

New Approach for Determination of Bearing Capacity of Soil using Direct Shear Test (Lab test)

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Abstract- This document gives a new way of finding bearing capacity of soil by combination of Direct shear test (Lab Test) and Bearing capacity equations (Analytical). In this work a new approach is shown which may be the addition in the literature of geotechnical engineering field. For this work a site from Naldurg (District Osmanabad) is selected and number of tests was conducted over $c - \phi$ soil. Based on the interpretation of results value of bearing capacity obtained which can be useful for further subsoil investigation and construction activity.

Keywords – Bearing Capacity, c and ϕ value of soil, Direct Shear Test, IS Code equation, Terzaghi's equation.

I. INTRODUCTION

The safe bearing capacity of soil is required for the design of the plan dimensions of the footing for the structure. The allowable bearing pressure (SBC) of field soil is determined by various methods of different criteria's like shear failure criteria and settlement criteria. The actual behavior of each type of soil depends on its strength properties, permeability, stability and many other own properties.

To compute bearing capacity of soil there are different field tests are available. Field tests like Plate bearing test, Standard penetration test, Pressuremeter test and Field vane shear test are generally used to determine bearing capacity of soil. Because of high range of bearing capacity of soil the load for field tests is so high, similarly the reaction load is much more. Hence these field tests are become laborious; heavy to handle and operate because of these disadvantages these tests for small structures like detached houses, small bungalows becomes costly. Cost of field tests are more as compared with the structure, so many contractors or engineers are avoiding these tests. They provide approximate sizes of footing, by considering arbitrary value of allowable bearing capacity of soil from their past site experience which may lead to uneconomical for foundation construction.

To avoid this approach of taking arbitrary or approximate value of bearing capacity in design of foundation this new approach will be useful, less costly and easy.

In this new approach using analytical bearing capacity equations like Terzaghi's and IS code equations bearing capacity of soil can be determined. While using these equations cohesion values (c) and angle of internal friction (ϕ) value need to be known. Values of c and ϕ of soil can be determined by Direct Shear Test and Unconfined compression test in the case of saturated clayey soil. Density or Unit weight of soil can be obtained by using field density tests like Sand replacement and Core cutter test.

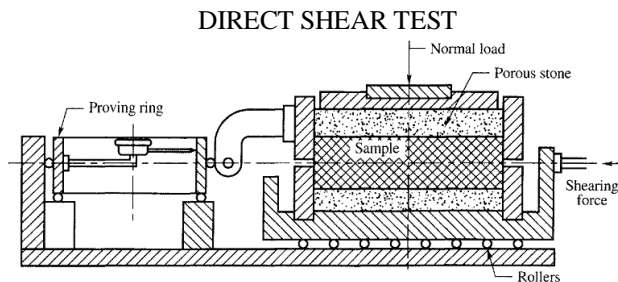


Figure 1: Direct Shear Test

The box shear test is simple in principle. The apparatus consists of a square brass box split horizontally at the level of the center of the soil sample, which is held between metal grilles and porous stones as shown in figure. Vertical load is applied to the sample as shown in the figure and is held constant during a test.

A gradually increasing horizontal load is applied to the lower part of the box until the sample fails in shear. The shear load at failure is divided by the cross-sectional area of the sample to give the ultimate shearing strength. The vertical load divided by the area of the sample gives the applied vertical stress σ . The test may be repeated with a few more samples having the same initial conditions as the first sample. Each sample is tested with a different vertical load.

For determination of c and ϕ value of soil Triaxial compression test also can be conducted. As Direct box shear test also having some advantages so it can also preferred to obtain soil the same soil property. The direct shear machine is simple, less expensive test and fast to operate. It facilitates drainage of the pore water quickly from a saturated specimen.

