ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

IARJSET

International Advanced Research Journal in Science, Engineering and Technology

nCORETech

LBS College of Engineering, Kasaragod

Vol. 5, Special Issue 1, Feburary 2016

Effect of Underground Void on Footings Resting on Reinforced Foundation Bed

Jayamohan. J[1], Aarya Vimal[2], Rajeev. K.P[3]

Associate Professor, Civil Engineering, LBS Institute of Technology for Women, Thiruvananthapuram, India[1]

Assistant Professor, Civil Engineering, Jai Bharath College of Engineering, Ernakulam, India[2]

Professor, Civil Engineering, TocH Institute of Science & Technology, Ernakulam, India[3]

Abstract: In this paper the results of a series of finite element analyses carried out to investigate the improvement in bearing capacity of a strip footing resting on a weak clayey soil with voids due to the addition of a Reinforced Foundation Bed are presented. The results of finite element analyses are validated by carrying out laboratory scale load tests. From the results of finite element analyses it is seen that the effect of void is considerable only when it is located within a critical depth and critical eccentricity. The critical eccentricity is found to reduce with depth of void from the base of footing. It is observed that the addition of Foundation Bed (FB) and Reinforced Foundation Bed (RFB) significantly improves the load-settlement behaviour. It is also observed that there is considerable stress concentration near the underground void.

Keywords: Underground void, Reinforced Foundation Bed, Finite Element Analyses, Stress Concentration.

I. INTRODUCTION

Voids occur under structures with sufficient frequency to warrant special attention, since voids may cause structural damage and loss of life. The frequency of voids occurring under structures is high in areas having soluble rock formations and in areas having active mining operations [1]. Voids can develop in subsoil due to many reasons like tension cracks in cohesive soils, settlement of localized pockets of compressible soil, differential settlement of municipal soil waste, melting of subsurface ice, settlement of poorly compacted backfill, collapse of underground cavities etc. [2]. Figure 1 show the photograph of an underground void developed near a house in Buckinghamshire, UK. Figure 2 show the photograph of a secret underground tunnel leading to the palace at Mysore, Karnataka.

Fig. 1. Underground void near a house at Buckinghamshire, UK

Fig. 2. Secret underground tunnel leading to the Palace at Mysore, Karnataka

The presence of void in the soil beneath the footing can cause instability to the foundation and thereby severely damaging the entire structure. It has been reported that the soil below the loaded footing collapses in the form of a wedge into the underlying void ([1]; [3]; [4]; [5] & [6]). It is also reported that there could be three modes of failure such as, bearing failure without void failure, bearing failure with void failure and void failure without bearing failure ([7] & [8]).

If a void is located in the subsoil the most economical solution is to place the foundation at a suitable depth so that the depth of void below the foundation is more than the critical depth and the presence of void does not affect the proposed foundation. If the thickness of soil above the void is less than the critical depth, an additional layer of reinforced granular soil should be provided on the ground and over this the foundation must be placed. References [2] and [9] have presented analytical methods for design of reinforced soil system overlying void.

Copyright to IARJSET

II. FINITE ELEMENT ANALYSES

Finite element analyses are carried out using the commercially available finite element software PLAXIS 2D.The size of the strip footing (B) is taken as 100 mm and the width and depth of soil mass are taken as 7.5B and 10B respectively in all analyses. The diameter of the void is taken as equal to 0.5 times the width of footing for all the cases. The geometrical model for finite element analysis is shown in Fig 3 and the typical stress distribution in soil after loading is shown in Fig 4. It is seen that there is considerable stress concentration around the void.

