International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 06 | June-2016 www.irjet.net p-ISSN: 2395-0072

A Model Study to Analyze the Improvement of Bearing Capacity of A Square Footing on Soft Soil with Sand Pile With or Without Confinements

Prof. Harish C[1], Shravan Balu[2]

[1] Assistant Professor, Department of Civil Engineering, East West Institute of Technology, Bengaluru, Karnataka, India.
[2] M.Tech Student, Department of Civil Engineering, East West Institute of Technology, Bengaluru, Karnataka, India.

Abstract – *A model tests are carried out to study the improvement of bearing capacity of square footing on the soft soil layer by using the sand piles with or without confinement. In this study, square footing of dimension 50mm x 50mm x 20mm and the skirts of dimension 50mm x 50mm are used and varying lengths decided based on the depth of soft soil layer. A sand bed is provided beneath soft clay layer of fixed depth.*
In order to study the improvement of bearing capacity of the square footing, the load-settlement behavior of the model foundation is tested in Universal Testing Machine. A series of load tests were carried out to investigate the effect of partially replaced sand pile with or without confinements by skirts.
The results show that the improvement of load bearing capacity is very nominal using both partially replaced sand piles with or without skirts. The chosen method can considerably alter the stress displacement curve of the foundation resting on the soft soil layer, notably decreases the settlement and the replaced soil acts as a deep foundation. It was observed in the study that the skirt length has a significant role in improving the bearing capacity and reduction in the settlement of footing.

Key Words: **Bearing Capacity, Settlement, Soil Stability, Soft Soil, Square Footing, Confinements, Sand Pile, Skirts etc.**

1. INTRODUCTION

The availability of good construction ground are in a declining trend which has enabled the Geotechnical Engineer to research and develop alternative methods by which the bearing capacity of foundation is enhanced and the settlement is reduced when rested on such grounds. Although there are various in situ ground improvement techniques such as soil stabilization, reinforcement, grouting and compaction etc. are used widely and well developed. These can be quite costly and depends largely on the site conditions. In such conditions, the structural skirts are a good alternative practice for enhancing the bearing capacity and also to reduce the settlement.

Skirted foundations are closed space where the soil is laterally restrained and behaves as a single unit with the confinement to transfer the load from the superstructure to the soil. It is studied that these help in the increase of stiffness of footing structure, restriction of settlement during the utility period of the structure, lesser brunt to environment during the installation operation at the site.

Horizontal loading capacity is enhanced by the resistance caused in sides of skirt by the soil that aids the foundation to prevent lateral sliding. In order to understand the feasibility of this concept, a consolidation of both structural skirts that are attached to the footing edge and partial restoration only to the inner of the skirted foundation can be contributed in the strengthening the soft soil.

The aim of this study is to ascertain the concept of both improvement of bearing capacity and reduction of settlement by using both partially replacement of soil of soft soil overlying sand bed and the most favorable skirts footing soil system. This study is performed to understand the effect of sand pile in the enhancement of bearing capacity and to regulate the settlement.

1.1 Applications of Skirted Foundation

Skirted foundations are extensively used in both off shore and on shore construction since it satisfies bearing capacity requirements and contributes to supplementary horizontal resistance mainly for the off shore environment.

The fundamental applications of skirted foundation are:

- For the foundation of bridges
- For the wind turbine foundations
- For the oil and gas petroleum off shore plants
- For Jack-up unit structure
- For Tension-leg platform

