Effects of Foundation Shape on Settlement and Bearing Capacity of Soils at Rajshahi City, Bangladesh

M. A. ALIM[1], M. M. RANA[2], M. A. ALAM[2], M. ROKNUZZAMAN[3]

[1]Department of Civil Engineering, RUET, Bangladesh (maalim89@yahoo.com)
[2,3]Department of Civil Engineering, RUET, Bangladesh (masud.ce08@gamil.com)

Abstract

Bearing capacity and the settlement are the two important parameters in the field of geotechnical .engineering. Dimension and shape of foundation, embedment depth, physico-mechanical properties of soil and load geometry are the controlling factor of bearing capacity and settlement of soils. The bearing capacity corresponding to this SPT value in Rajshahi city is not suitable to bear the super structure load at shallow depth. So, locally available fine sand found in Padma River are used to increase the bearing capacity of soil at shallow depth. In this study, physical models with different foundation shapes but in same materials properties are tested under vertically applied load and bearing capacity and settlement values are presented. The studies generally shows that load resistance of subsoil bases with square shape is mostly associated with the soil beneath the foundation base with/without improvement. Rectangular and circular shape foundations give relatively low resistance than square shape foundation.

Keywords: *Foundation shape; Bearing Capacity; Settlement.*

1 Introduction

Foundation is an integral part of a building whose stability determines the stability of the entire structure, as it acts as a medium through which loads are transmitted to the soil or rock below. Settlement and bearing capacity of soil under a foundation are both function of the latter’s dimension and shape, embedment depth, physico-mechanical properties of soil and load geometry. (Musa Alhassan et.al, 2013) Structural foundations transmit the structural load to the earth in such a way that the supporting soil is not overstressed and do not undergo deformation that would cause excessive settlement of the structure (Ranjan and Rao, 1985). Settlement (deformation) criterion is more critical than the bearing capacity one in the designs of shallow foundations (Das and Sivakugan, 2007). Generally the settlements of shallow foundations such as pad or strip footings are limited to 25 mm (Terzaghi et al. 1996). In recent years, a number of researches have been conducted on the effect of foundation shape on settlement and bearing capacity of soils. The reliability of settlement estimates for shallow foundations on granular soils has received considerable attention and has been discussed by Schultze and Sievering (1977); Tan and Duncan (1991); Nova and Montrasio (1991a, 1991b); Cherubini and Greco (1991); and Berardi and Lancellotta (1994); Cerato and Lutenegger (2007); Mahanta et al, (2008); Kumar and Khatri (2008); Jahanandish et al (2010); Al-Khuzaei (2011); Nareema (2012). Soil improvement is the technique to increase bearing capacity of soil. Rajshahi is the largest city in north western part of Bangladesh. Most part of this city has a SPT value in range of 4-7 within 10 feet depth and consist of soft clay and loose sand. For lower SPT value the soils of these areas do not have sufficient bearing capacity and undergoes a large settlement. In this study, effect of foundation shape on settlement and bearing capacity at shallow depth of foundation has been investigated for normal soil and it has been tried to determine shape effects on compacting soil at different layers.

2 Methodology

Several tests were conducted for the soil sample such as Specific gravity test, Standard Proctor test, Sieve Analysis. Practical areas of shallow foundations are around 36 to 64 square feet. Three wooden models of shallow foundations were used for the study. The areas of foundation were kept constant for all prototypes. The first prototype was a square shaped block (marked square shape) with dimension of 6”×6”. The second prototype was a rectangular shaped block (marked rectangular shape) with dimension of 7”×5.2” respectively; the third prototype was a circular shaped block (marked circular shape) having a diameter of 6.75 inch. The dimensions of the prototypes were chosen so as to resemble as the actual condition of foundation casting, i.e. according to scale of 1 inch in 1 foot. In accordance with the physico-mechanical properties of soils of Rajshahi and the classification of subsoil bases obtained from subsoil exploration; subsoil conditions were modeled in the Soil Mechanics Lab and Strength of Materials lab in Civil Engineering Department of Rajshahi University of Engineering & Technology, Rajshahi, Bangladesh. The experimental stand used for the study was a square container of dimension 24×24×18 inch for length, height and width respectively, with a transparency of all side made with silhouette fiber glass. The bottom of the container was made of steel sheet. All side of the fiber was caged with steel bar to resist lateral force exerted on the model (fig.2).

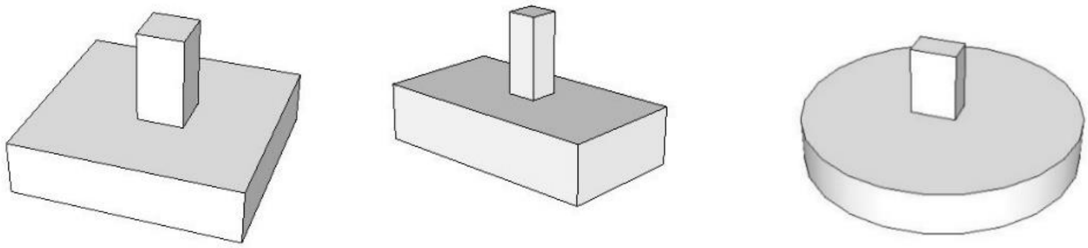

Figure 1. Foundation prototypes; Square, Rectangular and Circular shape.

