EFFECT OF DEPTH OF FOOTING AND WATER TABLE ON BEARING CAPACITY OF FOUNDATION SOIL: 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 depth and water table 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 effect of water table. Later the analysis has been performed for the varying depth of footing. The report also states the most economical depth that can be adopted for the same site considering water table and. The complete analysis is performed using software module 'GEO-5'.

Keyword: - *Bearing Capacity, Water Table, Depth, Saturated Soil, GEO-5*

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1. INTRODUCTION

Details are critical when constructing a sound building foundation that will withstand water and control dampness. Foundation repairs are often difficult and expensive, so it's important to build a foundation correctly the first time. Building a sound foundation depends particularly a lot upon the depth of ground water table at the site. Lesser the depth, harder it is to build a strong foundation as the soil will have low bearing capacity. Building a sound establishment depends especially a great deal upon the profundity of ground water table at the site. . Lesser the profundity, harder it is to assemble a solid establishment as the dirt will have low bearing limit. As talking about bearing limit, it is the greatest anxiety which a specific soil can withstand without falling flat. This paper accentuates on the specific theme of the different impacts of the water table on the bearing limit of soil and consequently on the simplicity of general establishment development. 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 in the construction world, in which the property of bearing loads coming upon has to be suitable. This property is the most significant one as the stability of the structure mostly depends on it. 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. Arindam Das et. al. [1] studied the important parameter which govern unit weight of soil depth of foundation and angle of internal friction and concluded that depth of foundation increases bearing capacity increases and higher water table lesser the bearing capacity of soil. 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. [6] 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 performed the experiments on soil and laboratory investigation of soils for different site. Studied on geotechnical properties of soil.

1.1 Effect of depth on bearing capacity of soil

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 depth may be analyzed using Terzaghi's equation

$$q = CN_C + 0.5\gamma B N_\gamma + \gamma D_f N_q$$

Where,

Nc, Nγ and Nq are the bearing capacity factors, which are functions of the internal friction angle of the soil, which can be calculated as

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

γ: unit weight of soil (KN/m^3),
D_f : depth of footing (m),and
B: footing width (m)

1.2 Effect of water table

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 water table is seldom above the base of the footing, as this would, at the very least, cause construction problems. If it is, however, the 'q' term requires adjusting so that the surcharge pressure is an effective value. This computation is a simple one involving computing the pressure at the GWT using that depth and the wet unit weight H- pressure from the GWT to the footing base using that depth X effective unit weight 'γ'. If the water table is at the ground surface, the effective pressure is approximately one-half that with the water table at or below the footing level, since the effective unit weight 'γ' is approximately one-half the saturated unit weight.

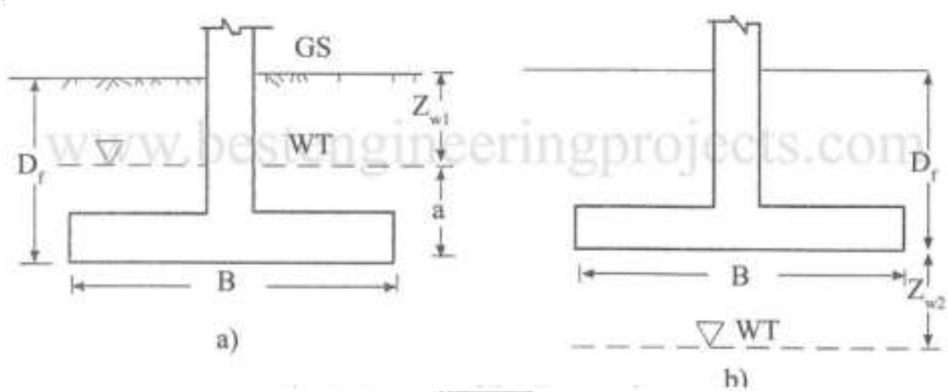


Fig-1 Location of Water Table

For any position of the water table, Bearing capacity can be found out using following equation:

$$q_f = c.\, N_C + \gamma_1\, D\, N_q\, Rw_2 + 0.5\, \gamma_2\, B\, N_\gamma\, Rw_1$$

Where, Rw_1 and Rw_2 are the reduction factors for water table and can be computed as shown in above figure.

