Bearing capacity prediction for shallow foundations by in-situ and experimental investigation.

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Abstract— It is a common phenomenon that people go for thump rules if a logical application issue arises. When it deals with soil engineering, the criterion remains the same. So now days, validation of shortcuts has its own importance. In this paper the principle of indentation hardness test is used as a tool to predict the bearing capacity of soil for shallow foundations. The paper mainly focuses on the test results and its interpretations made on an in-situ method which ascertain the density of soil at a depth lesser than 2m from the ground level.

Load impression tests are conducted at a site near Ambalathara which is in Trivandrum district of Kerala. The soil resistance towards the impacts made by a 10 kg load dropped through a height of 1m is examined and the bearing capacity values are computed by a thump rule based on indentation principle. Thereafter, triaxial test of ninety undisturbed soil samples are carried out to determine the shear strength parameters and wet sieve analysis for the soil gradation. The laboratory test results are used to calculate the bearing capacity of the soil by conventional method. There exists a proportionate variation in the bearing capacity values predicted by the in-situ method and the conventional method.

Index Terms— Bearing capacity, Indentation hardness test, Lab tests, Load impression test, Undisturbed sample.

1 Introduction

Geotechnical Engineering can be considered as a special tributary of Civil Engineering with all its peculiarities and it's on individuality. Now days the professionals in this area is experimenting new possibilities on substructure with the emerging technologies. Geotechnical engineer is a person who were professionally experienced on evaluating the soil strata and capable of predicting the behavior of the same by evaluating the concerned index and engineering properties of the soil. The right interpretation has a better influence on the various phases of the overall construction. A properly designed foundation transfers the load through the soil without overstressing the soil. Overstressing the soil can result in either excessive settlement or shear failure of the soil both of which cause damage to the structure. Thus, geotechnical and structural engineers who design foundations must evaluate the bearing capacity of soil depending on the structure and soil encountered.

As analysing the engineering properties of soil is a tedious job, the correlations of index properties with engineering properties are mostly preferred but applicable only for small structures. In this paper the principle of indentation hardness test is used as a tool to predict the bearing capacity of soil for shallow foundations. The paper mainly focuses on the test results and its interpretations made on an in-situ method which ascertain the density of soil at a depth lesser than 2m from the ground level.

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2 Bearing capacity calculations ; A brief review.

There are a lot of correlations for determining the soil parameters. Most of them are related to CPT, CPTU, and SPT. Among them the most popular correlations are raised with the Standard Penetration test (SPT) emphasizing the blow counts. For an experienced geotechnical engineer the prediction of the bearing capacity of the soil strata from the number of blows from the SPT test results is not a big deal. So in this work, the main objective is to analyse the range of variations in the values obtained from the in-situ method based on indentation hardness test principle and the conventional laboratory test method.

The bearing capacity of soil is mainly depends on the soil parameters, soil stratification and the type of foundation. This may influence the range of pressure zone by the imposed load and its distribution. There are mainly four theories for calculating the bearing capacities includes Terzaghi's bearing capacity theory (1943), Meyerhof (1963), Hansen (1970), Vesic (1973,1975). Terzaghi's bearing capacity theory superseded the other theories. These theories demand a number of trial and error process for getting the design dimensions as B and L, which predominantly influence the shape, depth, inclination factors.

3 OBJECTIVE OF THE STUDY

The main objective is to study the possibility of determining the bearing capacity of soil by a simple in-situ method and thereby reducing the time taken for bearing capacity calculations for shallow foundations. It improves the effectiveness of reconnaissance survey. It also aims to evaluate the variations between in-situ method and conventional method and to establish relevant relationships between the two. It reduces the overall time and cost for laboratory testing of soil.