Figure 2. Experimental set up

The model was created using clay layer in bottom and fine sand as backfill material locally found in Rajshahi, Bangladesh. The fine sand having specific gravity 2.67, moisture content of 15%, dry unit weight of 1.52gm/cc, fineness modulus of 1.71 and internal angle of friction of 24.1 degree. The model was prepared with 95% compaction of soil found in standard proctor test. Then the foundation prototypes were placed on the top of the soil. Using universal testing machine, loads were vertically, centrally and uniaxially applied to the foundations in an incremental manner, recording corresponding settlement for each load increment, using dial gauge 0.0125/mm division. The second model was loaded as the same way of first model.

3 Results & Discussion

Properties of Fine Sand which was used to improve the condition of soil beneath the foundation.

Table 1. Properties of locally available fine sand.

Index Property	Constituents
Specific Gravity	2.67
FM	1.71
OMC	15 %
Maximum Dry Density	1.52 gm/cc
Angle of Internal Friction, ϕ	24.1 degree

Results of load-settlement relationship of foundations prototypes on the first are shown in figs.3 and fig.4, fig.5, fig.6. From the figures, it is observed that the bearing capacities of square shape foundations are generally higher than those of circular and rectangular-shape foundations. Fig.3 represents the bearing capacity corresponding to settlement of foundation in soil without improvement. With 2 feet compaction of improved soil, bearing capacity of soil is increased than that of soil found in natural strata (fig.4). Further increment of soil compaction i.e. 3' and 5', load bearing capacity is also increased (fig.5 and fig.6).

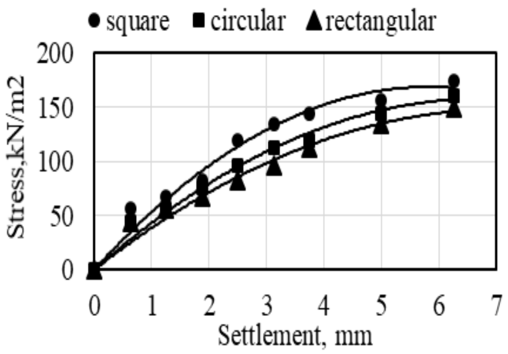

Figure 3. Load vs Settlement curve for soils without improvement

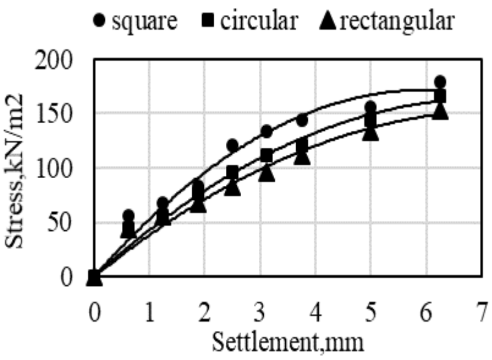

Figure 4. Load vs Settlement curve at 8' depth with 2' improvement

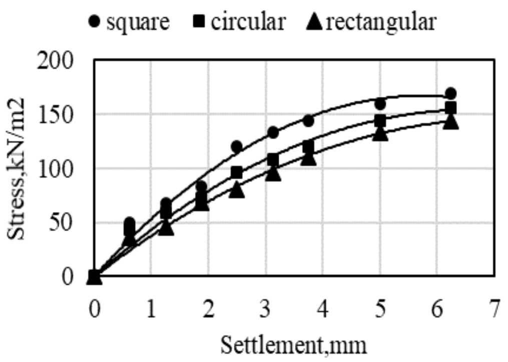

Figure 5. Load vs Settlement curve at 8' depth with 3' improvement

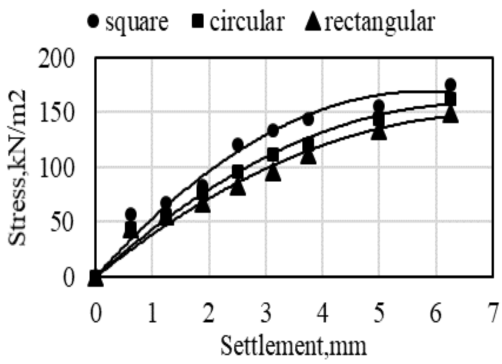

Figure 6: Load vs Settlement curve at 8' depth with 5' improvement

Table 2. Bearing capacity of foundation prototypes

Foundation Shape	Bearing Capacity (kPa)							
	Soil without improvement		Soil at 8' depth with 5' improvement		Soil at 8' depth with 3' improvement		Soil at 8' depth with 2' improvement	
	Prac.	Theo.	Prac.	Theo.	Prac.	Theo.	Prac.	Theo.
Square	156.45	285.29	181.64	375.40	174.5	362.4	169.30	343.61
Circular	144.34	267.71	169.30	352.65	161.35	342.65	156.45	326.17
Rectangular	132.23	249.83	156.45	334.11	149.25	322.11	144.34	308.91

