EXPERIMENTAL INVESTIGATION ON BEHAVIOUR OF FOOTINGS SUBJECTED TO HORIZONTAL LOADS

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Abstract - *Evaluations of bearing capacity of vertically loaded shallow foundations on various soils have been studied by many researchers. There are structures where horizontal loading has greater influence and much research has not been carried out to evaluate the horizontal load bearing capacity of shallow foundations. This paper investigates the load-settlement behaviour of footings subjected to horizontal loads by carrying out a series of laboratory scale load tests. The parameters varied are Depth of footing, Soil type, Ratio of vertical load to horizontal load etc. It is observed that depth of foundation and vertical load influences the lateral load bearing capacity of footings. It is observed that the lateral deformation decreases with the increase in depth of foundation and vertical load. The tilt of the footing is also found to decrease with depth when the footing is subjected to combined lateral and vertical loading. The influence of micropiles on the improvement in lateral load-deformation behaviour is also studied.*

Key Words: **Lateral load-deformation behaviour, Micro piles, Shallow foundation**

1. INTRODUCTION

The bearing capacity of foundations has always been one of the subjects of major interest in geotechnical engineering. Most of the bearing capacity theories have been developed for footings carrying vertical and symmetrical loads. In actual practice footings will also carry horizontal loads due to various climatic and boundary conditions. In foundations of certain structures like retaining walls, the major force is horizontal. But a satisfactory theory to evaluate the horizontal load bearing capacity of foundations is not yet comprehensively developed. Evaluations of bearing capacity of vertically loaded shallow foundations on various soils have been addressed by previous researchers. Taiebat H.A et al. (2000) did numerical studies on shallow foundations on cohesive soil subjected to combined loading. They did 3D Finite element analysis of circular foundations on cohesive soil under combined loading and proposed new equation for failure locus in terms of all three components. Patra et al. (2012) studied ultimate bearing capacity of strip footings under eccentric and inclined loadings and suggested empirical reduction factors based on lab tests. Gang Zheng et al. (2019) studied the effect of inclined loading on bearing capacity of strip footing on sand layer and they did parametric study to determine the factors influencing the failure mechanism. Abbasali et al.(2019) studied influence of using composite soils under shallow foundations. 3D Finite element analysis was done and studied bearing capacity improvement and shows that Sand clay mixture shows better performance than gravel clay mixture. Horizontal load bearing capacity of deep foundation had been investigated by Reese and Matlock (1956), Mayerhof (1983) etc. It is uneconomical to provide pile foundations for all structures carrying horizontal loads due to its cost and difficulty in construction. Hence it is important to investigate horizontal load bearing capacity of shallow foundations.

2. EXPERIMENTAL STUDIES

The load tests are conducted in a combined test bed and loading frame assembly. The test beds are prepared in a tank of internal dimension 1000mm length x 750 mm width x 750 mm depth. The test tank is constructed with 23 cm thick brick masonry walls on the three sides. The front side of tank is formed using a frame work of steel channels and angles. The model circular footing has a diameter of 100 mm, thickness 20mm and is fabricated with mild steel. Micropiles have a length of 200mm and diameter 3mm and are also made of mild steel. The clayey soil is filled in the test tank to the required level with compaction done in layers of 50 mm thickness. The water content of the clayey soil is maintained at 18%. To achieve the desired density of the soil, the layered filling technique is used. The pre-determined density of clay is used to calculate the desired weight of soil required to fill the tank in layers of 50mm height. A uniform density of 15.6kN/m3 for clay was maintained in all the tests. The clay was compacted by ramming. The compactive effort required to achieve the required density was determined by trial and error. The loading tests are carried out in a loading frame fabricated with ISMB 300. The vertical load is applied using a hand operated- mechanical jack of capacity 50kN. The applied vertical load is measured using a proving ring of capacity 100kN. Lateral load is applied by lateral loading apparatus which is welded in the loading frame. Lateral load is measured using a proving ring of capacity 50kN.The lateral displacement of the model footing is measured using two dial gauges of 0.01mm sensitivity kept diametrically opposite to each other. The tilt due to combined vertical and horizontal loading is also measured using two dial gauges of 0.01mm sensitivity kept diametrically opposite to each other. The model footing is placed exactly beneath the centre of loading jack to avoid eccentric loading. The photograph and schematic diagram of test setup is shown in Figure 1&2. The arrangement for Lateral loading is shown in Figure 3. Locally available clay is used as foundation soil. The properties of clay are listed in Table 1.

