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VARIATION OF BEARING CAPACITY OF SOIL WITH DIFFERENT PARAMETERS

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Abstract

Foundations of engineering structures are designed to transfer and distribute their loading to the underlying soil. This design is required to satisfy the main design criteria namely the bearing capacity of the foundation. Bearing capacity is affected by various factors like shape of footing, depth of footing ,change in level of water table, eccentricity of loading unit weight of soil ,etc.
This research aims to investigate the effects of the shape of footing, its depth and location of water table on the bearing capacity of layered soil determined by Terzaghi, Hansen and Meyerhof methods .The main findings of this study are that the values of ultimate bearing capacity and safe bearing capacity determined for square and circular shaped footings are found to be higher than strip and rectangular footings. As depth of foundation increases ultimate and safe bearing capacity of soil increases. The bearing capacity of soil is reduced to about 50% when water table is near ground level.

KEYWORDS: Bearing capacity, shape, Depth, water table, soil.

1. INTRODUCTION

Soil is considered by the engineer as a complex material produced by weathering of the solid rock. Soil is the most important material, which is in use for construction of civil engineering structures. Amongst all parameters, the bearing capacity of soil to support the load coming over its unit area is very important[1].Traditional bearing capacity theories for determining the ultimate bearing capacity of shallow foundations assume that the bearing stratum is homogenous and infinite. However this is not true in all cases. Layered soils are mostly encountered in practice. It is possible to encounter a rigid layer at shallow depth or the soil may be layered and have different shear strength parameters. In such cases shear pattern gets distorted and bearing capacity becomes dependent on the extent of the rupture surface in weaker or stronger material. [2]. There are various methods for calculation of bearing capacity of soil put forth by scientists like Terzaghi, Hansen, Meyerhof, Vesic and others. Principal factors that influence ultimate bearing capacities are type of soil, width of foundation, soil weight in shear zone and surcharge. In addition to properties of soil, depth of foundation, water table variation near the base of the footing, eccentricity of loading governs the ultimate and safe bearing capacity of soil[3]. Terzaghi was the first to propose a bearing capacity equation on the consideration of general shear failure in the soil below a rough strip footing. Using the principle of superposition, he demonstrated the effects of soil cohesion, its angle of internal friction, surcharge (soil lying above the level of footing base), soil unit weight and footing width on the ultimate bearing pressure. Later on, Brinch and Hansen introduced factor that accounted for footing shape and load inclination, in the bearing capacity equation[4]. Using the principles of plastic equilibrium, the ultimate bearing capacity, q_f, of a shallow footing, with a depth of *D*, from the surface and with a width of *B* and length *L*, is given by Terzaghi (1967) as ,

$$\mathbf{q_f = c\, N_c\, s_c + \gamma\, D\, N_q + 0.5\, \gamma\, B\, N_\gamma\, s_\gamma} \quad (1)$$

where: N_q, N_c and N_γ are the bearing capacity factors

While s_c, s_q and s_γ are the shape factors

Meyerhof(1951,1963) proposed a bearing capacity equation similar to that of Terzaghi but included depth factors d_i and inclination factors i_i

$$\mathbf{q_f = c\, N_c\, s_c\, d_c\, i_c + \gamma\, D\, N_q\, d_q\, i_q + 0.5\, \gamma\, B\, N_\gamma\, s_\gamma\, d_\gamma\, i_\gamma} \quad (2)$$

Where: d_c, d_q and d_γ are the depth factors and i_c, i_q and i_γ are the inclination factors

Hansen(1970)proposed the general bearing capacity equation. This equation is extension of Meyerhof equation. The extension include base factors for situations in which the footing is tilted from horizontal and for the possibility of a slope of the ground supporting the footing to give ground factors[5].

2. AIMS OF THE STUDY

The aim of this work is to study the effect of different parameters on bearing capacity of the soil. Three representative soil samples from proposed depth of foundation were collected. Experimental work was planned to study the properties of different soil samples collected for determination of ultimate and safe bearing capacity of the soil using Terzaghi, Hanson, and Meyerhof equations.

3. EXPERIMENTAL PROGRAM

The soil samples used in the study were collected from a site of construction for a multi story building .These soils samples were collected at a depth of 0.5m, 1.5m, and 3m. Experimental work was carried out to study the properties of soil samples for determination of ultimate bearing capacity of the soil. For the three samples the basic properties such as specific gravity, sieve analysis, consistency limit *i.e.* liquid limit and plastic limit were determined for classification of the soil. Soil density test was conducted and the direct shear tests were done to find soil cohesion c and the angle of internal friction $\emptyset$.The results of these tests for the three samples are as shown in table 1.