$Rw_1 = 0.5(1+Z_{W1}/B)$
$= 0.5$ if $Z_{W1}=0$
$= 1.0$ if $Z_{W1} \geq B$

$Rw_2 = 0.5(1+Z_{W2}/D_f)$
$= 0.5$ if $Z_{W2}=0$
$= 1.0$ if $Z_{W1} \geq D_f$

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- 2 Location of site

Fig- 3 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

2.3 Soil properties

Table-1 Bearing Capacity Factors

SR NO.	Soil	Depth Of Strata (m)	Cohesion 'C' in Kpa	Angle of friction 'ϕ' in °	Specific gravity 'ɣ' 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 Changes in Parameters

The study includes analysis for footing for change in parameters with respect to depth of footing and location of water table. The depth has been reduced from 2.5 m to 1.9 m at an interval of 0.1 m until FOS (Factor of Safety) falls below 1.5 (IS 456: 2000) . The change in location of water table has been considered from base of footing to until it reaches the ground level. The comparative analysis has been performed for reducing depth of square footing in comparison of the circular footing. The results have been obtained for variation in design bearing capacity and contact pressure below footing. Later, the results reflect the percentage change in design bearing capacity (R_d) and contact pressure (CP).

3. RESULTS

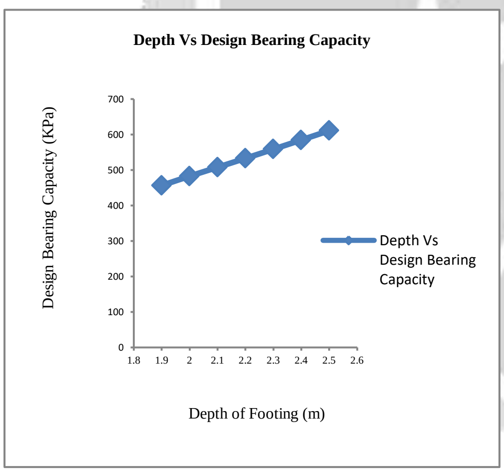
3.1 Change in Depth For Square footing

The Table -2 represents the numerical values obtained while considerable change in depth of footing is assumed. The values for R_d is changes significantly, there is unremarkable change in contact pressure.

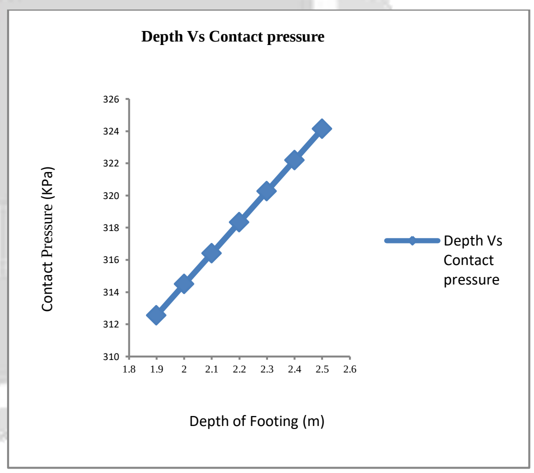
Table -2 R_d and CP Values for Square Footing

Sr. No.	Depth	R_d	CP	FOS
1	2.5	610.68	324.13	1.88
2	2.4	584.42	322.20	1.81
3	2.3	558.47	320.27	1.74
4	2.2	532.85	318.34	1.67
5	2.1	507.55	316.41	1.6
6	2.0	482.57	314.49	1.53
7	1.9	456.32	312.56	1.46

Graph 1, Graph 2 represents the amount of change in design bearing capacity and contact pressure for the square footing with change in the depth of footing.



Graph- 1, Depth Vs Design Bearing Capacity



Graph- 2, Depth Vs Contact Pressure

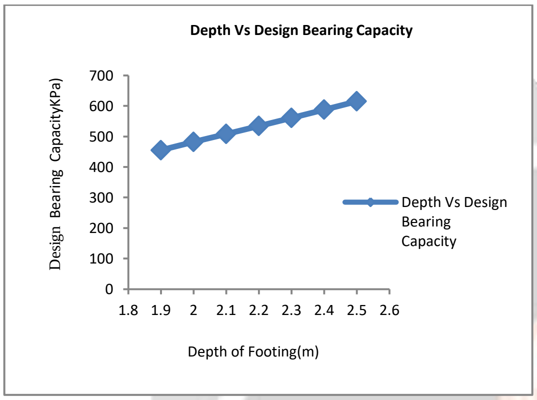
3.2 Change in Depth for Circular footing

The Table -2 represents the numerical values obtained while considerable change in depth of footing is assumed. The values for R_d changes significantly, while there is unremarkable change in contact pressure.

