An Investigation into the Bearing Capacity Problems of Surface Footing on Uniform Sand

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Abstract— Status of soil-structure interaction today has a grey area which is yet to be understood well. Bearing capacity of soil with reference to a particular type, size and depth of footing is dependent upon not only on the deform characteristics of soil but also on the footing, in so far as its surface or smoothness is concerned. In order to get a better understanding about the before said matter, a model study (of footing) has been taken up with different sized and typed (concrete and steel) footings of varied roughness/smoothness in a soil medium which is sand. It has been learnt that the bearing capacity factor 'Ny' is not a function of angle of internal friction only, even surface roughness of the footing has a considerable effect on the value of 'Ny'. The surface roughness of the footing increases the bearing capacity factor 'Ny' considerably in case of dense sand.

Keywords— Bearing capacity,Surface roughness

I. INTRODUCTION

Bearing capacity (ultimate) of a footing is defined as the minimum intensity of pressure at which a footing shall fail either in shear or due to excessive settlement. Besides field loading tests the analytical methods for calculating soil bearing capacity may be summed up as theory of plasticity, classical earth pressure theory, theory of elasticity and methods relying on laboratory experimental results. Some of the early researchers who worked on this problem are W,J.M..Rankine (1985), H.E.Pauker (1989),Bell(1915), L.Prandtl (1920), K.Terzaghi (1943), W.S.Houlsby (1956) etc. Out of these Russian military engineer cornel Pauker and Rankine postulated their theories of bearing capacity of cohesion less soil based on earth pressure theories. Prandtl's bearing capacity equation based on plastic equilibrium theories was applicable to cohesive or C-Φ SOIL. With Terzaghi and Taylor's correction the modified Prandtl's formula could he used for non cohesive soil (c=0).

Terzaghi's analysis for ultimate bearing capacity of a footing was based on partly theory and partly experimental. It was an improvement on the Prandtl's theory of plastic equilibrium.

During derivation of the equation of bearing of a strip footing, Terzaghi assumed the footing to be rough and also the two slanting lines of the elastic triangular wedge just below the footing make an angle of 'Φ' with the horizontal. However later model tests conducted by De Beer and Vesic (l958) showed that the Terzaghi's assumed rupture surface for bearing capacity failure is correct but the two slanting sides of the elastic prism make an angle of '45°+Φ/2' with the horizontal instead of (Φ) with the horizontal. Based on this mechanism of failure the ultimate bearing capacity of a strip footing may be written as

$$Q_c = Q_c + Q_q + Q_y \text{......................................} (1)$$

Where Q_c, Q_q and Q_y, are bearing capacity due to cohesion, surcharge and unit weight of the soil respectively. In deriving this theory Terzaghi assumed that the failure surface does not extend above the base of the footing i.e. the shear resistance aboNe the base of the footing is neglected. To obviate this lapse of the assumption surface footings have been chosen for analysis. With this strategy Qq=0. Also by choosing sand as the load bearing medium Q_c= 0, so

$$Q_u = Q_y \text{..} (2)$$

In addition to the above 3 types of uniform sand (4,75 mm to 2mm, 2 mm to 425μ and < 475μ) were chosen as the load bearing medium. The purpose of taking uniform sand was to keep 'Φ, more or less constant through out the testing.

After Terzaghi's simplified pioneering work many researchers (Mayerhoff,1951,1963;Lundgren and Mortensen,1953;Balla,1962;) gave their solutions which showed that the hearing capacity factors Nc, Nq do not change in a remarkable manner, on the other hand the value of `Ny' for any particular value of 'Φ' change in a wide manner which may be due to the assumption of a wedge shape soil zone located directly below the footing. However this investigation veers around Terzaghi's mode of analysis.