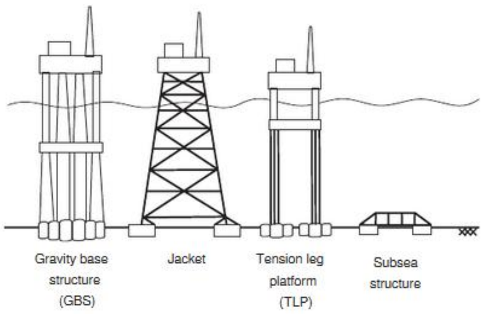

Fig -1: Applications of skirted foundation

2. LABORATORY MODEL TESTS

1 – Model Footing

2 – Skirts

3 – Replaced Soil

4 - Soft Soil

5 – Compacted Sand

6 – Model Box

B – Size of Foundation

D – Thickness of Compacted Sand Layer

h – Thickness of soft soil

L – Length of Skirts

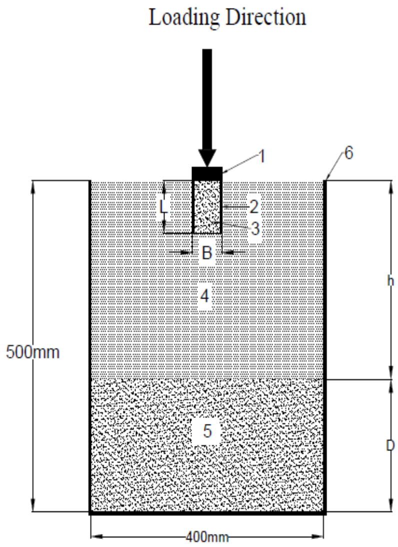

Fig -2: Schematic diagram of the model setup

2.1 Model box

The Figure 2 is the representative description of the experimental model setup utilised for this study.
The model box is having an inside dimension of 400 mm x 400 m and depth of 500 mm and the thickness of wall is 4mm. The box is fabricated to retain the plain strain conditions in all directions. The inner of the tank walls are painted to minimize the friction with the soil mass.

2.2 Model Footing

The model footing used for this study is a 20mm thick mild steel square plate of dimensions 50mm x 50mm as shown in Figure 3. The square plate was grooved and attached with a rod for the ease in the load transfer operations as indicated. A thin layer of sand was mended to the base of the footing plate to make rough.

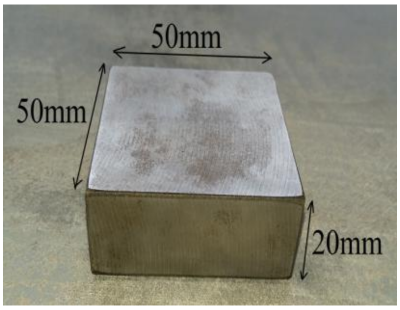

Fig -3: Model footing

2.3 Structural Skirts

A square mild steel pipe of dimension 50mm x 50mm of thickness of 4mm with sharp edge on one of its end is used as structural skirts with different lengths as illustrated in Figure 4. The lengths are based on the depth of soft soil layer.

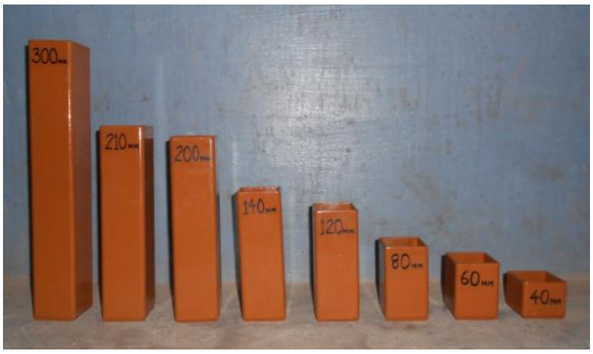

Fig -4: Structural skirts of varying heights

2.4 Material Used

2.4.1 Soft soil

The soft soil is brought from a lake bed in Kodaganur, Davanagere Taluk, Davanagere District. The soil is taken by an open excavation pit at a depth of 2 metres below the natural ground level. The procured soil is air dried and grinded by hand and soil which is passing through 4.75mm IS sieve is utilised for this research purpose. All the required tests were performed as per IS: 2720. The properties of soft soil are recorded in the Table 1.

Table -1: Properties of Soft Soil

Sl. No.	Property	Values
1.	Specific Gravity	2.60
2.	Field Moisture Content	28%
3.	Liquid Limit	62.85%
4.	Plastic Limit	21.18%
5.	Plasticity Index	41.67%
6.	Optimum Moisture Content	25.21%
7.	Maximum Dry Density	14.9 kN/m^3
8.	Coefficient of Curvature , C_c	0.63
9.	Coefficient of Uniformity, C_u	12.22
10.	Free Swell Index	45.45%
11.	Undrained Cohesion	11.348 kN/m^2

Percentage of clay is 58%, percentage of silt is 40% and percentage of sand is 2%. Using these values and those mentioned above, it's observed according to Indian Standard Classification System, that the soft soil is identified as CH i.e., inorganic clay with high plasticity.

