EFFECT OF SHAPE AND SIZE ON LOAD CARRYING CAPACITY OF FOUNDATION: A CASE STUDY

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ABSTRACT

Soil is a universally occurring natural element formed due to continuous denudation of different sorts of rocks and minerals. Each type of soil inherits a lot of similar characteristics from its parent rock like chemical composition, physical appearance, color, texture etc. In spite of these, there are yet a lot of other important characteristics that significantly comes into play in the construction sector and civil engineering. The bearing capacity is the most important soil property which governs the design of foundation soft clay strata and is often unable to bear the load transferred from the super structure to the foundation. Bearing capacity and settlement are the two important parameters in the field of geotechnical engineering as bearing capacity is affected by various factors like dimensions of footing, shape and type of loading etc. This report discusses the influence of size and shape on the bearing capacity of footing for G+3 commercial building. The analysis is a case study from India which involves initially finding index and physical properties of soil collected from the residential area of Nasik city. The study performed gives a detail study on the variation of contact pressure and load bearing capacity of underlying soil with respect to two types of footing (square and circular). Later the analysis has been performed for the varying width of footing. The report also states the most economical size and shape that can be adopted for the same site. The complete analysis is performed using software module 'GEO-5'.

Keyword: - *Bearing Capacity, Contact Pressure, Shape, Size, Width, Shape Factors, GEO-5*

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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. There are various methods for calculation of bearing capacity of soil put forth by scientists like Prandtl, Terzaghi, Meyerhoff, Hansen, Vesic and others. Principal factors that influence ultimate bearing capacities are type of soil, width of foundation, soil weight in shear zone and surcharge. Structural rigidity and the contact stress distribution do not greatly influence bearing capacity. Bearing capacity analysis assumes a uniform contact pressure between the foundation and underlying soil. With other factors unchanged the type of failure of soil, depth of foundation, and effect of water table also governs the bearing capacity of soil. Soil is the most important factor due to increase in population and industrialization; there is increase in construction activities in the cities and industrial area. Hence, it has become necessary to carry out construction activities on marshy land, low lying area, expansive soil having swelling and shrinkage characteristics, water logged areas etc. Safe bearing capacity values are assumed depending upon type of soil encountered at proposed depth of foundation. In addition to properties of soil, width of foundation, depth of foundation, water table variation near the base of the footing, eccentricity of loading governs the ultimate and safe bearing capacity of soil. Thus, based on investigations carried out, it will be possible to decide optimum depth of foundation for proposed structure, from economy and practical considerations.

M. S. Dixit et. al[1] studied the effect of depth of footing on load carrying capacity and concluded that increase in depth increases the bearing capacity of footing due to increase in surcharge weight. Arindam Das et. al [2] studied the different failures occurring in footing .For determining the bearing capacity of soil he used the Terzaghi's bearing capacity equation and Hansen's bearing capacity equation. Mr. Umesh N. Wghmare **et**. al [4] studied the important parameters of the soil, which governs the bearing capacity of soil such as cohesion, unit weight of soil, depth and width of soil, angle of friction. He performs the experiments on soil and laboratory investigation of soils for different site. Studied on geotechnical properties of soil. Then he conclude that for proposed structure, if water table may reach nearer to base of footing or up to ground level necessary water table correction must be applied for achieving the values of safe bearing capacity for design of foundation

1.1 Effect of Size on Bearing Capacity of Footing

The size effect of the footing and the ultimate bearing capacity can be observed for not only uniform grounds, but also multi-layered grounds. Since the ultimate bearing capacity formula was developed for uniform grounds, the applicability of the method is severely limited in design practice. The basic analysis has been done so far based on Terzaghi's equation. It involves majorly the dimensions of footing i.e. Width and depth of footing. Hence, the analysis of behavior of footing under different width size may be analyzed using Terzaghi's below equation

$$q = CN_C + 0.5\gamma BN_\gamma + \gamma D_F N_q$$

Where,

N_c, N_γ and N_q are the bearing capacity factors, which are functions of the internal friction angle of the soil, ϕ.

