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Comparative Study of Bearing Capacity of Clay Mixed with Sand Proportions

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Abstract. Clayey soils have low strength, high compressibility and may have swelling characteristics also. Shear strength of soil depends upon cohesive and friction parameters, which is governed by the equation $\tau = c + \sigma \tan\phi$. In this investigation, a locally available clay soil is used and sand fraction is added in different proportions to increase the friction component of the shear strength. The sand percentages vary and the shear strength values have been estimated using Triaxial test. It is known that increase in the ϕ value increases, the bearing capacity of soil increases. Modal footing tests are carried out on soil beds made of different percentages of clay mixed with sand. The experimental values of bearing capacity have been compared with the theoretical values. Bearing capacity of clay soil beds mixed with sand in different proportions increases with increase in the sand proportions. Experimental bearing capacity values are higher when compared with the theoretical bearing capacity values.

Keywords: Bearing capacity, Cohesion, Angle of internal friction.

1 Introduction

Clayey soils have low strength, high compressibility and may have swelling characteristics. Bearing capacity of the cohesive soils is less.
According to IS: 6403-1981, the equation of net ultimate bearing capacity for local shear failure is,

$$q_{nu} = \frac{2}{3} c N'_c s_c d_c i_c + q (N'_q - 1) s_q d_q i_q + 0.5 B \gamma N'_\gamma s_\gamma d_\gamma i_\gamma W' \quad (1)$$

where, N'_c, N'_q, N'_γ are bearing capacity factors which depends on the internal friction between the soil particles.

As the friction between the soil particles increases, the bearing capacity of soil increases. Cohesionless soil (sand) is used for introducing friction to the cohesive(clay) soil. Whereas, cohesive soils exhibit only cohesion between the particles. Upon addition of cohesion less soil to the cohesive soil, the bearing capacity is increased due to internal friction between the soil by the sand. comparison between the values of bearing capacity of Field and Laboratory Tests has been studied by Azad Abbas Ahmad et al. [2009].

2 Methodology

Model tests were performed in a circular tank of diameter 60cm and height 70cm. The test setup (Fig. 1) consists of following components: (a) Test tank, (b) Circular footing, (c) Foundation medium i.e. clay mixed with sand proportion, (d) Arrangement for application of loads and (e) Measuring devices (Three dial gauges). Plate load tests were performed on circular footing 125mm in diameter and 13mm thick.

Fig. 1. Schematic of test setup

A total of 5 tests were performed on the model circular footing which is subjected to axial load. Test data was retrieved using a proving ring and three number of dial gauges. The clay and sand in proportions i.e. 10, 20, 30, 40% are compacted at maximum dry density and optimum moisture content in 5 layers of uniform thickness up to height of 70cm respectively. The properties of clay and sand used for this study are given in Table 1, Table 2. It is classified as Highly Compressible clay (CH) and Poorly graded sand (SP) as per IS classification system.

Table 1. Properties of clay

Test conducted	Test result
Free Swell Index	100%
Specific Gravity	2.72
Consistency Limits	LL = 52.4%, PL = 24.38%, PI = 28.02 %
Standard Proctor Test	OMC = 20% MDD = 1.605 g/cc
Unconfined Compressive Strength, s_u	86 kN/m^2
Soil Classification	CH

Table 2. Properties of sand.

Test conducted	Test result
Specific Gravity	2.65
Particle Size Distribution	C_u = 3.63 C_c = 0.85
Relative Density	Max = 1.85 g/cc Min = 1.57 g/cc
Soil Classification	SP

2.1 Experimental Procedure

Clay mixed with Sand proportions was filled in five layers with equal thickness. The total weights of clay mixed with sand proportions used for maximum dry densi- ties of standard proctor test results were shown in Table 3. Thus, the weight of clay, clay mixed with sand proportions (10%, 20%, 30%, 40%) for each layer was 63.53kg, 65.31kg, 67.84kg, 69.86kg and 72.43 kg respectively. The dry soil weight for each layer of 0.14m is taken and mixed thoroughly with required amount water that is obtained from the OMC. For example, taking 90% clay with 10% sand: for every 100kgs of soil, 90kgs of clay and 10kgs of sand is used. Then the soil is compacted to required density by a rammer weighing 8.9kgs with 30 number of blows for each layer. This process is continued until the top layer is filled. The top surface was levelled and the circular footing is placed on the top layer below the hydraulic jack at centre and levelling is done to maintain it horizontally. The OMC values are checked using the bins. Three dial gauges were placed on circular footing (Fig. 1)

Table 3. Clay and sand proportions with MDD and OMC.