2.4.2 Sand

The sand utilised in this study work is from Ballari and was procured from a local vendor in Bengaluru. All the required tests were performed as per IS: 2720. The properties of sand are being listed in the Table 2.

Table -2: Properties of Sand

Sl. No.	Property	Values
1.	Coefficient of Curvature , C_c	1.125
2.	Coefficient of Uniformity, C_u	2.88
3.	Specific Gravity	2.67
4.	Angle of Shearing Friction, ϕ	45º
5.	Maximum Dry Density ,γ_{dmax}	17.5kN/m^3
6.	Minimum Dry Density ,γ_{dmin}	16.4 kN/m^3
7.	Minimum Void ratio, e_{min}	0.54
8.	Maximum Void ratio, e_{max}	0.74
9.	Relative Density D_r	50%

2.5 Experimental work and methodology

To study the variation in the load-settlement for different replaced depth for footing with or without skirt conditions, the Universal Testing Machine was used. It ensures that the setup in compressive movement is at an appropriate control strain rate. The dimension of the model box was chosen with respect to the dimension of foundation and the zone of influence and was decided should be within a range of 3 to 5 times the dimension of the foundation. The load and settlement were listed till maximum settlement of 20% of the size of foundation i.e., 25 mm. The settlement readings were obtained from the dial gauge which is attached to the lower lever of the universal testing machine.

Table -3: Particulars of the model test program

Test sequence	Description of the test	Testing Program Parameters	
		Constant	Variable
1	Typical footing without replacement	D = 4B = 200mm	h/D = 1, 1.5
2	Partially replaced without skirt	h/D = 1, D = 200mm	L/h = 0.2, 0.4, 0.7. and 1.0
3		h/D = 1.5, D = 200mm	L/h = 0.2, 0.4, 0.7. and 1.0
4	Partially replaced with skirt	h/D = 1, D = 200mm	L/h = 0.2, 0.4, 0.7. and 1.0
5		h/D = 1.5, D = 200mm	L/h = 0.2, 0.4, 0.7. and 1.0

2.5.1 Testing Procedure

Fig -5: Model testing setup

Fig -6: Dial Gauge setup

The sand of about 61kg is weighed and is filled in 25mm thick layers into the model tank and is compacted to reach the total depth of 200 mm and is to be maintained constant throughout the testing program. The soft soil is pulverised and passing through IS 4.75mm sieve is used for the testing. About 49kg is measured and mixed completely at optimal water content of 25.21% so as to get maintain the maximum dry density of 14.9kN/m^3.The soil is filled in layers of thickness 50mm and compacted to required field density to a depth of 200 mm. The skirts are inserted to the required depth and the soil is taken out from the outer surface of the skirt. To avert the eccentric loading the skirts is located at the centre of the model box. The skirt is filled with sand by compacting in layers of thickness 20 mm and up to the surface of the top of skirt. The model tank of size 400mm x 400mm x 500mm is loaded to the movable platform of UTM. The inner walls are coated with oil in order to reduce the boundary effects. The model box and the model footing are attached to the motorised jack of UTM which can move up and down to help in obtaining the load and settlement. The dial gauge is setup at the centre of loading jack to get the settlement reading. The applied load on the model footing is recorded from the analog display. The application of load to the footing is done at a steady rate. The process is repeated for the different heights of skirts

In the case of unskirted conditions, the structural skirt is taken out to a required length and the process of pouring and compacting of sand is continued for the next layer.

Fig -7: Skirt arranged for testing

3. RESULTS AND DISCUSSIONS

In this study work a total of eighteen load-settlement curves were obtained from the test conducted on both skirted and unskirted conditions. Maximum load was recorded for the settlement corresponding to 25 mm for all the analyses.