II. SCOPE OF PROJECT

Geotechnical investigation work was envisaged to assess the subsoil strata from safe bearing capacity point of view at Naldurg, Osmanabad district. This geotechnical investigation report is based on the data collected from two trial pits and from laboratory results and judgment of the author based on his experience. The scope of this investigative report is limited to assessing subsoil strata from safe bearing capacity point of view at above mentioned site. The recommendations presented in this report are applicable only to this specific site.

However, this approach or procedure can be used for any site with proper sample collection, lab testing and interpretation of results.

III. METHODOLOGY

Some of the tests are carried out at the above site while collecting the soil sample for lab tests. Test results of soil at foundation level are

1. Insitu density (γ) obtained by replacement test which is 1934 kg/m³. The test procedure is as per IS 2720 Part 28 - 1974. Core cutter test can also be used in case of soil is soft.
2. Insitu water content (w) of soil sample from oven dried method as per IS 2720 Part 2 - 1973,
 $w = 6.69\%$
3. Hence, Insitu dry density of soil,
 $\gamma_d = 1812.72 \text{ kg/m}^3$

Laboratory Direct shear box tests were performed on soil samples from the proposed site. The sample was prepared by maintaining same field density and water content of the site. As per IS 2720 Part XIII. The results of the direct shear test are as shown in Table 1 & Figure 2.

Table 1: Results of Direct Shear Test

Normal Stress (kN/m ²)	25	50	100	200
Shear stress (kN/m ²)	15	18.6	26.4	40.5

From graph of Fig. 2 shear strength parameters can be obtained by intersecting line to 'y' axis intercept cohesion (c) value is obtained. Angle of internal friction (ϕ) can be obtained by measuring angle of line with 'x' axis.

The same test is conducted on four trails of soil sample collected on above site and result is obtained as below,

Average Cohesion intercept, $c = 12.3 \text{ kN/m}^2$

Average Angle of internal friction, $\phi = 30^\circ$

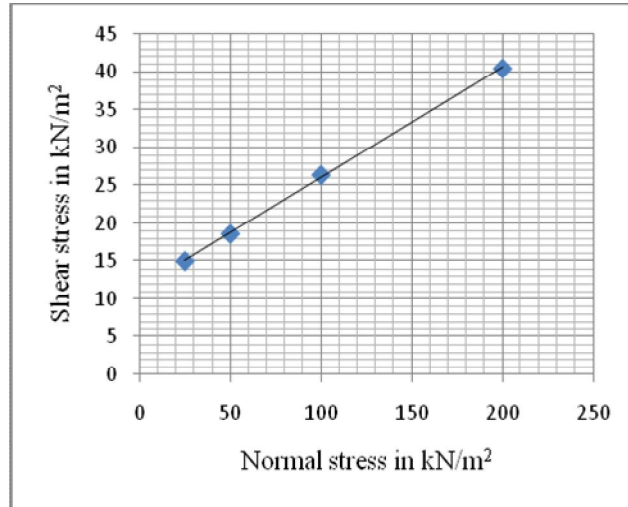


Figure 2: Plot of Direct box test results

Calculation of Safe Bearing Capacity using Direct Shear Test Results

Assume that, it is proposed to provide isolated footing at a depth of 1.5 m below existing ground level. The bearing capacity is calculated as per IS: 6403-1981.

Data for calculation:

1. The Assumed depth of the foundation (D_f) = 1.5 m
2. Size of footing = 1 m x 1 m (Assumed square isolated)
3. Water table correction factor, $W' = 0.5$, (Assuming the water table rises to the ground level in this condition least SBC value may get)
4. Bearing capacity factors for $\phi = 30^\circ$,

As from ϕ value criteria and from density of soil it is predicted that a General shear failure is possible. Hence, bearing capacity factors for general shear failure are as follow,

$N_c = 30.14$, $N_q = 18.40$, $N_\gamma = 22.40$ (from IS: 6403-1981 Table 1)