Thus equation of bearing capacity of a surface footing on sand according to Terzaghi i.e. equation (2) can be written as

$$Qu = 0.5Y\ B\ Ny \text{.............................} (3)$$

II. EXPERIMENTAL SET UP

The test was carried out in a masonry tank having an internal dimension of 60cm*60cm*30 cm. A mild steel loading frame was used, to the center of which a hollow vertical shaft (guide pipe) has been welded. The solid iron rod, which carries the loading platform at its top passed through the hollow cylindrical metal shaft. The bottom of the iron rod was threaded so that either the smooth steel footing or small metal plate in case of rough concrete footing is used, this plate rests over the concrete block used as footing. There is a horizontal bolt connected to the hollow vertical shaft to clamp and unclamp the iron rod carrying the loading platform. To accommodate higher intensity of loading a wooden platform has been attached to the steel loading platform by nut and bolt arrangement. Two dial gauges with magnetic base are used for measuring the settlement of footings. The dial gauges used have a least count of 0.001 cm and 5 cm range. The dial gauges were mounted on two opposite sides of the wooden platform to measure the settlement of the footing. Steel (smooth base) and concrete (rough base) footings of circular (5.08 cm Φ and 6.35 cm Φ and square (5.08 cm* 5.08 cm and 6.35 cm * 6.35 cm) shape are used.

Three types of dry uniform sand (4.75 mm to 2mm, 2 mm to 425µ and < 475µ) representing coarse, medium and fine sand were used as the load bearing medium. The properties of sands were given in Table-1.

TABLE I. PROPERTIES OF SANDS

Sl.No	Particle Size	Specific Gravity	Relative Density (I_D) in %	Placement Density (Kg/m3)	Uniformity coefficient (C_U)	Coefficient of Curvature (C_C)
1	4.75mm to 2mm(Coarse Sand)	2.605	69.76	1541	-	-
2	2mm to 425µ (Medium Sand)	2.616	63.67	1542	1.33	0.947
3	Finer than 425µ (fine Sand	2.718	62.80	1519	1.75	1.329

The loading frame was put across the masonry tank so that the axial loading shaft occupies the central position. After the loading platform was loaded to desired degree, the rod carrying the platform was unclamped and the settlement was observed for a period of 24 hours before applying the next load increment .This procedure was repeated till failure of footing took place. The experimental set up was shown in figure -1. The value of bearing capacity factor 'Ny' was calculated from the experimental ultimate bearing capacity value for both smooth and rough footings.

Figure – 1: Experimental set up

III. TEST RESULTS

TABLE II. COMPARISON OF 'N_Y' VALUES FOR SMOOTH AND ROUGH FOOTING(5.08CM X5.08CM)

Φ in Degree	Smooth Footing	Rough Footing	Difference	% Increase
40	72.18	168.47	96.29	133.40
42	118.72	365.105	246.385	207.53
44	195.44	562.06	366.62	187.58

FIGURE – 2: COMPARISON OF 'N_Y' VALUES FOR SMOOTH AND ROUGH FOOTING(5.08CM X5.08CM)

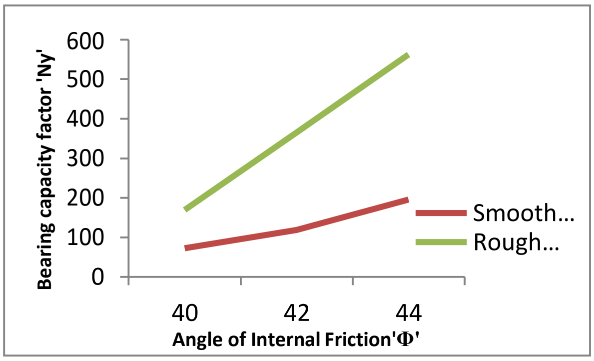


TABLE III. COMPARISON OF 'N_Y' VALUES FOR SMOOTH AND ROUGH FOOTING(6.35CM X6.35CM)

Φ in Degree	Smooth Footing	Rough Footing	Difference	% Increase
40	78.48	182.46	103.98	132.49
42	134.8	372.76	237.96	176.53
44	199.28	577.39	378.11	189.73