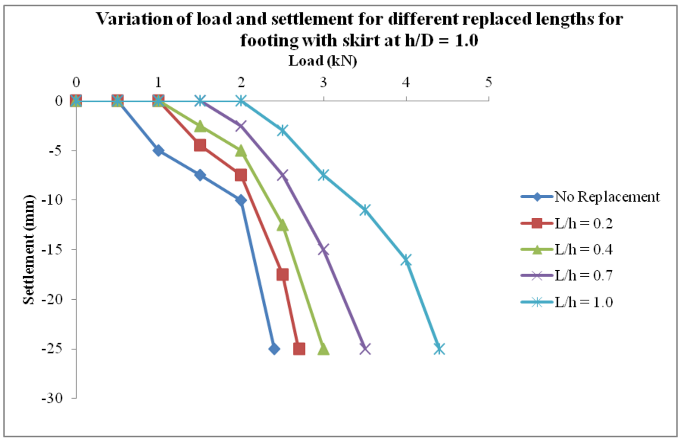

Chart -1: Variation of load and settlement for different replaced lengths for footing with skirt at h/D = 1.0

From the Chart 1, the maximum load at the maximum settlement of 25mm is 2.4kN for typical footing without replacement, 2.7kN for L/h = 0.2, 3.0kN for L/h = 0.4, 3.5kN for L/h = 0.7 and 4.4kN for L/h = 1.0.

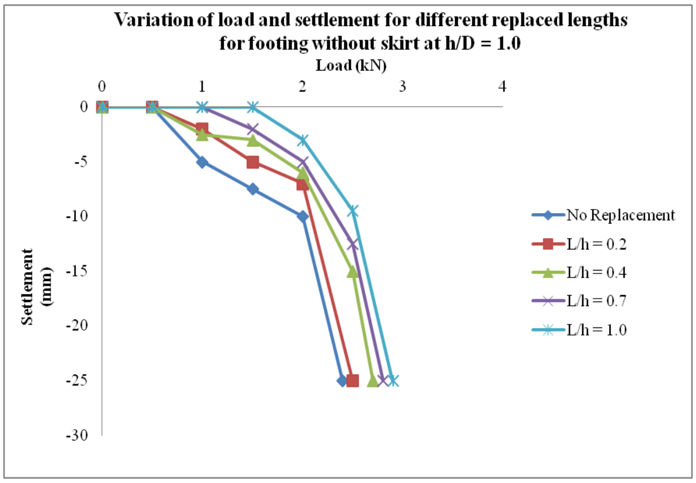

Chart -2: Variation of load and settlement for different replaced lengths for footing without skirt at h/D = 1.0

From the Chart 2, the maximum load at the maximum settlement of 25mm is 2.4kN for typical footing without replacement, 2.5kN for L/h = 0.2, 2.7kN for L/h = 0.4, 2.8kN for L/h = 0.7 and 2.9kN for L/h = 1.0. It was observed that the skirt installed with the replaced fill evidently enhances the bearing capacity of the footing and also rigidity of the foundation bed. Structural skirts behave as a confining material since they are drawn vertical and thereby adequately reduce the strain beneath the foundation and also the settlement is controlled based on the skirt lengths. To understand the percentage variation in the bearing capacities of footing with or without skirt, two correlations were formulated as follows:

Case I:

$$\frac{\text{Ultimate Bearing capacity with skirt - Ultimate Bearing capacity of foundation}}{\text{Ultimate Bearing capacity with skirt}} \times 100$$

Case II:

$$\frac{\text{Ultimate Bearing capacity without skirt - Ultimate Bearing capacity of foundation}}{\text{Ultimate Bearing capacity without skirt}} \times 100$$

From the analysis it was found that the presences of structural skirts have broadly changed the stress strain curves and also the bearing capacity is increased with respect to the increment in the skirt length. Percentage gain in the load carrying capacity of skirted footing for h/D =1.0 and L/h = 1.0 is 32.20% as compared to 11.11% for L/h = 0.2 likewise in case of unskirted footing for h/D =1.0 and L/h = 1.0 is 16.67% as compared to 11.11% for L/h = 0.2