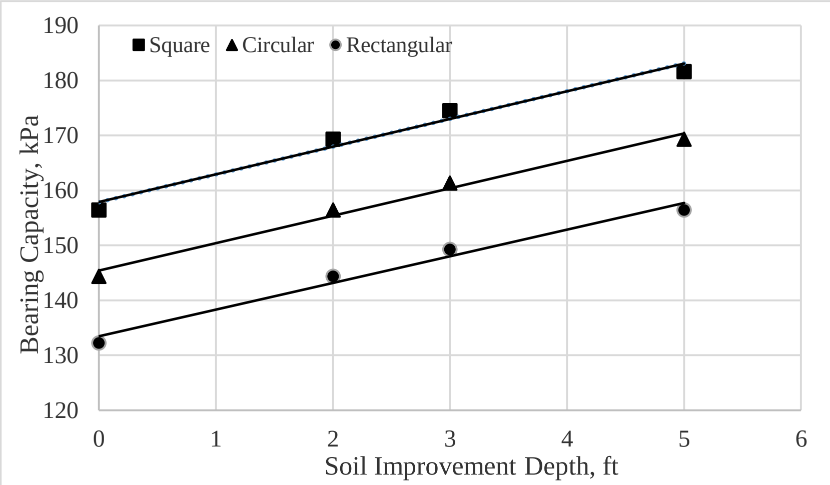

Figure 7. Bearing Capacity of soil with improvement depth

From table 2 and figure 7, it can be seen that, practically the highest bearing capacity was recorded with square shaped foundation with 5 feet improvement of soil. It is because of that in square shaped foundation the load is evenly distributed through the foundation area.

4 Conclusion

From the data analysis of the experimental study it can be concluded that square shaped foundation resist more load than other shaped foundation within same settlement. Fine sands with/without compaction bear more load than existing in situ soils with lower SPT value. So, we can use locally available fine sand as backfill material to get higher bearing capacity.

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References

Boiko, I. L. and Alhasan, M. (2009). Effect of Vertical Cross-Sectional Shape of Foundation on Settlement and Bearing Capacity of Soils. Procedia Engineering. 57, 207–212.

Rao, B. G. and Ranjan, G. (1985). Settlement Analysis of Skirted Granular Piles. Journal of Geotechnical Engineering. 11, 111.

Das, B. M. and Sivakugan, N. (2007), "settlements of Shallow Foundations on Granular Soil-An Overview", International Journal of Geotechnical Engineering, J. Ross Publishing, Inc. 1, 19-29.

Terzaghi, k., Peck, R. B., and Mesri, G. (1996). Soil Mechanics in Engineering Practice. 3rd Edition, John Wiley & Sons, New York.

Terzaghi, k. (1943). Theoretical Soil Mechanics. John Wiley & Sons, New York.

Das, B. M. (1999). Shallow foundations – Bearing Capacity and Settlement. CRC Press LLC, USA, PP. 2, 46.

Das, B. M. (2010). Principles of Foundation Engineering. 7th edition. CL Engineering.

Montrasio, L. and Nova, R. (1997) "Settlement of Shallow Foundation on Sand", Geotechnique. 47(1), 49-60.

Al- Khuzaei, H. M. (2011). Verification of Scale Effect of Shallow Foundation in Determination of Bearing Capacity of Sand. Al-Rafidain Engineering. 2(2), 1-11.

Cerato, A. B. and Lutenegger, A. j., (2007). Scale Effects of Shallow Foundation Bearing Capacity on Granular Material. Journal of Geotechnical and Geo-environmental Engineering, ASCE. 10, 1192-1202.

Komar, J. and Khatri, V. N. (2008). Effect of Footing Width on Bearing Capacity Factor, N. Journal of Geotechnical and Environmental Engineering, ASCE. 134, 1299-1310.

Nareeman, B. J. (2012). A Study on the Scale Effect on Bearing Capacity and Settlement of Shallow Foundations. International Journal of Engineering and Technology. 2(3), 480-488.

Jahanandish, M, Veiskarami, M. and Ghahramani, A. (2010). Effect of Stress Level on the Bearing Capacity Factor, N, by the ZEL Method. KSCE Journal of Civil Engineering. 14(5), 709-723.

Mahanta. R, Prakasha, K. S., Deshpande, A. R. and Dholey, H. S. (2008). Assessment of Bearing Capacity and Settlement of Irregular-Shaped Mat Supported Oil Drilling Rigs Using Finite Element Analysis. Proceedings of the 12th International Conference of International Association for Computer Methods and Advances in Geomechanics (IACMAG), Goa, India. pp. 3127-3132.