilo Cesar Consoli, Francisco Dalla Rosa, Anderson Fonini, "Plate Load Tests on Cemented Soil Layers Overlaying Weaker Soil", J. Geotech. Geoenviron. Eng. 2009.135:1846-1856.

5. Deb, K., Dey, A., and Chandra, S. (2007) "Modeling of layered soil system" First Indian Young Geotechnical Engineers Conference (FIYGEC), Jawaharlal Nehru Technological University, College of Engineering, Hyderabad, pp. 50-55.

6. I.S: 1888 – 1982 Indian Standard Method of Load Test on Soils (Second Revision)

7. I.S**:** 2720 (Part 3/Set 2)-1980 Methods of test for soils: Part 3 Determination of specific gravity, Section 2, Fine, medium and coarse grained soils.

8. I.S : 2720 (Part 4)-1985 Methods of test for soils: Part 4 Grain size analysis.