Soil	Max. dry density (10^3 kg/m^3)	OMC (%)	Total weight of soil (kg)
Clay	1.605	20	317.65
90% clay with 10% sand	1.65	18.5	326.55
80% clay with 20% sand	1.712	17	339.2
70% clay with 30% sand	1.765	15.7	349.3
60% clay with 40% sand	1.83	14	362.15

3 Results and Discussions

3.1 Triaxial test results

Figure 2 depicts stress, versus strain, at different confining pressures of a clay sample at maximum dry density and optimum moisture content. The Mohr circles were drawn from this stress strain curves. The c and ϕ values for the clay sample are 60 kN/m^2 and 10˚. c and ϕ values for clay mixed with sand proportions are shown in Table 4.

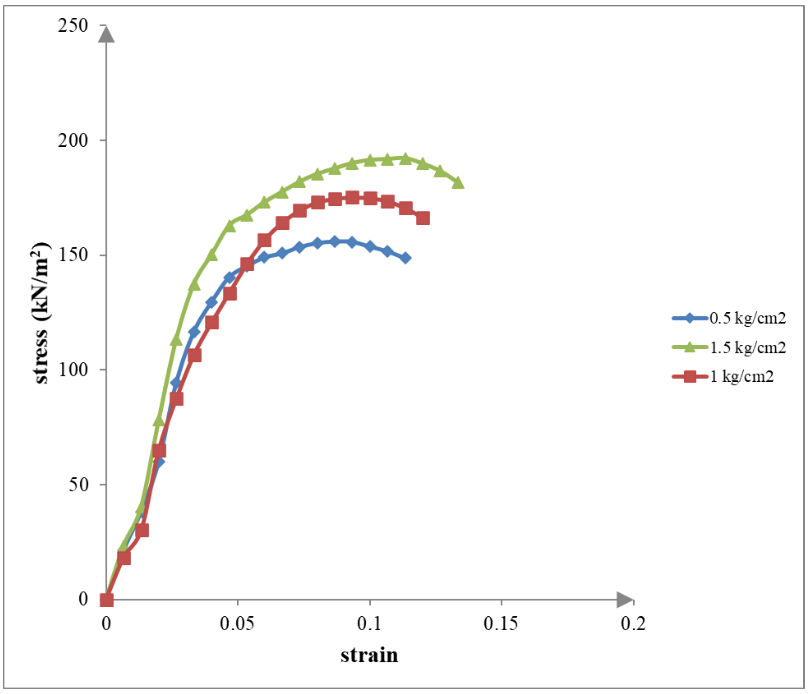

Fig. 2. Triaxial test for clay sampl

Table 4. c and ϕ values for clay mixed with sand proportions.

Soil	C (kN/m^2)	ϕ
Clay sample	60	10˚
90% clay with 10% sand	58	12.5˚
80% clay with 20% sand	55	16˚
70% clay with 30% sand	54	21˚
60% clay with 40% sand	51	26˚

Figure 3 compares c, ϕ with % sand proportions. It can be observed that c and ϕ values for clay, clay mixed with 10, 20, 30, 40% sand proportions are 60, 58, 55, 54, 51kN/m^2 and 10˚, 12.5˚, 16˚, 21˚, 26˚ respectively. Angle of internal friction is increased with an increase in % sand mixed with clay but it is vice-versa in case of cohesion with an increase in % sand with clay. There is a Cumulative decrease in c values for clay mixed with 10, 20, 30, 40% sand proportions when compared with clay are 3.33%, 8.33%, 10%, 15% respectively and a cumulative increase in ϕ values for clay mixed with 10%, 20%, 30%, 40% sand proportions when compared with clay is 25%, 61%, 110%, 160% respectively.