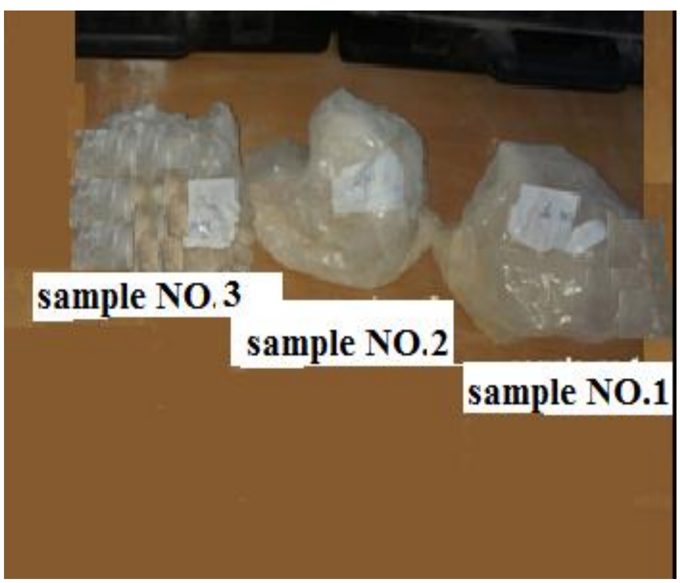

Figure1: The soil samples

Table 1. properties of soil samples

Properties of soil samples		Depth of Sample (m)		
		0.5	1.5	3
Sieve analysis ASTM D421	Gravel size(4.75-75mm) in%	37.9	52.1	60.15
	Sand size(0.075-4.75mm) in%	53.4	40.13	30.94
	Silt and clay size(below 0.075mm) in%	8.7	7.8	8.91
Atterberg limits ASTM 4318	Liquid limit%	14	12	10
	Plastic limit %	8.8	8	9.09
	Plasticity index %	5.2	4	0.91
Soil density kN/m^3 ASTM D4253 and D4254		17.6	18	18.4
Shear strength parameters ASTM D3080	Cohesion kN/m^2	8	5	4
	Angle of internal friction (∅).	33	36	38
Soil classification	ASTM	Well graded sand with silt and gravel	Well graded gravel with silt and sand	Well graded gravel with silt and sand

Based on the laboratory experimentation carried out the values of c , ∅. and ɣ are obtained. These parameters are important to determine the ultimate bearing capacity of soil. The effect of shape of footing, depth of footing, and effect of water table on bearing capacity of soil are studied in following paragraphs.

4. EFFECT OF SHAPE OF FOUNDATION

The shape of footing influences the bearing capacity of soil. Terzaghi and other contributors have suggested the correction to the bearing capacity equation for shapes other than strip footing based on their experimental findings. In this study strip, square rectangular and circular shaped footing are used. keeping other parameters constant, the effect of shape of footing on ultimate bearing capacity of soil is studied. The values of ultimate bearing capacity for soil are determined by Terzaghi , Hansen, and Meyerhof equations ,the values in parenthesis indicate the safe bearing capacity of soil , these values are in kPa are tabulated in Table 2.

Table 2. Effect of shape on ultimate and safe bearing capacity of soil

Method of analysis	Shape of footing			
	strip	square	rectangular	circular
Terzaghi Eq.	918 (306)	1169.7 (390)	1107.4 (369.1)	1169.7 (390)
Hansen Eq.	849 (283)	1131 (377)	1060.8 (353.6)	1131 (377)
Meyerhof Eq.	850.2 (283.4)	1144 (381.33)	1070.4 (356.8)	1144 (381.33)

5. EFFECT OF DEPTH OF FOOTING ON BEARING CAPACITY

The depth of footing is important parameter which governs the ultimate bearing capacity of soil. The effect of depth of rectangular footing with(1.5mx2m)dimensions on bearing capacity of soil is studied for different depths by keeping other parameters constant. In this study it is assumed that irrespective of variation in depth of foundation the properties of soil remain constant. The values of ultimate bearing capacities determined for soil by different methods are as shown in Table 3.