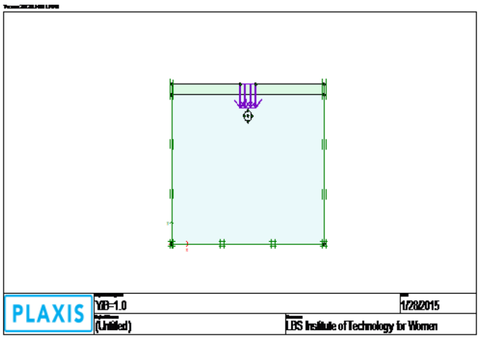

Fig. 3. Geometric Model for Finite Element Analysis

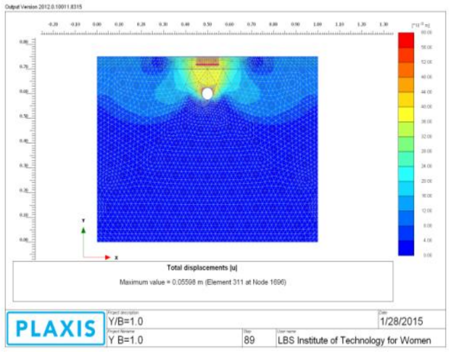

Fig. 4. Stress Distribution after loading

Settlement of the rigid footing is simulated using vertical prescribed displacements. The foundation system is simulated using plain strain model. The continuous void is modelled as a tunnel without lining. The boundary conditions are taken as full fixity at the base of the geometry and smooth conditions at the vertical sides. To simulate the behaviour of soil, material parameters and appropriate soil model are chosen. The Mohr–Coulomb model is adopted as the soil model for all analyses. The properties of soil given in Table 1, are assigned as material parameters of clay and Foundation Bed. The soil is modelled using 15-node triangular elements. Poisson's ratio of the soil is assumed to be 0.25 for all cases.

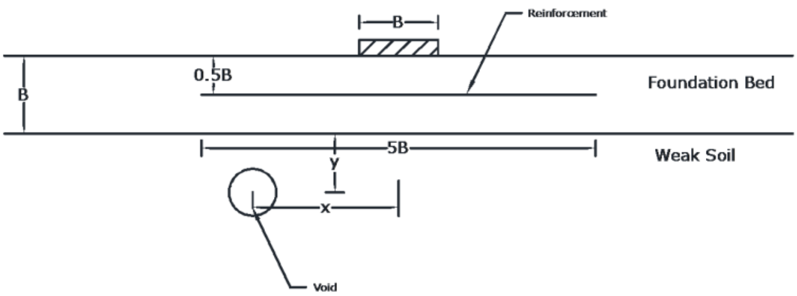

Fig. 5. Parameters defining the position of void

The eccentricity of the void is defined by the parameter 'x' and depth of void from the surface of clay by the parameter 'y', as shown in Fig 5. Analysis is done for various values of (x/B) and (y/B), as given in Table 1. The thickness of foundation bed for all cases is taken as B, which is the width of the footing. In all the analyses, the width of footing is taken as 0.1m.

ABLE 1. :POSITIONS OF VOID CONSIDERED IN THE STUDY

Depth Parameter (y/B)	Eccentricity parameter (x/B)
0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0	0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.20, 1.4, 1.6, 1.8, 2.0

III. LABORATORY MODEL STUDIES

The laboratory work reported in this paper was carried out at the research laboratory of LBS Institute of Technology for Women, Thiruvananthapuram. The test tank is made of brick masonry on three sides and steel channels on the fourth side. The internal dimensions of the test tank are 75 x 75 x 100cm. The model strip footing is made using an inverted steel T-section with flange width 100mm. A lubricated steel pipe, shown in Fig 6, is kept in the tank at the specified location during filling of soil. This lubricated pipe is slowly rotated and pulled out after the soil s compacted so that the void is formed. The soil with void formed is shown in Fig 7. The load is applied using a mechanical jack of capacity 35kN. The applied load is measured using a Proving Ring of capacity 10kN. The settlement of the model footing is

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
nCORETech
LBS College of Engineering, Kasaragod
Vol. 5, Special Issue 1, Feburary 2016

measured using two dial gauges placed diametrically opposite to each other. The stresses at the interface between Foundation Bed and underlying clayey soil are measured using load cells. The deformation at the interface is measured using movement sensors and LVDTs. The arrangement is shown in Fig 8 and the datalogger used for recording data is shown in Fig 9.

Fig. 6. Lubricated steel pipe in tank during filling and compaction of soil

Fig. 7. Void in Soil after removing pipe

Fig. 8. Arrangement for application of load and Measurement of settlement

Fig. 9. Datalogger for recording data

IV. RESULTS AND DISCUSSION

A. Effect of depth of void from the surface of weak soil

Vertical stress vs normalized settlement curves for the strip footing for various vertical positions of the void are shown in Fig 10. The curve for soil without void also is included so that the reduction in strength due to the presence of void could be clearly understood. From the figure it is seen that as the depth of void from the surface of weak soil increases, the influence of void diminishes. The effect of void is very negligible when its depth from the surface of weak soil is equal to thrice the width of footing.

