EFFECT OF ROUGHNESS OF RECTANGULAR COMBINED FOOTING BASED ON ULTIMATE BEARING CAPACITY AND SETTLEMENT IN COHESIVE SOIL

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Abstract - *The decreasing availability of good construction sites has led to increased use of sites with marginal soil properties. In view of these criteria the requirement for onsite treatment of foundation to improve its bearing capacity and reducing the settlement in the soil which now become essential. The soil confinement is a necessary method of improving bearing capacity of soil and reducing the settlement of the footings resting on cohesive soil. Prototype models and formulas for design of foundation have been developed and modified over time. It is now necessary to develop a model that can simulate the actual behavior of soils as they experience bearing capacity failure. This process will help the engineers to generate more economical considered design and better assessments of the impacts of loads in the soil. The accurate prediction of the bearing capacity of shallow or deep foundations on soils has been complicated by their stress behavior and the surface roughness of the foundation with soil interface. The results from laboratory model tests on surface roughness for rectangular combined footings resting on soil are presented. The effect of bearing capacity of soil below the footing on surface roughness for rectangular plate with variation in depth of soil cushion below the footing and the effect of permissible settlement is evaluated and analyzed*

Key Words: **Combined footing, bearing capacity, cohesive soil, settlement**

1. INTRODUCTION

In recent years civil engineering professionals have adopted the practice of soil improvement by geo textile reinforcement, compaction, grouting etc, the properties of the soil such as compressibility, plasticity or bearing capacity of the soil always affect the design process in the construction. Lack of understanding of the properties of the soil can result in construction errors on such condition quality of soil for a particular use should be determined based on laboratory test or site investigation and not on visual inspection or apparent similarity to other soils. Every foundation design requires two major criteria limiting settlement and ultimate bearing capacity of foundations. However, the experimental researches are generally carried out on smaller sized models, which are highly scaled down models compared to real footings with environment replicate real conditions of footing over soil.

2. REVIEW OF THE LITERATURE

Rajeev Gupta, AshutoshTrivedi in the literature **"Effects of Non-Plastic Fines on the Behavior of Loose Sand– An Experimental Study"** have discussed about Soil Confinement has a significant Effect on improving the Behavior of circular footing Supported on silty sands. In cases where structures are very sensitive to settlement, Soil Confinement can be used to obtain the same allowable Bearing Capacity at a much lower settlement. Bearing capacity of circular footing decreases and settlement.

Mr. S. S. DeDalal and **Mr AmitNath** in the literature of **"The Role of Plasticity Index in Predicting Compression Behavior of Clays"**. Have explained about Plasticity and compressibility are typical properties of clays. Atterberg's limits of a clayey soil reflect the clay content and clay type of a soil. Compression index is also a clay dependent parameter. Among different correlations between the engineering and index properties of soils, which are often used to lessen the work load of a soil investigation program, Skempton's relationship between compression index (C_c) and liquid limit (w_L) given as C_c=0.007(w_L-10) for the remolded clays is well known. Its modified form for the normally consolidated clays proposed by Terzaghi and Peck is very popular in geotechnical practice. Another popular relationship between compression index and initial void ratio (e_0) has been proposed by Nishida. There are similar other relationship given by different researchers, but the use of plasticity index, I_P in the prediction of C_c is scarce.

Vinod Kumar Singh, Arun Prasad and **R. K. Agrawal** in the literature **"Effect of Soil Confinement on Ultimate Bearing Capacity of Square Footing Under Eccentric–Inclined Load"** they have arrived major experimental test results, the following Soil confinement has a significant effect on improving the behavior of square footing supported on granular soil. The ultimate bearing capacity was found to increase by a factor of 6.75 as compared to the unconfined case. Based on experimental results, soil confinement could be considered as a method to improve the bearing capacity of isolated footings resting on medium to dense sand. The BCR is highly dependent on the B/b ratio (cell width/footing width). The optimum ratio is about 1.50 beyond which the improvement decreases as the ratio increase. Increasing the height of the confining cells, results in increasing the surface area of the cell-model footing, this transfers the footing load to deeper depth and leads to improving the BCR. Optimum value of h/b ratio is 2