FIGURE – 3: COMPARISON OF 'N_Y' VALUES FOR SMOOTH AND ROUGH FOOTING(6.35CM X6.35CM)

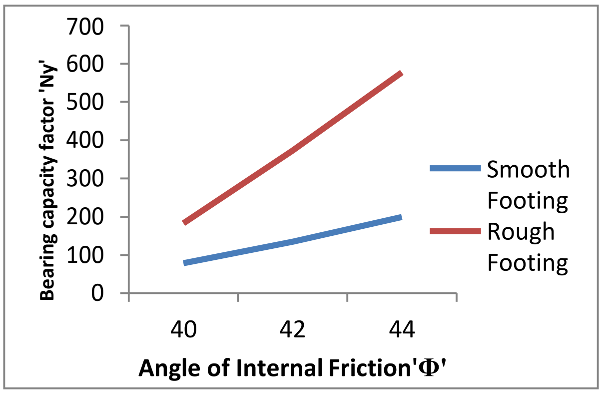


TABLE IV. COMPARISON OF 'N_Y' VALUES FOR SMOOTH AND ROUGH FOOTING(5.08CM Φ)

Φ in Degree	Smooth Footing	Rough Footing	Difference	% Increase
40	58.835	152.92	94.08	159.90
42	108.76	293.62	184.86	169.97
44	146.90	441.99	295.09	200.87

FIGURE – 4: COMPARISON OF 'N_Y' VALUES FOR SMOOTH AND ROUGH FOOTING(5.08CM Φ)

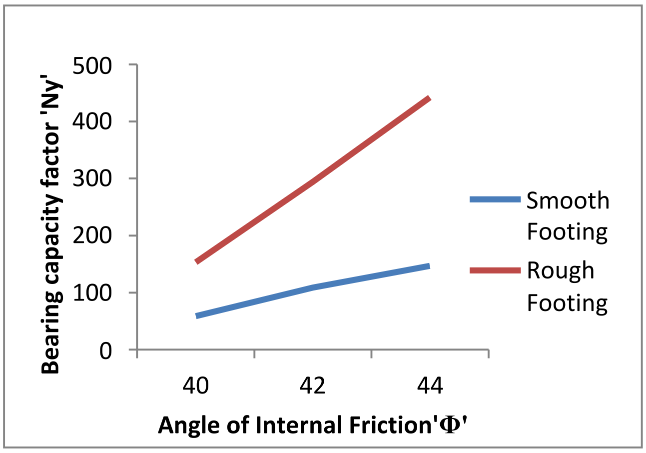


TABLE V. COMPARISON OF 'N_Y' VALUES FOR SMOOTH AND ROUGH FOOTING(6.35CM Φ)

Φ in Degree	Smooth Footing	Rough Footing	Difference	% Increase
40	58.31	141.41	83.1	142.51
42	109.07	289.02	179.95	164.98
44	158.4	460.89	302.49	190.96

FIGURE – 5: COMPARISON OF 'N_Y' VALUES FOR SMOOTH AND ROUGH FOOTING(6.35CM Φ)

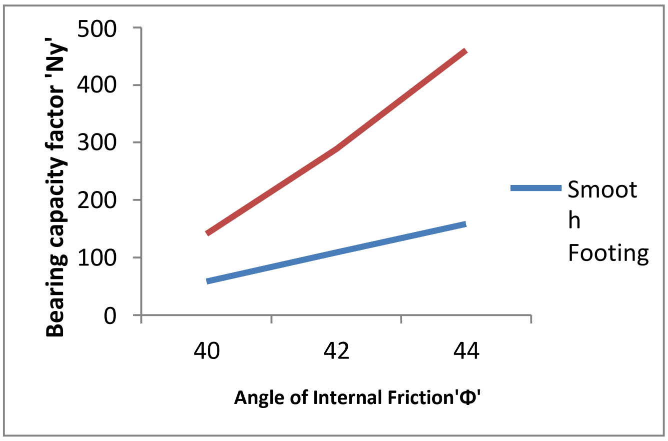


TABLE VI. COMPARISON OF BEARING CAPACITY FACTOR 'N_Y' FOR SMOOTH CIRCULAR FOOTINGS(CASSIDY VS. EXPERIMENTAL)