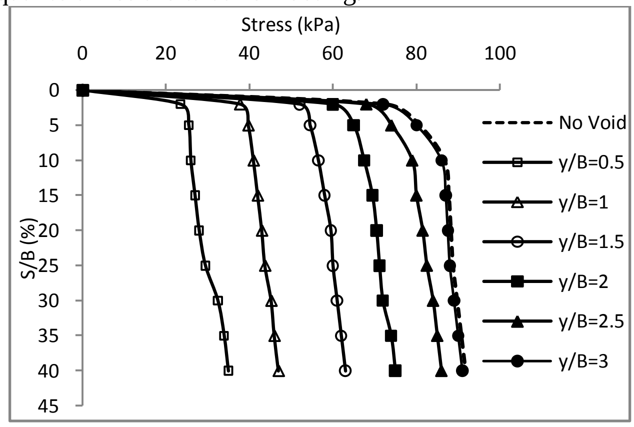

Fig. 10. Vertical Stress vs normalized settlement curves for various

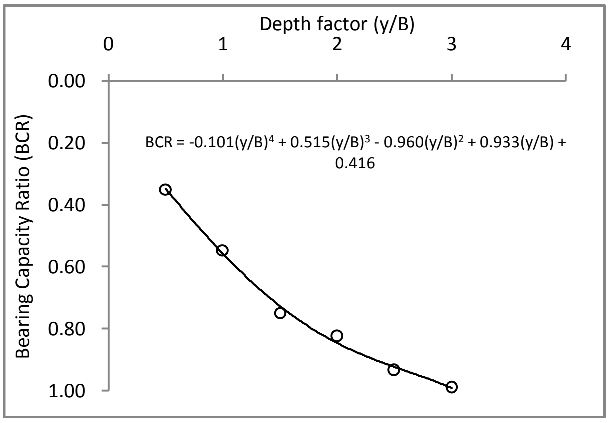

Fig. 11. Bearing Capacity Ratio vs Depth factor curve vertical positions of void

The variation of bearing capacity ratio (BCR) with increasing depth of void from the surface of weak soil is presented in Fig 11. Bearing capacity ratio is defined as the ratio of bearing capacity of soil with void at 5% settlement to that without void at the same settlement. It is seen from the figure that the value of BCR approaches unity when the depth factor (y/B) is three. The equation of the best fit curve is also shown in the figure.

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
nCORETech
LBS College of Engineering, Kasaragod
Vol. 5, Special Issue 1, Feburary 2016

B. Effect of eccentricity of void

Fig 12 presents the vertical stress vs normalized settlement curves for the strip footing for various values of eccentricity of the void. It is observed that the influence of void decreases with increasing eccentricity of void. The effect of the void becomes negligible when the value of eccentricity exceeds 1.6 times the width of footing.

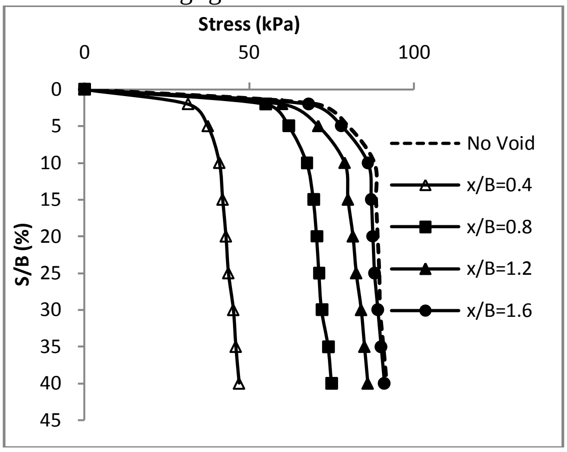

Fig. 12. Vertical Stress vs normalized settlement curves for various

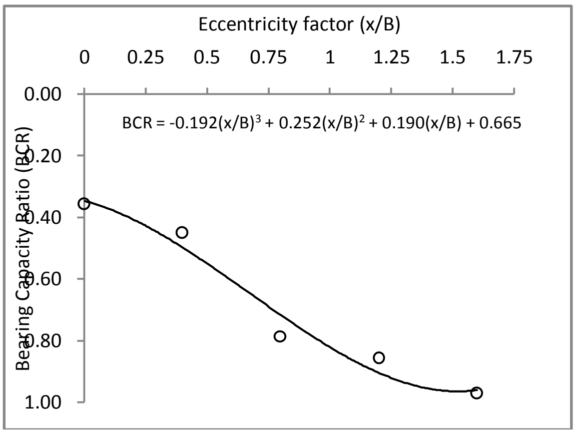

Fig. 13. Bearing Capacity Ratio vs Eccentricity factor curve horizontal positions of void

From Figure 13, which presents the variation of BCR with eccentricity of the void, it is seen that the value of BCR approaches unity when the eccentricity factor (x/B) is 1.6. The equation of the best fit curve is also shown in the figure.