5. As per above IS code Shape factors for square footing are,

$$S_c = 1.3, S_q = 1.2, S_\gamma = 0.8$$

6. As per above IS code Depth factors are,

$$d_c = 1.51, d_q = 1.25, d_\gamma = 1.25$$

7. If there is no inclined load acting on the foundation, then all inclination factors are 1, i.e. $i_c, i_q, i_\gamma = 1$

Now, Net Ultimate Bearing Capacity (q_{nu}) is given by (as per IS: 6403-1981- 5.1.2)

$$q_{nu} = c N_c S_c d_c i_c + q (N_q - 1) S_q d_q i_q + 0.5 \gamma B N_\gamma S_\gamma d_\gamma i_\gamma W'$$

$$= (12.3 \times 30.14 \times 1.3 \times 1.51 \times 1) + \{(19.34 - 9.81) \times 1.5 \times (18.40 - 1) \times 1.2 \times 1.25\} + (0.5 \times 19.34 \times 1 \times 22.04 \times 0.8 \times 1.25 \times 1 \times 0.5)$$

$$q_{nu} = 1207.39 \text{ kN/m}^2$$

Now, Net Safe Bearing Capacity or safe bearing capacity is given by using an appropriate factor of safety (FS) value.

Factor of safety (FS) for net safe bearing capacity is used generally in between 2.5 to 3. Here if the factor of safety used 3 then the value of bearing capacity will be far more than BIS suggested values and not practicable value. Hence, in this approach it is needed to suggest higher value of factor of safety since there are chances of errors while lab

testing of soil sample in direct shear test. This value can be approximately assumed based on experience of soil investigator or it can be found out by following method.

To find the optimum factor of safety value, soil needed to test under field condition. Plate bearing test or Standard penetration tests are mostly preferable.

Bearing capacity value obtained from plate load test is considered as reliable and using this value a better factor of safety calculated for the above IS code equation.

IV. FIELD TEST FOR VALIDATION AND TO OBTAIN FACTOR OF SAFETY:

A plate bearing test is conducted on a same field of soil sample where direct shear test results are obtained. Plate load test is conducted with the help of the square plate of 30 cm x 30 cm as per guidelines of IS: 1888 – 1982.

Table 2: Results of Plate Load Test

Pressure in kN/m ²	0	185	386	543	789	1060
Settlement in mm	0	6.3	12.5	18.1	22.5	31.5

The results of the test are shown in Table 2. The same results plotted on a graph and from the result, it can be seen that there is a sudden change in settlement after fourth increment of load, hence ultimate bearing capacity can be taken corresponding to 25 mm settlement of bearing plate that is 880 kN/m².

Ultimate bearing capacity of soil from plate load test, $q_u = 880 \text{ kN/m}^2$

Hence safe bearing capacity will be $880 / 3 \approx 300 \text{ kN/m}^2$ (Factor of safety for plate load test considered as 3)

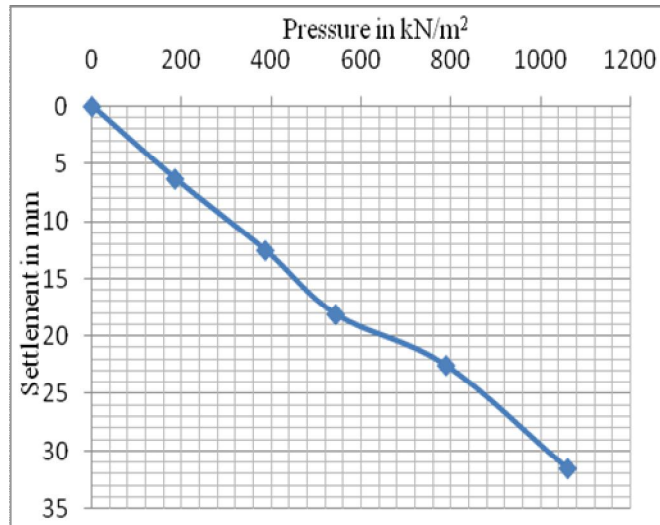


Figure 3: Plot of Plate load test results

Here value of safe bearing capacity considered as actual and reliable value for above site mentioned.