Φ in Degree	According to Cassidy	Experimental Values	
		5.08cm Φ	6.35cm Φ
40	50.46	58.83	58.31
42	96.316	108.76	109.07
44	142.172	146.9	158.40

FIGURE – 6 : COMPARISON OF BEARING CAPACITY FACTOR 'N_Y' FOR SMOOTH CIRCULAR FOOTINGS(CASSIDY VS. EXPERIMENTAL)

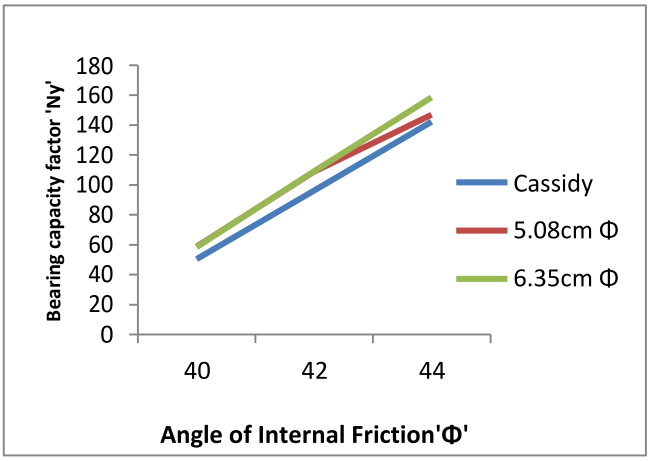
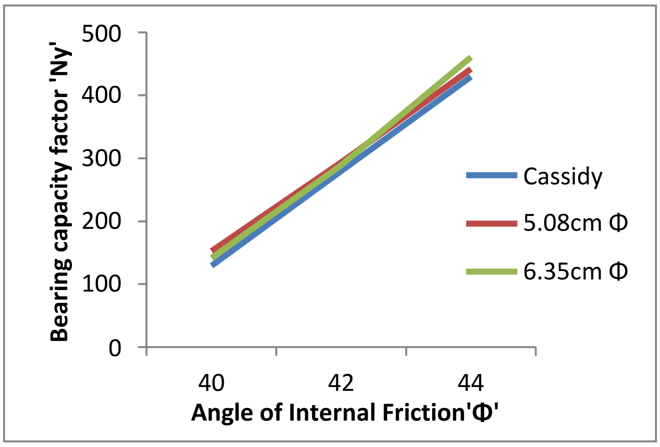


TABLE VII. COMPARISON OF BEARING CAPACITY FACTOR 'N_Y' FOR ROUGH CIRCULAR FOOTINGS(CASSIDY VS. EXPERIMENTAL)

Φ in Degree	According to Cassidy	Experimental Values	
		5.08cm Φ	6.35cm Φ
40	129.4	152.92	141.41
42	279.64	293.62	289.02
44	429.88	441.99	460.89

FIGURE – 7 : COMPARISON OF BEARING CAPACITY FACTOR ‘N_Y’ FOR ROUGH CIRCULAR FOOTINGS(CASSIDY VS. EXPERIMENTAL)



IV. CONSLUSION

Graphs of bearing capacity factors versus angle of internal friction were drawn for all the above cases. The comparison between smooth and rough footings were shown in figure 2 to 5.From figure 2 to 5, the bearing capacity factor `Ny' of square footings was approximately 2.3 times than that of smooth one in fine sand and 2.8 times in case of medium and coarse sand. The same trend also holds well in case of circular footings. In case of rough footings, with increase in angle of internal friction the value of bearing capacity factor ‘N_Y’ increases at a faster rate as compared to smooth footings.

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