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Influence of Hydraulic Gradient on the Behaviour of Strip Footing Resting on Cohesive Soil

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Abstract: The influence of position of water table and magnitude of hydraulic gradient on the behaviour of a strip footing resting on a cohesive soil is investigated by carrying out a series of finite element analyses using the software PLAXIS 2D. The results of finite element analyses are compared with those obtained from conventional mathematical models. It is observed that the effect of magnitude of hydraulic gradient is much more pronounced than the effect of position of water table. The results obtained from finite element analyses with respect to position of water table slightly differ from those obtained from conventional analyses.

Keywords: Water Table, Hydraulic Gradient, Finite Element Analysis, Mathematical Model.

I. INTRODUCTION

Bearing capacity of shallow foundations is a fundamental issue in geotechnical design and has been widely addressed. Many exactor established theoretical solutions exist for shallow foundations under uniaxial vertical load, pure horizontal load, pure moment centrally applied inclined load and eccentrically applied vertical loads ([1], [4], [12], [16], [17]). In general, most geotechnical analyses are treated deterministically, in which the soil medium is considered as a single homogeneous layer or a layered medium with uniform material properties in each layer based on “average” values of soil parameters. However, in nature, soil parameters generally show significant spatial variation in both vertical and horizontal directions, and the results of deterministic analyses are only expected values which may vary from actual performance of constructed facilities [3]. In most of the practical situations, the bearing capacity will be considerably influenced by the presence of adjacent footings [9].Many researchers have carried out numerical and experimental work to study the mechanisms of failure and bearing capacity of soil in the past decade ([5], [6], [7], [8], [10], [11], [13], [14], [15] and [18])

The presence of water table has considerable influence on bearing capacity of a footing. In the classical theory, influence of water table is quantified by considering the reduction in unit weight of soil due to the submergence. In most of the recent studies the influence of position of water table is not considered. The bearing capacity will also be influenced by the hydraulic gradient of ground water wherever there is seepage. In this paper, the influence of position and hydraulic gradient of water table on bearing capacity of a strip footing is investigated by carrying out a series of finite element analyses using the software PLAXIS 2D. The parameters varied are depth of footing from ground level, position of water table and magnitude of hydraulic gradient.

II.FINITE ELEMENT ANALYSIS

Finite element analyses are carried out using the commercially available finite element software PLAXIS 2D. For simulating the behaviour of soil, different constitutive models are available in the FE software. In the present study Mohr-Coulomb model is used to simulate soil behaviour. This non-linear model is based on the basic soil parameters that can be obtained from direct shear tests; internal friction angle and cohesion intercept. Since strip footing is used, a plain strain model is adopted in the analysis. The settlement of the rigid footing is simulated using non zero prescribed displacements.

The displacement of the bottom boundary is restricted in all directions, while at the vertical sides; displacement is restricted only in the horizontal direction. The initial geostatic stress states for the analyses are set according to the unit weight of soil. The soil is modelled using 15 noded triangular elements. Mesh generation can be done automatically. Medium mesh size is adopted in all the simulations.The size of the strip footing (B) is taken as one meter and the width and depth of soil mass are taken as 5m and 8m respectively in all analyses. The geometric model is shown in Fig 1 and typical stress distribution in soil after loading in Fig 2.

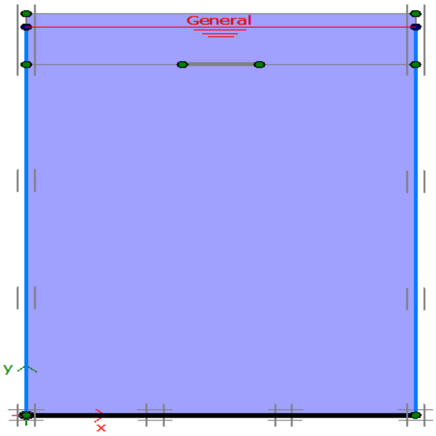

Fig. 1. Geometric model

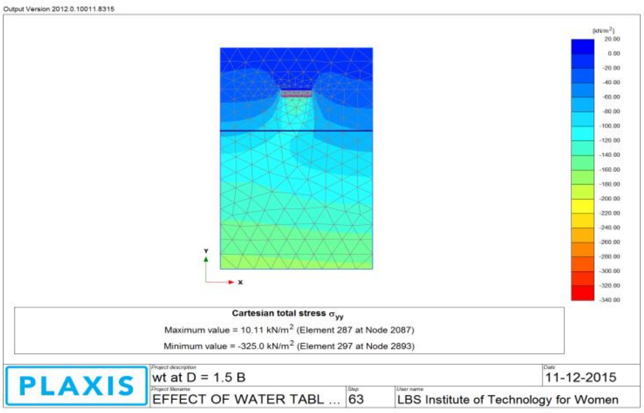

Fig. 2 Stress Distribution in Soil

TABLE I PROPERTIES OF SOIL

Property	Clay
Specific gravity	2.23
Dry unit weight (kN/m^3)	15
Liquid Limit (%)	58
Plastic Limit (%)	22
Plasticity Index (%)	36
Permeability (m/sec)	3.03×10^{-6}
Friction angle Φ (degrees)	5
Cohesion (kPa)	20