Table 1. Properties of clayey soil

Sl No	Properties	Values
1	Specific gravity	2.68
2	Optimum Moisture Content (%)	18
3	Maximum Dry Density (kN/m^3)	15.61
4	Liquid Limit (%)	58
5	Plastic Limit (%)	22
6	Shrinkage limit (%)	16.2
7	Plasticity Index (%)	36
8	IS Classification	CH
9	Unconfined Compressive Strength, UCC (kN/m^2)	140.08
10	Permeability, k (m/s)	3.03×10^{-6}
11	Cohesion , c (kN/m^2)	25

Fig. 1 Test tank and loading frame

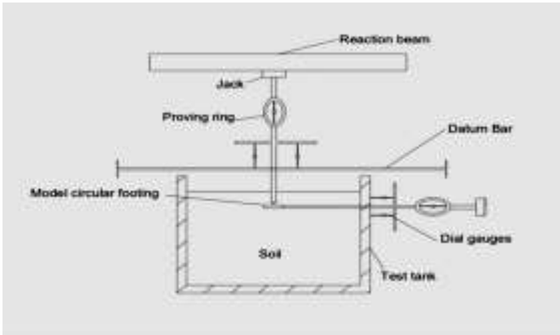

Fig. 2 Schematic diagram of test setup

Fig. 3 Arrangement for Lateral loading

The parameters varied are presented in Table-2

Table 2. Parameters Varied

Parameter	Diameter of Footing (B)	Vertical Load (N)	Depth of footing (d/B)
Value	100 mm	0, 90, 130, 170	0, 0.5, 1

3. RESULT AND DISCUSSION

Load settlement behaviour of circular footing subjected to combined vertical and horizontal loading is investigated by carrying out a series of laboratory scale load tests. Influence of depth of foundation and vertical loading on lateral displacement and rotation of footing are presented below

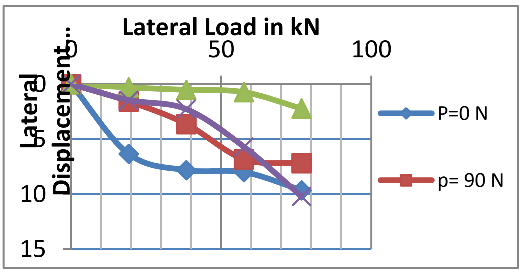

Chart-1: Influence of vertical load on the lateral load-deformation behaviour when D/B=0

From the curves it is observed that as lateral loading increases, lateral displacement increases. At all depths as vertical loading (P) increases, lateral displacement decreases. This is because as vertical load increases, normal stress beneath the footing increases and thereby increasing the force of friction. Hence lateral displacement decreases.

Minimum lateral displacement is found at vertical load of 130 N. Increase in displacement at higher load may be due to decrease in soil resistance since some part of soil surrounding the footing get separate due to tilting of footing.

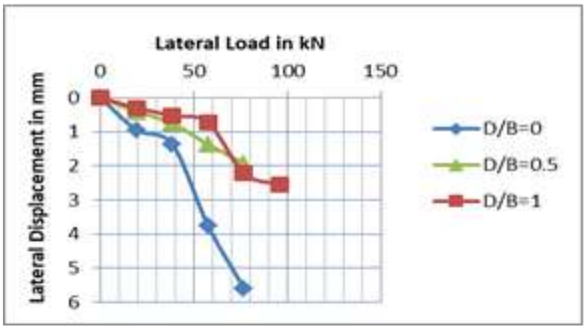

Chart-2 : Influence of depth of footing on the lateral load-deformation behaviour when vertical load= 130 N

As depth increases lateral displacement decreases .This is because increase in depth causes footing to get confined with more soil and thereby decreasing lateral displacement.