Table 3.Effect of depth of footing on ultimate and safe bearing capacity of soil

Method of analysis	Depth of footing (m)			
	1	**1.2**	**1.5**	**1.8**
Terzaghi Eq.	981.3 (327.1)	1107.2 (369.1)	1293.3 (431.1)	1479.3 (493.1)
Hansen Eq.	909.9 (303.3)	1060.8 (353.6)	1296.5 (432.2)	1453.3 (396.4)
Meyerhof Eq.	979.7 (326.5)	1070.4 (356.8)	1303.1 (434.3)	1510 (503.3)

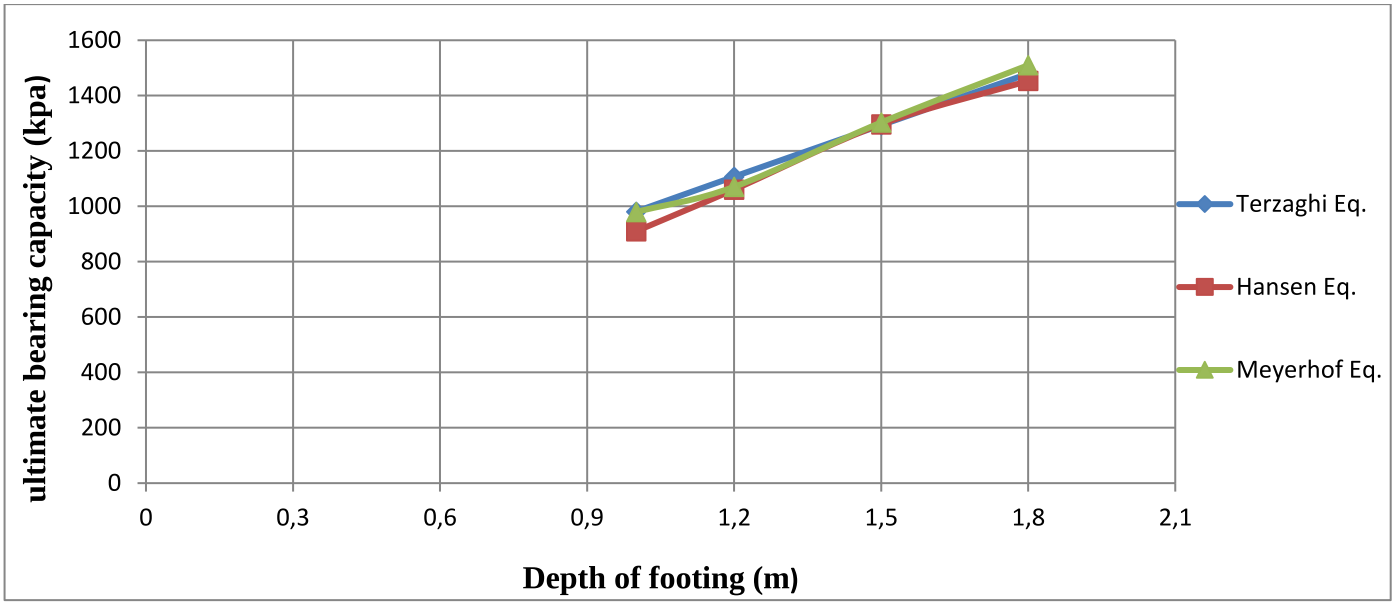

Figure 2. Variation of ultimate bearing capacity with depth of footing

6. EFFECT OF WATER TABLE FLUCTUATION

The basic theory of bearing capacity is derived by assuming the water table to be at great depth below and not interfering with the foundation. However, the presence of water table at foundation depth affects the strength of soil. Further, the unit weight of soil to be considered in the presence of water table is submerged density and not dry density. Hence, the submerged density should be used in second and third terms of bearing capacity equation to consider the effects of water table. Table 4. show the effect of water table variation on the bearing capacities of rectangular footing with(1.5m x2m) dimensions and 1.2m depth.

Table 4. Effect of water table on ultimate and safe bearing capacity bearing capacity of soil.