The properties of a locally available Clayey soil, are assigned as material parameters. The properties of soil are given in Table I. The soil is modeled using 15-node triangular elements. Poisson's ratio of the soil is assumed to be 0.25 for all cases. The depth of footing is defined by the dimensionless parameter (D/B), where D and B are depth and width of footing respectively. Similarly the depth of water table is defined by the parameter (H/B), where H is the depth of water table from ground surface. The hydraulic gradient is defined by (I = h/L), where h is the difference in level between water surface at two reference points and L, the horizontal distance between these two points. The details of parameters varied in the study are outlined in Table II.

TABLE II PARAMETERS VARIED

Sl. No:	Depth of footing (D/B)	Depth of Water Table (H/B)	Hydraulic Gradient (h/L)
1	0.5,1,1.5,2	0.25, 0.5, 0.75, 1, 1.25, 1.5, 1.75, 2, 2.25, 2.5, 2.75, 3	0.1, 0.2, 0.3, 0.4, 0.5, 0.6

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III. RESULTS AND DISCUSSIONS

A. Effect of depth of water table

Vertical stress v/s normalized settlement curves for a strip footing at a depth of 1.5 B from ground surface for various positions of water table is presented in Figure 3. It is seen from the figure that bearing capacity increases with depth of water table until the depth of water table becomes equal to depth of footing. The increase in bearing capacity with depth of water table, when the water table is below the base of footing is comparatively less.

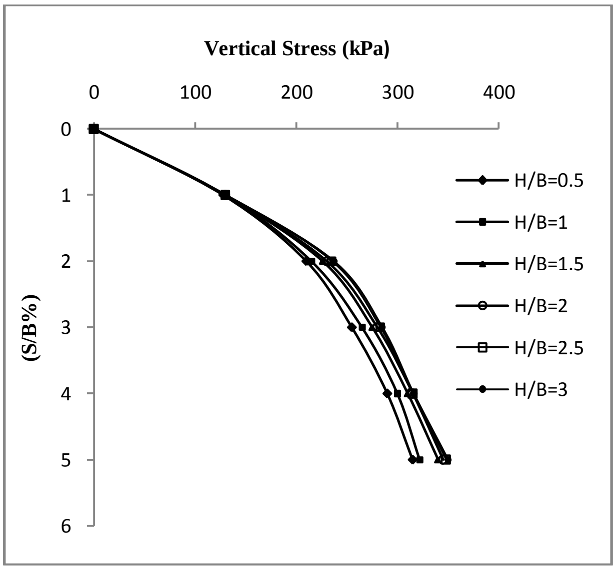

Fig. 3. Stress vs normalized settlement curves for D/B=1.5

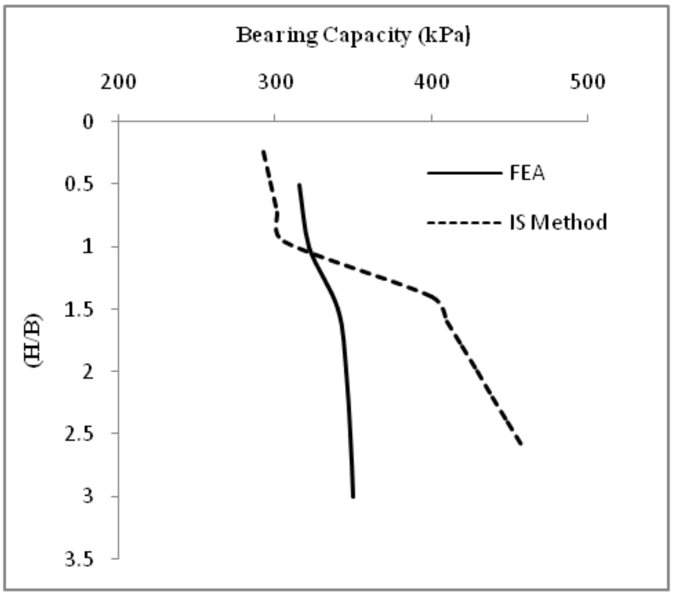

Fig. 4. Variation of Bearing Capacity with depth

The variation of bearing capacity with depth obtained from Finite Element Analyses is compared with those obtained from IS method in Figure 4. It is observed that there is considerable variation between the results obtained from FEA and conventional IS method.