γ: unit weight of soil (kN/m³),

D_f: depth of footing (m), and

B: footing width (m)

$N_q = \tan^2 (45 + \phi/2)\, e^{\pi \tan\phi}$ and $N_\gamma = 2(N_q+1) \tan\phi$

1.2 Effect of shape on bearing capacity of footing

Shape effects on bearing capacity of rectangular footing are evaluated without using the conventional superposition. To avoid error induced by superposition, cohesion and soil unit weight are normalized as one parameter. The major factors which enhance the load carrying capacity of footing are the shear areas and shear parameters which completely are a function of footing dimension; hence these parameters vary with change in plan shape of footing. The effects of footing shape are also different with the characteristics of soil. In general, effects of footing shape are more obvious for soils with high cohesion, while they are slight on soils with low cohesion.

Table-1: Bearing Capacity Factors

Shape of base	Shape factor		
	Sc	Sq	S_γ
1. Rectangular	1+0.2(B/L)	1+0.2(B/L)	1-0.4(B/L)
2. Square	1.3	1.2	0.8
3. Circular	1.3	1.2	0.6

2. METHODOLOGY

2.1 Site Characteristics

The construction site is a residential cum commercial G+3 building which is located at a highly dense residential area of Nasik, India. The top soil is found to be clayey up to a shallow depth and thereafter weathered basalt was found. The geological strata were determined by trench method itself which can be seen in below figures.

Fig 1 - Location of site

Fig 2 - Soil strata

2.2 Test performed

The soil samples were collected from site considering each layer, and various tests were performed to determine physical properties as well as shear parameters. Classification was performed using sieve analysis and specific gravity test along with consistency limit tests. For obtaining bearing capacity of soil beneath footing, shear parameters are necessary which were calculated experimentally using Direct Shear Test. The analysis for footing has been done under Spread Footing Module of GEO-5

Fig 3- Direct shear test

2.3 Soil properties

Table-2: Bearing Capacity Factors

SR NO.	Soil	Depth Of Strata (m)	Cohesion ‘C’ in Kpa	Angle of friction ‘ϕ’ in °	Specific gravity ‘γ’ in KN/m^3
1.	Soft clay	1.2	35	18	16
2.	Soft murum	0.8	1.8	29	18
3.	Hard murum		1.2	32	20

2.4 Existing structural properties

The existing project consists of varying structural dimensions of columns and footings, but for analysis a single footing with maximum dimension and load is considered. The proposed G+3 building consists of a square column having size 380mm x 380mm in plan supported on a square flat slab footing of side 2m. The analysis has been done for the footing subjected to maximum design load of 1100 KN. The existing design footing is assumed to be resting at depth 2.5 m (i.e. on hard murum) from ground level.

2.5 Change in parameters

The study includes analysis for footing for change in parameters with respect to width. The width has been reduced from 2.2m to 1.7m at an interval of 0.1m until FOS (Factor of Safety) falls below 1.5 (IS 456: 2000) . The comparative analysis has been performed for reducing width of square footing. The results have been obtained for variation in design bearing capacity and contact pressure below footing. Later, for obtained results, a comparison is done by replacing square footing with circular one for same lateral dimension. The results reflect the percentage change in design bearing capacity (R_d) and contact pressure (CP).

3. RESULTS

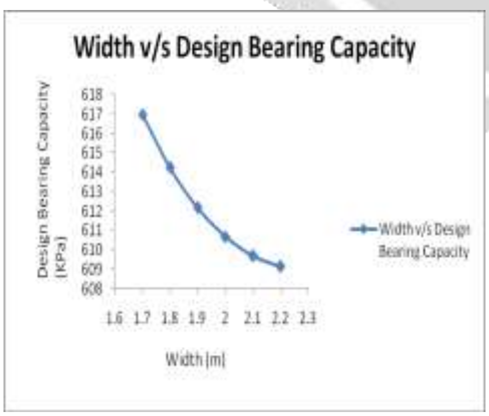
3.1 Square footing

Table 3 shows variation in design bearing capacity and contact pressure with respect to change in width. The FOS for each width has been found out, where analysis has been terminated since FOS fell down below than 1.5.