Xi-yuan Sun, Xiao-wei Tang and **Mao-tian Luan** in the literature "**Study on the Horizontal Bearing Capacity of Bucket Foundation on Saturated Soft Clay Ground**" were explained Bucket foundation used as a foundation for the offshore platform is subjected to lateral loads, vertical loads and moments during using period. According to experiences, the horizontal bearing capacity is more important to the stability of bucket foundation. Therefore, increasing attentions from both academe and engineering are paid on it now. There are usually four main ways to study on the bearing capacity of bucket foundation: model test (laboratory model test and field model test), finite element analysis, limit equilibrium analysis and limit analysis (upper bound method and lower bound method). With the analysis results, an equation to evaluate the horizontal bearing capacity for engineering practice is given at last.

Manish S., PatilKailas.Ain the literature **"Study Of Effect Of Different Parameters On Bearing Capacity Of Soil"** have discussed about the estimation of load carrying capacity of footing is the most important step in the design of foundation. A number of theoretical approaches, in-situ tests and laboratory model tests are available to find out the bearing capacity of footings. The reliability of any theory can be demonstrated by comparing it with the experimental results. Results from laboratory model tests on square footings resting on sand are presented in this paper. The variation of bearing capacity of sand below a model plate footing of square shape with variation in size, depth and the effect of permissible settlement are evaluated.

3. LABORATRY TEST

The properties of the soil such as compressibility, plasticity or strength of the soil always affect the design process in the construction. Absence of understanding of the properties of the soil can result in construction errors. The suitability of properties of soil for a particular use should be determined based on laboratory test or site investigation and not on visual inspection or apparent similarity to other soils. The loading carrying capacity of soil depends upon the type of soil. The increasing economic developments all over the world have resulted into the need for taller and bigger structures that will provide more space for offices, shops, accommodation, etc. Every foundation design requires two major criteria limiting settlement of foundations and ultimate bearing capacity of soil. Of these two criteria, the ultimate bearing capacity is governed by shearing strength of the soil which can be determined by various laboratory tests and their results are listed below with the results obtained the safe bearing capacity of soil is calculated, as per Indian standard code all the tests are carried out.

Table -1: LABORATORY TEST RESULT OF SOIL

SL	TESTS	RESULT
1	Specific Gravity Test	G = 2.62
2	Water content test	w = 9.13 %.
3	Liquid limit test	Liquid limit of soil = 24.2 %. Flow index of soil = 14.9 %.
4	Plastic limit test	Plastic limit = 11 % Plasticity index = 13 % Consistency index = 2.69 %
5	Grain Size Distribution (Wet Sieve Method)	Clay content = 53%.
6	Standard Proctor Soil Compaction Test	MDD =1.477 g/cm^3 (maximum dry density) Optimum water content =22 %
7	Unconfined Compressive strength of the soil	UCS =3.344 Kg/ cm^2. C = 1.667 Kg/ cm^2.
8	Consistency of soil	Very stiff

4. SAFE BEARING CAPACITY CALCULATION

The net safe bearing capacity is the net ultimate bearing capacity divided by a factor of safety F $q_s = q_f / F$ The ultimate bearing capacity is defined as the minimum gross pressure intensity at the base of the foundation at which the soil fails

$$q_f = c N_c S_c d_c i_c + q (N_q - 1) S_q d_q i_q + b_\gamma N_\gamma i_\gamma W$$

$$= 924.20 \text{ KN/m}^2$$

$$q_s = qf / F$$

$$= 924.20 / 2.5$$

$$\text{SBC} = 369.716 \text{ kN/m}^2$$

NOTE: We used "IS 6403:1981 – Indian standard code of practice for determination of bearing capacity of shallow foundations"

5. TEST MODEL FABRICATION

5.1 FOOTING DESIGN

For footing design fallowing column details was considered as size of Column A - 350mmX350mm, size of Column B -

400mmX400mm, Load on column A - 1200kn, Load on column B -1500kn, center to center between column A to B-2.5m, Soil bearing capacity -369.716Kn/m2. with the above details footing design was worked out as per footing design size of footing was 2mx4mand thickness of footing as 300mm with all above value a working prototype of footing was prepared, due to scale effect we prepared a steel footing instead of concrete footing of size 200mmx400mm with all necessary footing detailing like center to center distance and offset of edges from column faces as shown in Fig-1