The variation of maximum effective stress in soil after loading with various positions of water table, for (D/B=1.5) is presented in Figure 5. It is seen that the maximum effective stress in soil after loading increases steadily when the water table is lowered up to the base of the footing. A further lowering of water table does not cause any change in the maximum effective stress.

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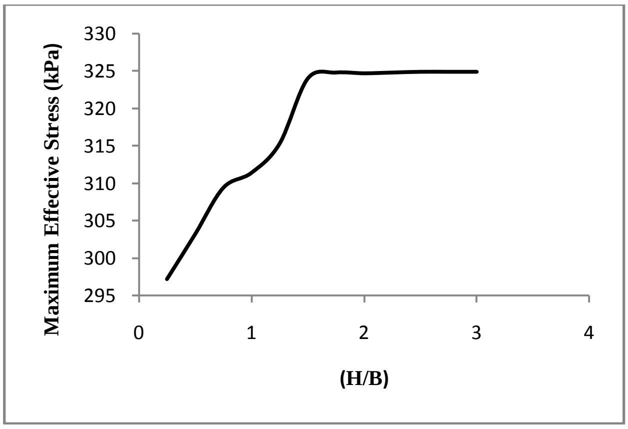

Fig.5. Variation of maximum effective stress after loading with depth of water table

B. Variation of bearing capacity with hydraulic gradient

The effect of variation in bearing capacity due to hydraulic gradient of ground water was studied by giving a slope to the water surface. The geometric model is shown in Figure 6.

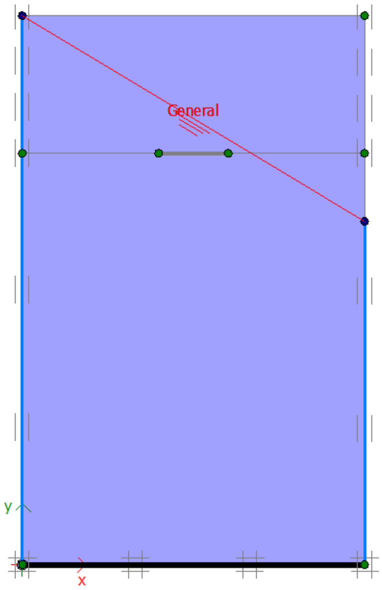

Fig.6. Geometric model for water table with hydraulic gradient

Figure 7 presents the variation of bearing capacity with hydraulic gradient obtained from finite element analyses. It is seen that bearing capacity reduces considerably with the increase in hydraulic gradient of ground water.

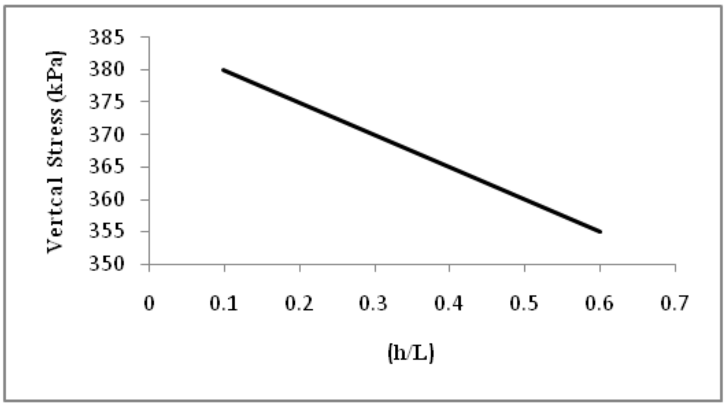

Fig.7. Variation of Bearing Capacity with Hydraulic Gradient

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IV. CONCLUSIONS

Based on the results of finite element analyses carried out, the following conclusions are made on the effect of position of water table and hydraulic gradient on Bearing Capacity.

- The effect of position of water table on bearing capacity is more significant when it is above the base of footing.
- It is observed that there is considerable variation in the results obtained from Finite Element Analyses and those obtained from conventional analytical methods.
- The position of water table has considerable influence on the maximum effective stress due to loading when it is above the base of footing
- It is observed that the bearing capacity is considerably influenced by the hydraulic gradient of ground water

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