4 INDENTATION HARDNESS TEST PRINCIPLE:

Indentation hardness test is used in engineering field mainly to determine the deformation caused due to the failure in the hardness of a material. It is a relationship connecting the depth of impression (Di) imposed by the load (P) from a known height (Hf). In the present study, the resistance offered by the soil to the imposed loads are examined using this technique. It is somewhat similar to the energy principle of Standard Penetration test in which the number of blow counts is a proportionate reflection of the density of the soil layer at which the loads are imposed. It is evident that the driving energy is proportionate to the blow count and it is computed as follows:

$$Ein = \frac{mv^2}{2} = \frac{Wv^2}{2g} \qquad (1)$$

$$v = (2gh)^{\wedge}(1/2) \qquad (2)$$

By substituting (1) on (2)

$$Ein = Wh$$

Where W is the weight of hammer and h is the height of free-fall. SPT mainly preferred for soil exploration demands a depth greater than six meters due to the cost parameters. So it is normally preferred for deep foundations. The test report includes detailed test results examining the soil properties like gradation, shear parameters, depth variations etc which demands a particular time period for validations.

The significance of indentation hardness principle arises at this stage, by this relation we can find the bearing capacity if demands even at the time of preliminary survey of land, if we know about the pressure influence zone. By using the relation,
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Soil resistance,

$$R = \frac{PH_f}{D_i} \qquad (3)$$

Soil resistance / unit area,

$$R_S = \frac{PH_f}{ADi} \qquad (4)$$

Safe / Allowable bearing capacity,

$$Q_S = \frac{R_S}{FOS} \qquad (5)$$

P is weight the imposed load with known dimensions. Hf is the free fall height of load. A is the area of cross section of the imposed load. Di is the depth of impression in response to the impact load. Factor of safety normally for soil ranges from 2.5 to 3.

Validation of this method needs a specific frame structure which should be precise, including soil type, depth from ground level, weight of drop, height of fall. For this, a load impression test by using a weight of 10kg with a falling height of 1m Milad et al. On soil having some cohesiveness for the easiness of getting undisturbed sample for conducting the lab tests and depth favoring the shallow foundation.

5. FIELD AND LABORATORY TESTS HINTS

Load impression tests were conducted at a site near Ambalathara which is in Trivandrum district of Kerala. The soil resistance towards the impacts made by a 10 kg load dropped through a height of 1m with a crosectinal area of 209.98cm2 is examined and the bearing capacity values are computed by a thump rule based on indentation principle. A field density of 16.3KN/m3 was obtained by core cutter method. Triaxial test of ninety undisturbed soil samples were carried out to determine the shear strength parameters and wet sieve analysis for the soil gradation. The laboratory test results were used to calculate the bearing capacity of the soil by conventional method.

6. RESULTS AND DISCUSSION

The laboratory test results were used to calculate the bearing capacity of the soil by conventional method using Meyerhof's theory. Width of foundation 1m, length 1m, foundation depth 1.25m, specific gravity 2.53, bulk density 16.3KN/m3,water content 0.46 and factor of safety 2.5 were taken for the calculation purposes.

TABLE 1.
LOAD IMPRESSION TEST RESULTS

Sl.No	Dip (cm)	R (KN)	Qsf (kPa)
1	1.8	3.2700	62.2902
2	2.0	2.9430	56.0611
3	1.5	3.9240	74.7482
4	1.8	3.2700	62.2902
5	2.1	2.8029	53.3916
6	1.4	4.2043	80.0874
7	1.7	3.4624	65.9543
8	2.2	2.6755	50.9647
9	2.0	2.9430	56.0611
10	1.8	3.2700	62.2902
11	1.6	3.6788	70.0764
12	1.7	3.4624	65.9543
13	1.5	3.9240	74.7482
14	1.8	3.2700	62.2902
15	2.1	2.8029	53.3916
16	1.5	3.9240	74.7482
17	1.7	3.4624	65.9543
18	1.6	3.6788	70.0764
19	1.9	3.0979	59.0117
20	1.8	3.2700	62.2902
21	1.8	3.2700	62.2902
22	1.5	3.9240	74.7482
23	1.4	4.2043	80.0874
24	1.8	3.2700	62.2902
25	1.9	3.0979	59.0117
26	1.6	3.6788	70.0764
27	2.0	2.9430	56.0611
28	2.2	2.6755	50.9647
29	1.9	3.0979	59.0117
30	1.8	3.2700	62.2902