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 06 | June-2016 www.irjet.net p-ISSN: 2395-0072

3.1 Effect of replaced length and the installation of skirts

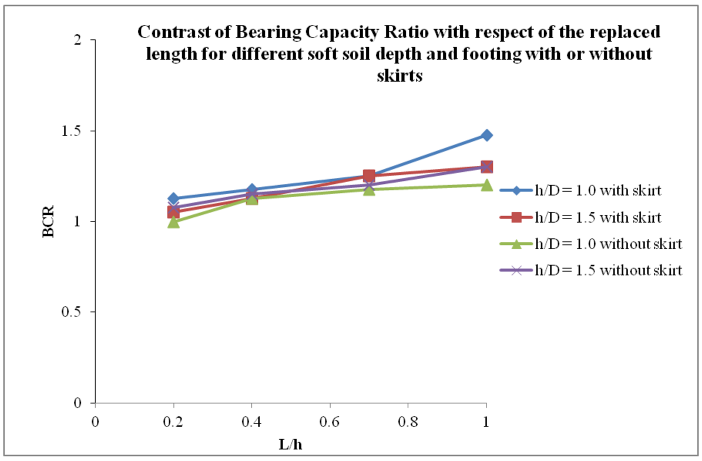

Chart -3: Contrast of Bearing Capacity Ratio with respect to the replaced length for different soft soil depth and footing with or without skirts

The proposed definition of Bearing capacity ratio or BCR in this study is the ratio of bearing capacity of footing with or with skirts to that of footing. Chart 3 shows Contrast of Bearing Capacity Ratio with respect of the replaced length for different soft soil depth and footing with or without skirts. It was observed that the BCR moderately increase with the increment in the replaced depth. Likewise it's found that the amount of gain in the BCR is purely based on the soft soil layer thickness. Therefore, increase in the bearing capacity is directly proportional to the thickness of soft soil. The lateral displacement lessens by the structural skirts and limits the bulging of sand inside the skirt. A stage is reached when the skirts and sand inside it behaves like a single unit and acts as a deep foundation. Skirts increases the load carrying capacity to 1.475 times of the bearing capacity of soft soil at h/D = 1.0 and 1.3 times at h/D = 1.5 and in case of unskirted, the bearing capacity increased by 1.2 times at h/D = 1.0 and 1.3 times at h/D = 1.5.

3.2 Effect of confinement in the reduction of settlement

The additional investigation of study work was done in order to understand the effects that helps in the reduction and also to control the settlement. The reduction factor for settlement (Percentage reduction in settlement) is defined in this study work as

$$PSR = \frac{(So - Sr)}{S_0}$$

where the settlement of foundation on soil with respect to its ultimate load carry capacity = S_0 and the settlement of foundation with /without skirt with respect to its ultimate load carry capacity = S_r

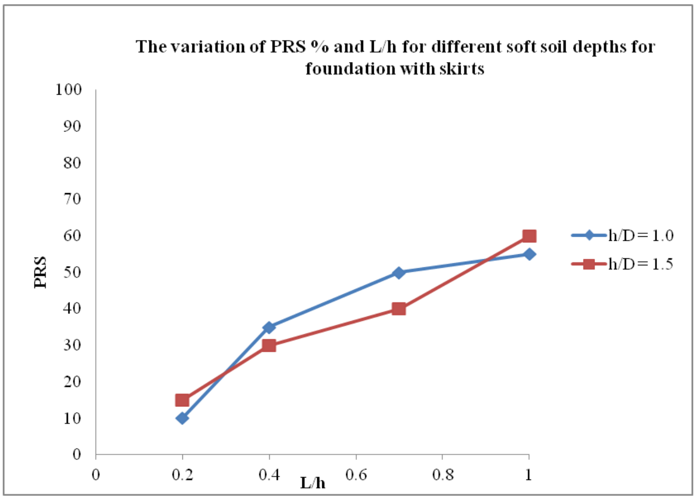

Chart -4: The variation of PRS % and L/h for different soft soil depths for foundation with skirts