Fig 1-Model footing

in addition to its two bottom surface of footing was prepared one with steel plate of smooth surface and another with steel plate of rough surface achieved by pasting 10mm coarse aggregate with adhesive as shown in Fig-2

Fig 2-Rough surface under footing

5.2 MODEL TANK

Model tests were conducted in a test tank; the model footings used for the tests were rectangular in shape According to the prototype model footing size the load tests were conducted in a rectangular steel tank of 450mm×600mm in plan and 800mm in depth. Total volume of tank 0.22m^2 nearly 4.86kn (310kg) of soil. Our test is going to take place at various depth of soil filling likely 800m depth, 600mm depth and 450mm depth so according to this criterion we designed a model tank which reinforced with steel wall. The test tank is made of steel with separate glass screen on one side to see soil layer and settlement effect and has arrangement to fix the proving ring with specially fabricated inclined load device for applying the axial as well as inclined load to the footing as shown in Fig-3

6. TESTING MATERIAL (SOIL)

Locally available cohesive soil collected from stream bank is used as the foundation bed. The physical properties of cohesive are presented in Table 1.

7. TEST SETUP

7.1. PREPARATION OF MODEL TANK

Fill the model tank with soil at 100mm each layer to required depth and rammer each layer thoroughly till the soil become compacted and stiff as it collected from site, place the tank under loading frame and after preparing the bed, the surface was leveled, and the footing was placed exactly at the center of the loading jack to avoid eccentric loading.

7.2. SETUP

A hydraulic jack was placed under loading frame which have attached to the proving ring was used to push the footing model slightly into the soil bed for proper contact between the soil and footing. A defflectometer was placed at tank with help of magnet with tip have contact over top of footing surface as shown in Fig-3

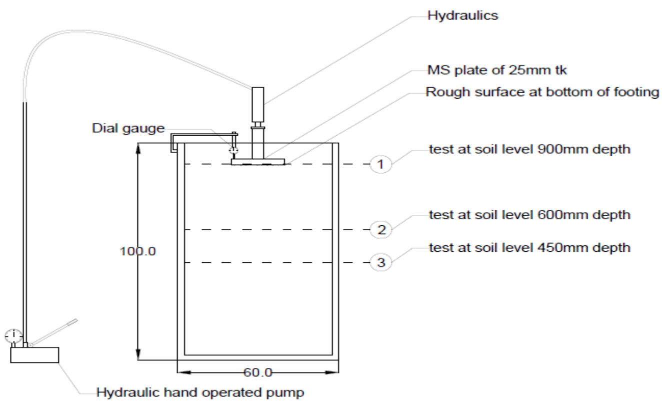

Fig-3: Exprimental setup diagram

8. TESTING PROCEDURE

After footing, proving ring, hydraulic jack, dial gauge was placed in position and the load was applied to it by the hydraulic jack through the proving ring. The load was applied to footing in small increments until failure occurred. Each load increment was maintained at a constant level until the footing settlement had stabilized. The settlements of the footing were measured by dial gauges. The placement of the soil, model footing, and confining box is shown in Fig-4. The test program consisted of carrying tests on combined footing to study the effect of soil over the soil-foundation response as shown in Table 2. Initially, the test has been carried out under axial load on the footing resting on the unconfined bed. The tests were carried out under smooth surface and rough surface to study the effect of settlement over soil.

Fig-4 experimental setup

9. TEST RESULTS

The tests were carried out under axial load to study the effect of intensity of loading on settlement at different footing surface over soil cushion below the footing (D_{sc})

Table 2a: Effect of q and Dsc on settlement in mm, with smooth base

sl	Intensity of loading (q) (kN/m^2)	Dial gauge reading	settlement in mm
1	0	100	0
2	0.5	89.5	10.5
3	1	82.3	17.7
4	1.2	73.54	26.46
5	1.4	67.75	32.25
6	1.8	55.8	44.2
7	2	50.2	49.8

Table 2a: Effect of q and Dsc on settlement in mm, with rough base

sl	Intensity of loading (q) (kN/m^2)	Dial gauge reading	settlement in mm
1	0	100	0
2	0.5	98.2	3.8
3	1	94.7	5.3
4	1.2	93.5	6.5
5	1.4	92	8
6	1.8	89.6	10.4
7	2	86.32	12.68

10. CONCLUSION

Based on the studies carried out the different conclusions drawn as there is considerable reduction in the settlement for rough base in comparison with smooth base for the intensity of loading 1 kN/m^2 onwards. Rough footing over Soil confinement has a significant effect on improving the behavior of combined footing supported on granular soil the ultimate bearing capacity was found to increase.