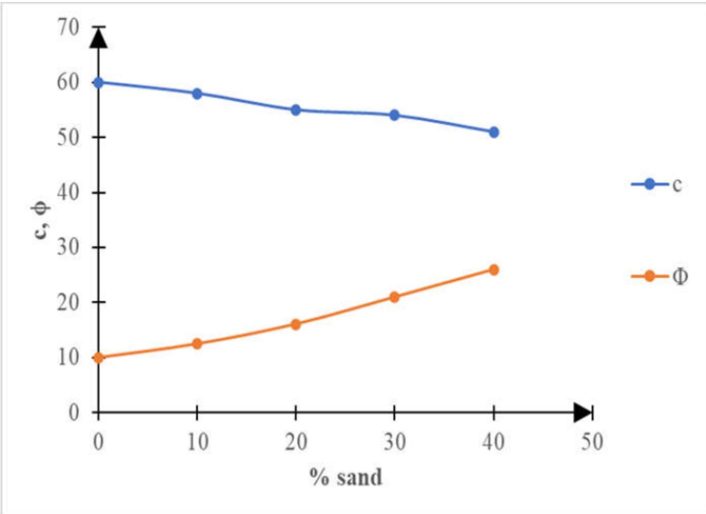

Fig. 3. Comparison of c, ϕ with % sand

From the Equation 1, the computed allowable bearing capacity values for clay sample, clay mixed with sand proportions (10%, 20%, 30%, 40%) are 123.59, 130.13,139.64, 166.074, 196.79 kN/m^2 respectively.

3.2 Plate Load test

Figure 4 depicts the load versus settlement for Comparison of bearing capacity of clay, clay mixed with sand proportions. Bearing capacity results are increased with addition of sand to the clay. It is observed that the bearing capacity results for clay, clay mixed with (10%, 20%, 30%, 40%) sand proportions are 287.7, 339.6, 415.6, 467.5, 491.5kN/m^2 respectively. There is cumulative increase in bearing capacity of clay mixed with 10%, 20%, 30%, 40% sand proportions, when compared to clay is 18.03%, 44.45%, 62.49%, 70.83% respectively. The