Hence factor of safety (FS) for IS code equation can be introduced as $1207.39 / 300 \approx 4$

$$q_{ns} = q_{nu} / FS = 1207.39 / 4$$

$$q_{ns} = 301.84 \text{ kN/m}^2,$$

Safe bearing capacity (SBC) is given by,

$$q_s = q_{ns} + \gamma D_f = 301.84 + (9.53 \times 1.5)$$

$$q_s = 316.135 \text{ kN/m}^2$$

Safe Bearing Capacity of soil can be taken as 316 kN/m^2 (31 tonne/m^2). This value can be used for further investigation and design of foundation.

V. CONCLUSION

- From this approach it is proved that for small and less important work bearing capacity can be found easily without performing any heavy field tests.
- This approach of bearing capacity can be used as an alternative method for plate load test and other cumbersome field tests.
- It is also suggested that in this approach factor of safety varies according to the site and the type of soil.
- Factor of safety value can be judged by field density tests and other simple tests of soil investigation like augers etc.
- Factor of safety value in above approach may vary person to person, it solely depends on the experience of the engineer.
- Terzaghi's equation gives conservative bearing capacity results for various depths on $c-\phi$ soil.
- Plate load test is carried out only for finding factor of safety for IS code equation, however without this field test one can get safe bearing capacity.

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REFERENCES

- [1] Virgil Ping W. and Zenghai Yang (2002). "Field and Laboratory Determination of Granular Subgrade Moduli." ASCE, 2002.
- [2] IS: 1888 - 1982. "Method of load test on soils."
- [3] Bowles Joseph E. (1996). "Foundation Analysis and Design." Tata McGraw – Hill Publishing Company Ltd. 5th Edition 1996.
- [4] Gopal Ranjan and A.S.R. Rao (2006). "Basic and Applied Soil Mechanics." 2nd Ed. New Age International Publishers New Delhi.
- [5] Meyerhof, G. G. (1951), "The Ultimate Bearing Capacity of Foundations" , Geotechnique Vol. 2, No 4, pp.301-331
- [6] "National Building Code 2005".
- [7] Terzaghi K. (1943) ,"Theoretical Soil Mechanics" , John Wiley and sons ,New York.
- [8] K R Arora, "Soil Mechanics and Foundation Engineering"
- [9] K. Kaptan, Z. Ozdemir and S. S. Tezcan (2011). "A refined formula for the allowable soil pressure using shear wave velocities" Journal of Soil Science and Environmental Management Vol. 2(7), pp. 175-183, July 2011.
- [10] Khazanovich, L., Tayabji, S.D., and Darter, M. I. (2001). "Back calculation of layer parameters for LTPP test sections" Technical Rep. No. FHWA-RD-00-086, Federal Highway Administration, McLean, Va.
- [11] Lawton Evert C. and Brian J. Warner (2008). "Performance of a group of geopier elements loaded in compression compared to single geopier elements and unreinforced soil." University of Utah.
- [12] Lin Ping-Sien, Li-Wen Yang, and C. Hsein Juang (1998). "Subgrade reaction and load-settlement characteristics of gravelly cobble deposits by plate-load tests." Canadian Geotechnical Journal 35: 801–810 (1998).
- [13] Meigh A.C. & Nixon I.K. (1961). "Comparison of Insitu Tests for granular soils." Proceedings of fifth international conference on soil Mechanics and foundation Engineering Paris 1961 vol I PP 499.
- [14] Mohan Dinesh and V.S. Aggarwal (1980). "Bearing capacity from Dynamic cone penetration tests." Journal of Indian National Society of Soil Mechanics and Foundation Engineering , Vol 16 pp (133-142).
- Widjaja B. (2008). "Parametric Studies for Obtaining the Dimension of Soil Improved Area." Dinamika Teknik Sipil, Volume 8, No. 1, pp. 31–35.