C. Effect of Foundation Bed

The effect of addition of unreinforced and reinforced foundation beds over clay with void is presented in Fig.14. It is observed that addition of foundation bed (FB) and Reinforced Foundation Bed (RFB) significantly improves the load-settlement behaviour. The clay having underground void provided with foundation bed performs even better than the clay without void.

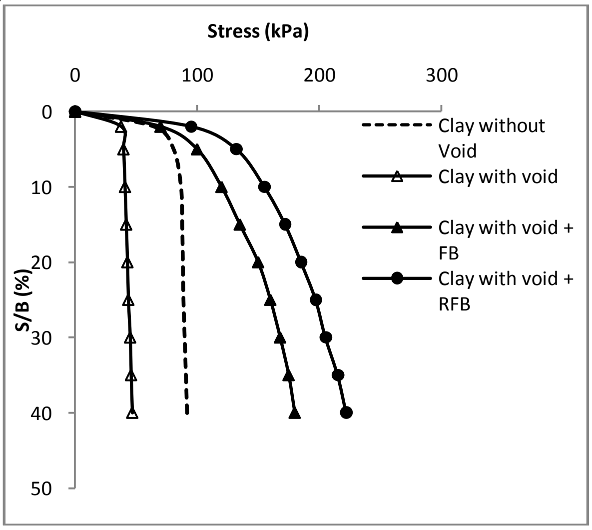

Fig. 14. Vertical Stress vs normalized settlement curves for y/B=1

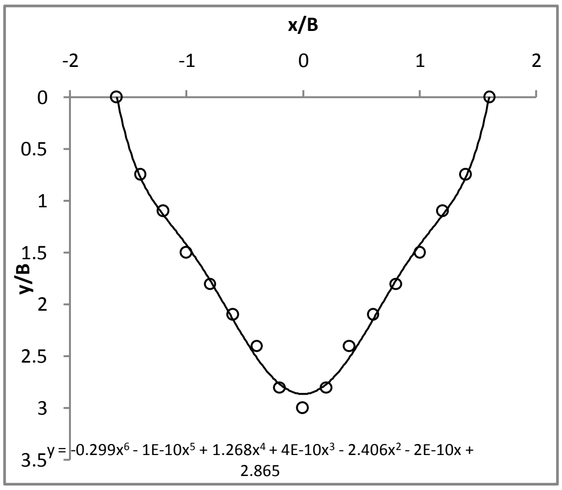

Fig. 15. Depth Factor vs Critical Eccentricity factor for clay without FB

D. Effect of Depth of void on Critical Eccentricity

Figure 15 shows the variation of critical eccentricity with depth of void for clay without foundation bed. It is observed that the critical eccentricity reduces with depth of the void. This curve represents the zone of soil within which the presence of void would affect the behaviour of footing. The equation of the best fit curve is also shown in the figure.

E. Stress Concentration around an underground void

Figure 16 shows the distribution of vertical stress along a horizontal plane passing through an underground void. It is seen from the figure that there is considerable stress concentration adjacent to the void.