Method of analysis	Location of Water table			
	Water table may reach up to the ground level	Water table lies between the ground level and the base of footing	Water table may reach up to the base of the footing	Without water table
Terzaghi Eq.	569.2 (189.7)	780.6 (260.2)	992 (330.6)	1107.4 (369.1)
Hansen Eq.	554 (184.6)	763.7 (254.5)	973.3 (324.4)	1060.8 (353.6)
Meyerhof Eq.	558.4 (186.1)	724.3 (241.4)	890.2 (296.7)	1070.4 (356.8)

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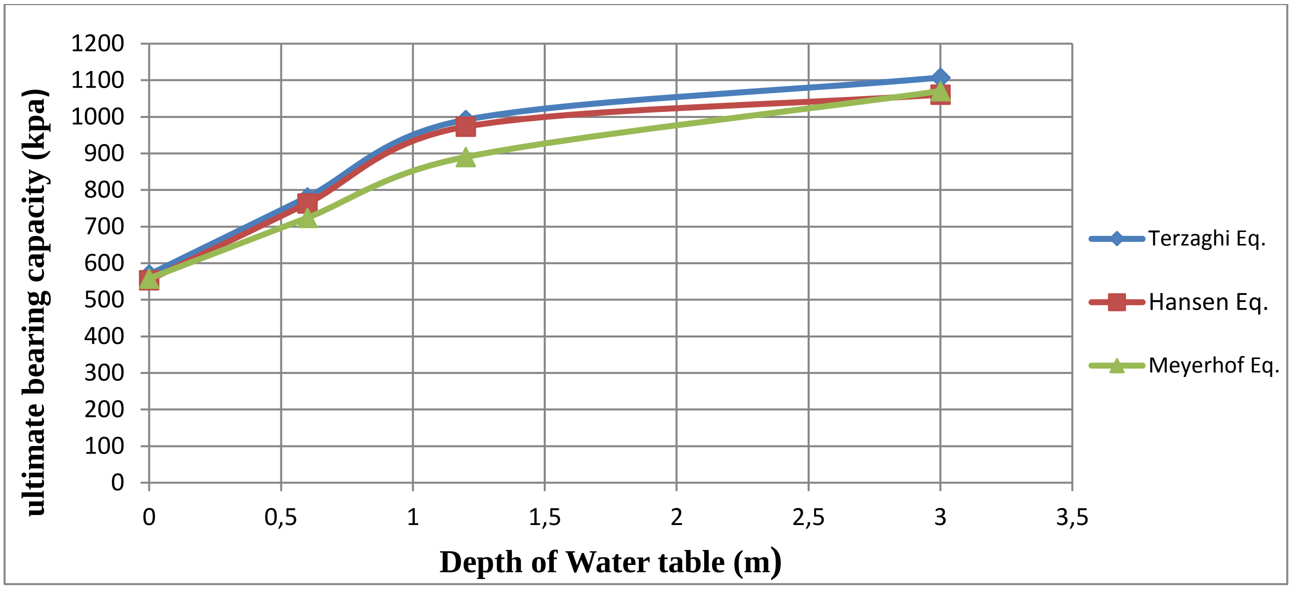

Figure 3 Variation of ultimate bearing capacity with depth of water table

7. CONCLUSIONS:

Based on this study the following conclusions are drawn :

a. The important parameters which govern the bearing capacity of soil are shape of footing, depth of proposed foundation, location of water table, cohesion, angle of internal friction, and unit weight of soil.

b. The values of ultimate bearing capacity determined for circular and square shaped footings are found to be higher than strip and rectangular footings. The square and circular shaped footings have fairly same values of ultimate bearing capacity.

c. The effect of shape of footing on ultimate bearing capacity determined by methods given by Terzaghi , Hansen and Meyerhof is different for different footings, due to combined effect of values of shape factors , depth factors and values of bearing capacity factors.

d. As depth of foundation increases the ultimate bearing capacity of soil increases. The effect of increase in depth on bearing capacities predominant due to increase in surcharge weight.

e. The position of ground water has a significant effect on the bearing capacity of soil. Presence of water table at a depth less than the width of the foundation from the foundation bottom will reduce the bearing capacity of the soil. The change in water level affects the properties of the density of soil. Similarly, if soil gets submerged its ability to support the load coming over its unit area is reduced when the water table is above the base of the footing, the submerged weight is used for the soil below the water table for computing the surcharge.

f. The Terzaghi equation, being the first proposed, have been very widely used. Because of their greater ease of use(one does not need to compute all extra depth and inclination factors) .Terzaghi equation is suitable for a concentrically loaded footing on horizontal ground.

g. Both Meyerhof and Hansen methods are widely used especially for footing with horizontal loads or sloping ground and for deep footing.

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