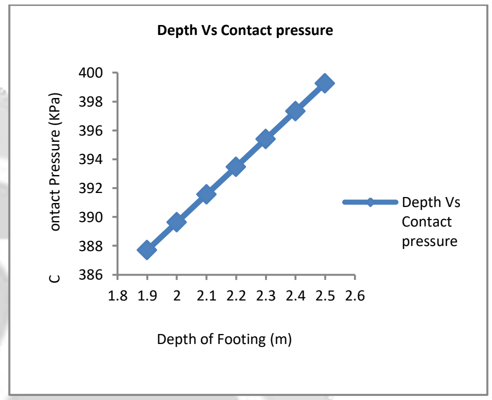
Table -3 R_d and CP Values for Circular Footing

Sr.No	Depth	Rd	Cp	FOS
1	2.5	614.91	399.27	1.54

2	2.4	587.64	397.34	1.48
3	2.3	560.74	395.41	1.42
4	2.2	534.20	393.48	1.36
5	2.1	508.02	391.56	1.30
6	2 .0	482.20	389.63	1.24
7	1.9	455.29	387.7	1.17



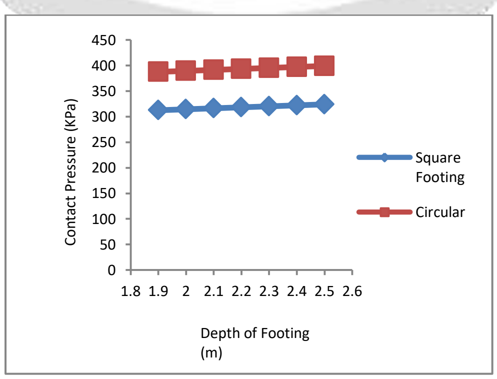
Graph- 3, Depth Vs Design Bearing Capacity



Graph- 4, Depth Vs Contact Pressure

Table -4 – Percentage Increment In Contact Pressure

Sr. No.	Depth	Contact Pressure		Percentage Inc
		Square	Circular	
1	2.5	324.13	399.27	23.18206
2	2.4	322.2	397.34	23.32092
3	2.3	320.27	395.41	23.46145
4	2.2	318.34	393.48	23.60369
5	2.1	316.41	391.56	23.75083
6	2.0	314.49	389.63	23.89265
7	1.9	312.56	387.70	24.04018

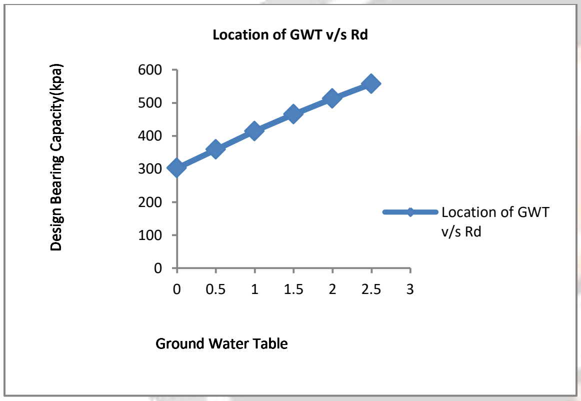


Graph- 5, Comparative Depth Vs Contact Pressure for Square and Circular Footing

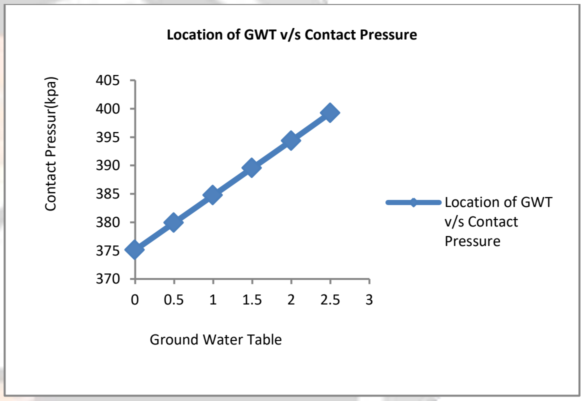
3.3 Effect of water table on square footing