REFERENCES

[1] Vinod Kumar Singh, Arun Prasad and R. K. Agrawal on "Effect of soil confinement on Ultimate Bearing Capacity of Square Footing under Eccentric–Inclined Load" 2007 EJGE Vol. 12, Bund. E
[2] Rajeev Gupta, AshutoshTrivedi in the literature "Effects of Non-Plastic Fines on the Behavior of Loose Sand– An Experimental Study"
[3] Mr. S. S. DeDalal and Mr AmitNath in the literature of "The Role of Plasticity Index in Predicting Compression Behavior of Clays"
[4] Xi-yuan Sun, Xiao-wei Tang and Mao-tian Luan in the literature "Study on the Horizontal Bearing Capacity of Bucket Foundation on Saturated Soft Clay Ground"
[5] Manish S., Patil Kailas.Ain the literature "Study Of Effect Of Different Parameters On Bearing Capacity Of Soil"
[6] Abdel-baki,S., G.P. Raymond, and P. Johnson "Improvement of the Bearing Capacity of Footing by a Single Layer of Reinforcement," Proceedings, Vol. 2, Geo synthetics 93 Conference, Vancouver, Canada. pp. 407-416
[7] De Beer, E.E., "Bearing capacity and settlement of shallow foundations on sand", International proc. of the Bearing Capacity and Settlement of foundations Symposium, Duke University, Durham, NC, pp15-34
[8] Ingra, S.T. and Baecher, G.B. (1983) "Uncertainty in bearing capacity of sand", Journal Geotechnical Engineering, ASCE, 109(7), pp.899-914
[9] Md. Enayet Chowdhury, Md. Azijul Islam, Tahsina Islam, Nafeesa Khan: "Evaluation of Shear Strength of Cohesionless Soil from Maximum, Minimum Dry Density and Fines Content using Polynomial Surface Fitting Method" Electronic Journal of Geotechnical Engineering, 2018 (23.01), pp 31-56
[10] Shi Xiaochun, Xu Riqing, Gong Xiaonan (1999) "Experimental study on horizontal bearing capacity of single bucket foundation" Chinese Journal of Geotechnical Engineering, 21(6): 723–726
[11] Selig, E.T., McKee, K.E., 1961. Static and dynamic behavior of small footings. *J. Soil Mech. Found. Div.* ASCE 87 (6), 29e47

[12] Dr. Cfa Akayuli, Bernard Ofosu, Seth O. Nyako and Kwabena O. Opuni, "The Influence of Observed Clay Content on Shear Strength and Compressibility of Residual Sandy Soils", International Journal of Engineering research and Applications (IJERA), Vol. 3, Issue 4, pp. 2538-2542 Jul-Aug 2013.
[13] B.H. Fellenius and A. Altaee, Stress and settlement of footings in sand, In Proc. of the American Society of Civil Engineering, ASCE, Conference on Vertical and Horizontal Deformations for Foundations and Embankments, Geotechnical Special Publication, GSP, No. 40, College Station, TX, (June 16-18, 1994) Vol. 2 1760-1773
[14] E.E. De Beer, Bearing capacity and settlement of shallow foundations on sand, In Proc. of the Bearing Capacity and Settlement of Foundations Symposium, Duke University, Durham, N.C. (1965) 15-34.
[15] N.K. Ovesen, Centrifugal testing applied to bearing capacity problems of footings on sand, Geotechnique 25 (2) (1975) 394-401.
[16] T. Kimura, O. Kusakabe and K. Saitoh, Geotechnical model tests of Bearing capacity problems in a centrifuge, Géotechnique 35 (1) (1985) 33-45.
[17] M.D. Bolton and C.K. Lau, Scale effect in the bearing capacity of granular soils, Proc. the 12th Int'l Conf. Soil Mech. Found. Eng., Rio De Janeiro, Brazil (1989) Vol. 2 895-898.