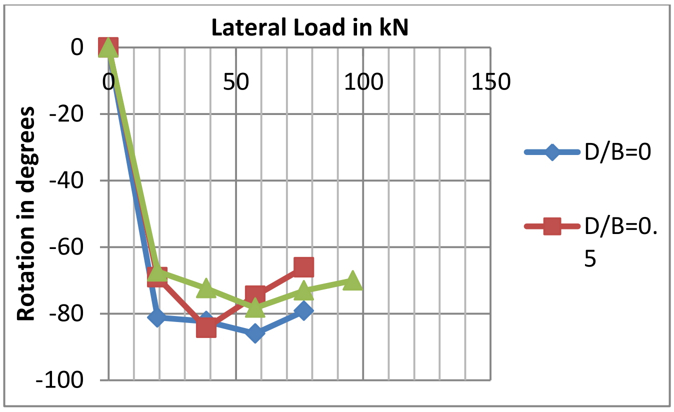

Chart-3: Lateral load v/s rotation curve for P = 0 N

Chart 3 shows relation of lateral load and rotation with increase in depth. From Chart 3 it is observed that as lateral loading increases, rotation increases. Also it found that as depth increases tilt decreases. Rotation is found minimum for D/B = 1. Maximum rotation is found at surface. Decrease in tilt is due to increase in confinement of soil with depth.

INFLUENCE OF MICROPILES

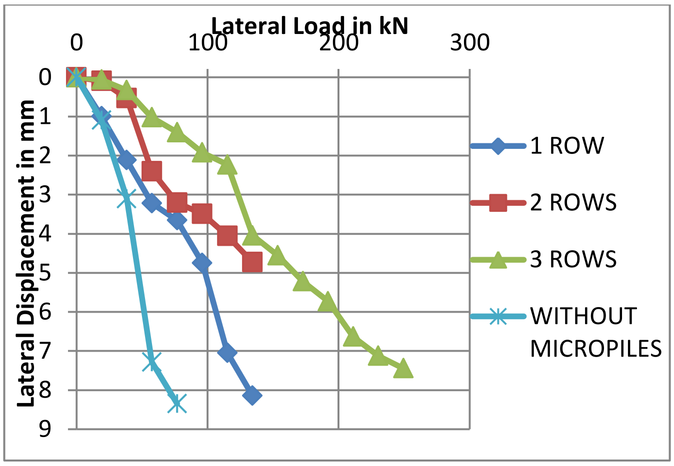

Chart-4: Lateral load v/s displacement curve for P=130 N and D/B=1

Use of micropiles shows improvement in lateral displacement. Maximum decrease in lateral displacement is found when three layers of micropiles were used

4. CONCLUSIONS

The following conclusions are deduced from this study:

- ✓ Depth of foundation and vertical loading influences the behaviour of footings subjected to lateral loads
- ✓ Rotation decreases with depth & found minimum for d/b =1
- ✓ As depth increases rotation of footing decreases due to increase in confinement
- ✓ Lateral displacement decreases with increase in vertical loading due to increase in normal stress.
- ✓ As number of micropiles increases, lateral displacement decreases. Thus the behaviour of clayey soil against lateral loading can be improved.

REFERENCES

[1] Abbasali., Taghavi Ghalesari., Mohammadreza Khaleghnejad. (2019). "Behaviour of eccentrically loaded shallow foundations resting on composite soils." J. Build.Eng.,102(18), 303-315.

[2] Gang Zhenga., Jiapeng Zhaoa. (2019). "Ultimate bearing capacity of strip footings on sand overlying clay under inclined loading." Computers and Geotechnics.,106 (5), 266–273.

[3] Hudson Matlock., Reese. (1956). "Generalized Solutions for Laterally Loaded Piles" Transactions of the American Society of Civil Engineers, 1962, Vol. 127, Issue 1, Pg. 1220-1247.

[4] Mayerhof.,Mathur. (1983). " Lateral resistance and deflection of rigid walls and piles in layerd soil" Canadian Geotechnical Journal 18(2), 159 - 170

[5] Patra, C.R., Behera, R., Sivakugan, N., and Das, B.M. (2012). "Ultimate bearing capacity of shallow strip foundations under eccentrically inclined load." International Journal of Geotechnical Engineering.,6(4), 507-514.

[6] Taiebat, H. A., and Carter, J. P. (2000). "Numerical studies of the bearing capacity of shallow foundations on cohesive soil subjected to combined loading." J. Geotech. Eng., 122(4), 409-418.