Table -5 Rd and Contact Pressure for Location of GWT on Square Footing

Sr.No.	Location of water table	Rd	Contact pressure
1	No GWT	610.68	324.13
2	2.5	546.97	324.14
3	2	503.35	319.22
4	1.5	457.02	314.4
5	1	407.41	309.58
6	0.5	352.89	304.76
7	0	298.38	299.94



Graph- 6, Location of GWT Vs Design Bearing Capacity



Graph- 7, Location of GWT Vs Contact Pressure

3.4 Effect of Water table on Circular Footing

Table -5 Rd and Contact Pressure for Location of GWT on Circular Footing

Sr.No.	Location of water table	Rd	Contact pressure
1	No GWT	614.91	399.27
2	2.5	557.11	399.27
3	2	512.47	394.63
4	1.5	465.03	389.54
5	1	414.25	384.72
6	0.5	358.43	379.90
7	0	302.65	375.08

The results show heavy reduction in design bearing capacity of foundation in both square as well as circular type of footing, while the contact pressure doesnot show any wider change in results. Reduction in design bearing capacity has been charted as below in comparison to no GWT.

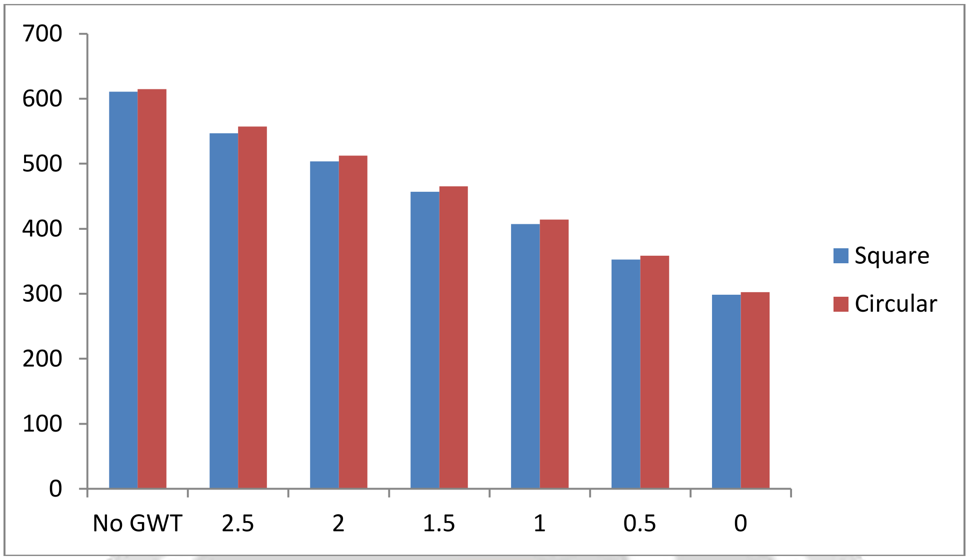


Chart 1, Comparative Reduction in Design Bearing Capacity for Different location of GWT

4. CONCLUSIONS

1. From the results it can be concluded that with decrease in depth of foundation, the design bearing capacity increases considerable, as the surcharge load coming on the foundation increases. For the given site condition, the adopted depth is 2.5 m, but this depth can be reduced upto 2 m without failure as factor of safety remains in prescribed limit without considering the effect of ground water table.
2. While the amount of contact pressure changes with respect to shape, the design bearing capacity doesnot depend much on it and percentage reduction is almost same for both shape of footing. But in such case circular footing need to be rest at 2.5 m only.
3. The location of ground water table plays an important role in design bearing capacity of footing. The higher is the GWT, the lesser will be the bearing capacity. For the given site condition, the footing size of 2 m can be rest at 2.5 m depth only while the water table is at base of footing.
4. In increase in water table level, the structure may fail due to reducing design bearing capacity.

5. ACKNOWLEDGEMENT

We state our sincere gratitude to Nashik based Er. Rohit Nimse, structural engineer, STRUCTINFRA Pvt. Ltd. for providing us sufficient data of the site for case study.

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