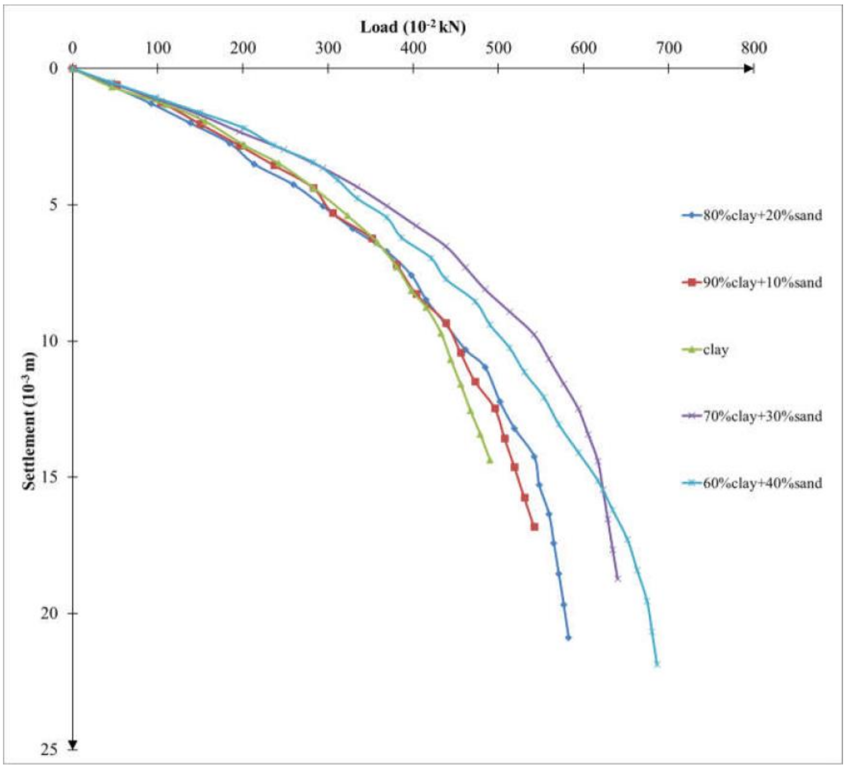

Fig. 4. Comparison of bearing capacity of clay mixed with sand proportions

The experimental bearing capacity values are higher when compared to theoretical bearing capacity values. The experimental bearing capacity values for clay, clay mixed sand proportions (10%, 20%, 30%, 40%) are 2.32, 2.60, 2.97, 2.81, 2.49 times more than theoretical baring capacity values respectively. τ is a function of c and ϕ from the equation $\tau = C + \sigma \tan\phi$. So, bearing capacity is increased with increase in angle of internal friction. Bearing capacity is increased due to increase in angle of internal friction, even though there is a decrease in cohesion of soil. Size of the footing also effects the bearing capacity, but this study is limited to constant diameter of the plate. Bearing capacity of the soil also depends on the gradation of the sand mixed with clay. The sand used in this study is "Poorly Graded Sand". In case of well graded sand we can observe more increase in the friction angle.

3.3 Free swell index

Figure 5 is a plot between % free swell and % sand. It is observed that for both passing 425µ and clay with locally available sand, the %free swell values of clay, clay with 10, 20, 30, 40% sand proportions are 100, 88.88, 75, 62.5, 55.55 % and 100, 75, 62.5, 56.25, 50% respectively. Free swell index is decreased with increase in sand proportion

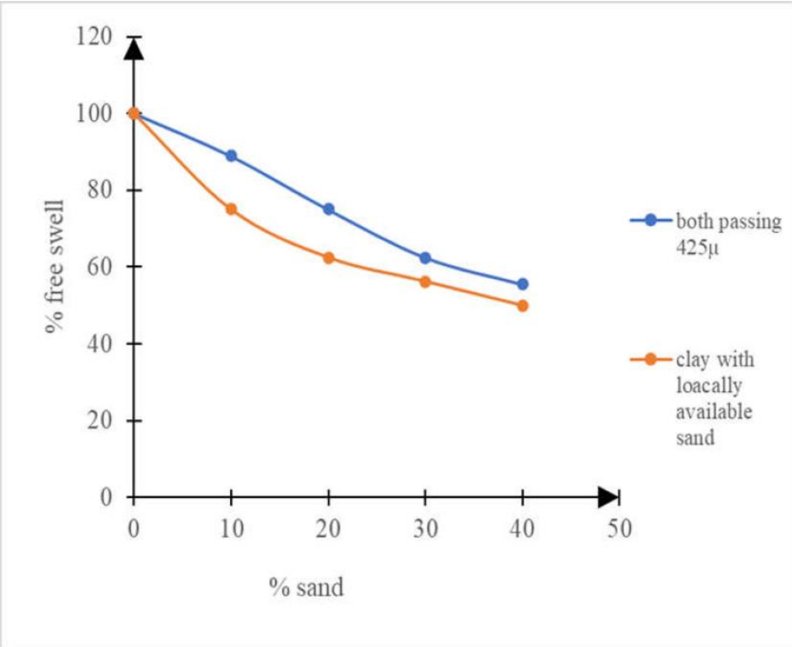

Fig. 5. Comparison of free swell with %sand

4 Conclusions

1. Bearing capacity is increased with increase in sand proportions to the clay.
2. Allowable bearing capacity of Model test is increased when compared to the theoretical allowable bearing capacity.
3. Maximum dry density is increased with the increase in sand proportions to the clay.
4. Free swell index decreases upon addition of sand to the clay.

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