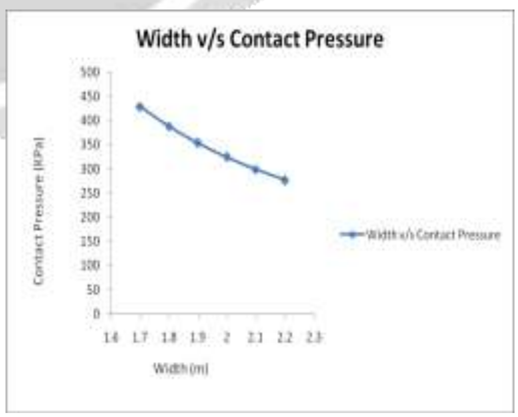
Table -3 R_d and CP for square footing

Sr. No.	Width	R_d	CP	FOS
1	2.2	609.13	276.68	2.2
2	2.1	609.7	298.71	2.04
3	2	610.68	324.13	1.88
4	1.9	612.17	353.66	1.73
5	1.8	614.23	388.25	1.58
6	1.7	616.97	429.12	1.44

Graph -1 and Graph -2 represents the change in behavior of footing under varying reduced width



Graph -1, Width v/s Design Bearing Capacity



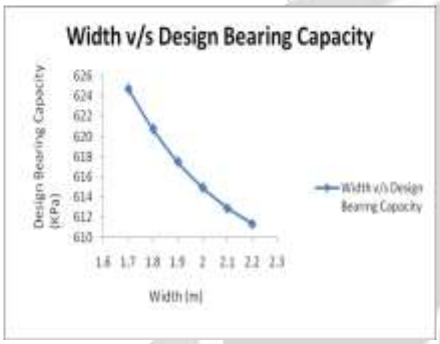
Graph -2, Width v/s Contact Pressure

3.2 Circular footing

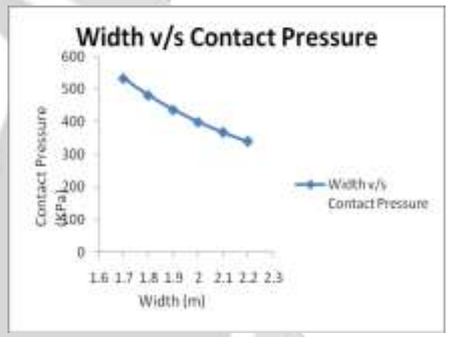
Table-4 Rd and CP for circular footing

Sr. No.	Width	Rd	CP	FOS
1	2.2	611.36	338.78	1.8
2	2.1	612.9	366.86	1.67
3	2	614.91	399.27	1.54
4	1.9	617.48	436.92	1.41
5	1.8	620.71	481.2	1.29
6	1.7	624.7	533.13	1.17

Graph -3 and Graph -4 represents the change in behavior of footing under varying reduced width



Graph -3 Width v/s Design Bearing Capacity

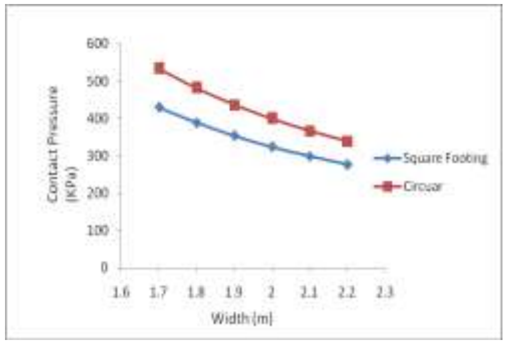


Graph -4, Width v/s Contact Pressure

3.3 Comparative study of square and Rectangular footing

Table-5 %age Increment Between square &circular footing

Sr. no.	Depth	Contact Pressure		
	(m)	Square	Circular	%age Increment
1	2.2	276.68	338.78	22.4447
2	2.1	298.71	366.86	22.81477
3	2	324.13	399.27	23.18206
4	1.9	353.66	436.92	23.54239
5	1.8	388.25	481.2	23.94076
6	1.7	429.12	533.13	24.23798



Graph -5, Comparison between square & Circular Footing

4. CONCLUSIONS

1. From results it is obtained that, with increase in width the contact pressure (CP) decreases as load transferred on footing is distributed vertically on larger area. For the given site condition the width can be reduced up to 1.8m within safety when no effect of water table is considered.
2. From the results, it is clearly seen that the shape of footing imparts huge change in contact pressure due to change in shear parameters for the same width but different shape. As compare to circular footing, square footing is advantageous results with respect to contact pressure.
3. Average increment in contact pressure is 23.360% for circular footing with respect to square footing.
4. For the same ground condition, where width of square footing can be reduced to 1.8m, the required width must be 2m for circular footing within factor of safety.

5. Acknowledgement

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