TABLE 2.
TRIAXIAL TEST RESULTS AND BEARING CAPACITY VARIATIONS

SET NO.	C (kN/m2)	Φ-value	Vertical
			Qsf kPa
1	9.81	3.0	39.7756
2	9.81	3.0	39.7756
3	9.81	2.0	37.2539
4	10.79	2.0	39.9556
5	9.81	4.0	42.3189
6	10.79	2.0	39.9556
7	8.63	5.0	41.1020
8	9.81	4.0	42.3189
9	9.81	4.0	42.3189
10	8.53	5.0	40.7868
11	8.53	5.0	40.7868
12	8.53	5.0	40.7868
13	8.53	3.5	37.2429
14	8.53	4.5	39.6007
15	10.99	2.0	40.4960
16	8.53	4.5	39.6007
17	9.81	3.0	39.7756
18	10.99	2.0	40.4960
19	8.53	4.0	38.4194
20	9.81	3.0	39.7756
21	9.81	4.0	42.3189
22	8.53	4.0	38.4194
23	7.36	4.0	34.8198
24	8.53	4.5	39.6007
25	12.26	2.0	44.0082
26	8.53	4.0	38.4194
27	7.36	4.5	35.9101
28	7.36	4.5	35.9101
29	8.53	5.0	40.7868
30	8.53	5.0	40.7868

By evaluating the results obtained from load impression test (Table 1) and conventional method (Table 2), a ratio of 1:

1.5 was observed between the in-situ and lab values. The values are given in the Table 3

TABLE 3.
RATIO BETWEEN LAB AND SITE METHOD.

	LAB	SITE	RATIO
SET NO.	Qult kPa	Qult kPa	LAB:SITE
1	39.776	62.290	1.566
2	39.776	56.061	1.409
3	37.254	74.748	2.006
4	39.956	62.290	1.559
5	42.319	53.392	1.262
6	39.956	80.087	2.004
7	41.102	65.954	1.605
8	42.319	50.965	1.204
9	42.319	56.061	1.325
10	40.787	62.290	1.527
11	40.787	70.076	1.718
12	40.787	65.954	1.617
13	37.243	74.748	2.007
14	39.601	62.290	1.573
15	40.496	53.392	1.318
16	39.601	74.748	1.888
17	39.776	65.954	1.658
18	40.496	70.076	1.730
19	38.419	59.012	1.536
20	39.776	62.290	1.566
21	42.319	62.290	1.472
22	38.419	74.748	1.946
23	34.820	80.087	2.300
24	39.601	62.290	1.573
25	44.008	59.012	1.341
26	38.419	70.076	1.824
27	35.910	56.061	1.561
28	35.910	50.965	1.419
29	40.787	59.012	1.447
30	40.787	62.290	1.527

7. Conclusion

The soil resistance towards the impacts made by a 10 kg load dropped through a height of 1m during load impression test was examined at a depth of 1.25m from the ground surface. The average bearing capacity obtained from the site was 63.98 kPa.The bearing capacity of the soil by conventional method using Meyerhof's theory was obtained as an average value of 39.78kPa. A factor of safety of 2.5 was considered. The maximam variation on internal friction ranges from 2. ° to 5° and Wet sieve analysis validates that the soil sample collected was silty clay with 50% of silt, 46% of clay followed by 4% of sand.

So for a siltyclay soil a proportionate variation of 1:1.5 with LAB: SITE in the bearing capacity value was obtained which can be used for predicting the BC values.

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