International Advanced Research Journal in Science, Engineering and Technology

nCORETech

LBS College of Engineering, Kasaragod

Vol. 5, Special Issue 1, Feburary 2016

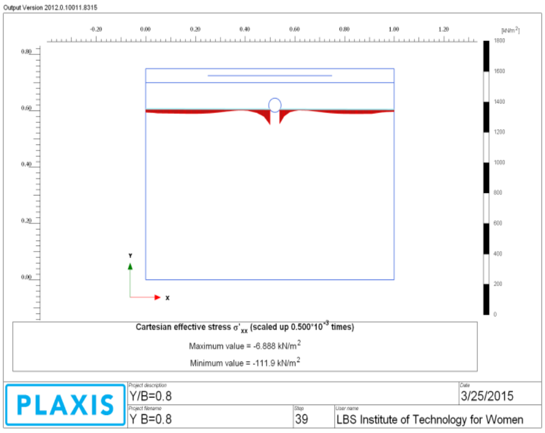

Fig. 16. Vertical Stress distribution along a horizontal section

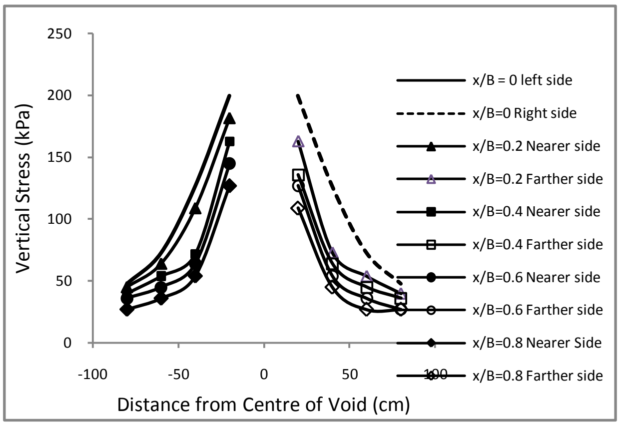

Fig. 17. Stress distribution on either side of void for various (x/B)

Figure 17 presents the distribution of vertical stress on either side for various horizontal positions of the void. It is seen that the stress surrounding the void reduces as the eccentricity factor (x/B) increases. It is observed that the stress at the side nearer to the load is higher than the stress at the farther side.

V. CONCLUSION

Based on the results of experimental studies and finite element analyses, the following conclusions are made on the behaviour of strip footing resting on foundation bed overlying clay with voids.

1. The presence of void in soil will cause a considerable reduction in Bearing Capacity
2. The presence of void has only a negligible effect when it is at a depth of more than thrice the width of footing from the surface of soil
3. The effect of void is negligible when the eccentricity of void is more than 1.6 times the width of footing
4. The addition of Foundation Bed and Reinforced Foundation Bed significantly improves the load-settlement behaviour of Clay with underground voids
5. The critical eccentricity, within which the void influences the behaviour of footing, decreases with the depth of void.
6. There is considerable stress concentration surrounding the void which reduces with eccentricity of the void.

REFERENCES

[1]. Wang, M. C. and Badie, A. (1985). Effect of underground void on foundation stability. Journal of Geotechnical and Geo environmental Engineering, ASCE, Vol. 111, No. 8, August 1985, pp.1008 – 1019.
[2]. Giroud, J. P., Bonaparte, R., Beech, J. F. and Gross, B. A. (1990). Design of soil layer-geo synthetic systems overlying voids. Geo textiles and Geo membranes, 9, pp.11–50.
[3]. Baus, R. L. and Wang, M. C. (1983). Bearing capacity of strip footing above void. Journal of Geotechnical and Geo environmental Engineering, ASCE, Vol. 109, No. 1, January, pp.1 – 14.
[4]. Badie, A. and Wang, M. C. (1984). Stability of spread footings above voids in clay. Journal of Geotechnical Engineering, ASCE 110, pp.1591–1605.
[5]. Wang, M. C and Hseigh, C. W. (1987). Collapse load of strip footing above circular void. Journal of Geotechnical and Geo environmental Engineering, ASCE, Vol. 113, No. 5, May 1987, pp.511 – 515.
[6]. G. Azam, W. Hseigh, and M. C Wang,. (1991). Performance of strip footing on stratified soil deposit with void. Journal of Geotechnical and Geo environmental Engineering, ASCE, Vol. 117, No. 5, May 1991, pp. 753 – 772.
[7]. Kiyosumi, M., Kusakabe, O., Ohuchi, M. and Peng, F. L. (2007). Yielding pressure of spread footing above multiple voids. Journal of Geotechnical and Geo environmental Engineering, ASCE, Vol. 133, No. 12, December 2007, pp.1522 – 1531.
[8]. Kiyosumi, M., Kusakabe, O. and Ohuchi, M. (2011). Model tests and analyses of bearing capacity of strip footing on stiff ground with voids. Journal of Geotechnical and Geo environmental Engineering, ASCE, 137, No. 4, April 2011, pp.363 – 375.
[9]. Briancon, L. and Villard, P. (2008). Design of geo synthetic-reinforced platforms spanning localized sink holes. Geo textiles and Geo membranes, 26, pp.416 – 428.