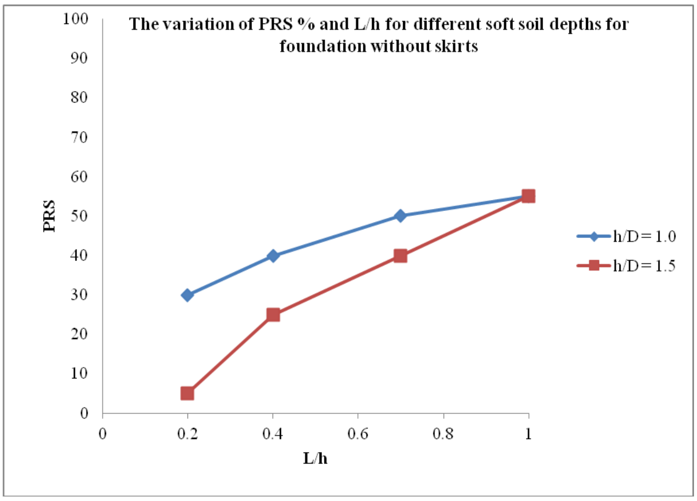

Chart -5: The variation of PRS % and L/h for different soft soil depths for foundation without skirts

Chart 4 and 5 shows the changes between PRS and the replaced depth for foundation with or without skirts.
The result shows that there is a percentage reduction in the settlement under both the conditions but the plots show more of abnormality in the analysis. However as the depth of replaced soil increases there is reduction in settlement. It's also accounted that presence of skirt with adequate depth notably increases the percentage reduction in settlement. Structural skirts are more useful to increase the stiffness of the foundation and to regulate the displacement in both vertically and laterally beneath the foundation.

4. CONCLUSIONS

The model study was carried to analyse the improvement of bearing capacity of a square footing lying on the soft soil using sand pile and with or without structural skirts as confinements. A set of loading test were performed on a square footing placed on a layered soil system of soft soil and sand.

The following are the conclusions induced from the model study:

- The enhancement of load carrying capacity of the footing was increased nominal in both partial fill of sand piles with or without skirts.
- The percentage increment of bearing capacity of square foundation with skirts lying on the soft soil layer at conditions h/D = 1.0 and L/h = 1.0 with respect to the same only on the soft soil, was found to be 32.2% and that for the conditions L/h = 0.2 was found to be only 11.11%.
- The percentage increment of bearing capacity of square foundation with skirts lying on the soft soil layer at conditions h/D = 1.5 and L/h = 1.0 with respect to the same only on the soft soil, was found to be 23.08% and that for the conditions L/h = 0.2 was found to be only 4.76%.
- The percentage increment of bearing capacity of square foundation with skirts lying on the soft soil layer at conditions h/D = 1.0 and L/h = 1.0 with respect to the same only on the soft soil, was found to be 16.67% and that for the conditions L/h = 0.2 was found to be only 11.11%.
- The percentage increment of bearing capacity of square foundation with skirts lying on the soft soil layer at conditions h/D = 1.5 and L/h = 1.0 with respect to the same only on the soft soil, was found to be 23.08% and that for the conditions L/h = 0.2 was found to be only 6.98%.
- It was observed that as the skirt length increased, there was a moderate increase in the bearing capacity of the square foundation and also depends on the depth of each layer in a layered soil system.
- The percentage reduction in the settlement was found to be nominal and depends greatly on the fill height and length of skirt.

REFERENCES

[1] A.F. Zidan, 2015, “Bearing Capacity and settlement of circular footing resting on confined sand (Experimental study)”, Proceeding of the Third International Conference Advances in Civil, Structural and Mechanical Engineering, 65-70

[2] Ahmed Elzoghby Elsaied, Nasser Mosleh Saleh and Mohi Eldeen Elmashad , 2015, “Behavior of circular footing resting on laterally confined granular reinforced soil”, Housing and Building National Research Center Journal,11,240-245

[3] Amr Z. El Wakil, 2010, “Horizontal capacity of skirted circular shallow footings on sand”, Alexandria Engineering Journal, 49, 379-385

[4] Ashraf Kamal Nazir and Wasim R. Azzam, 2010,” Improving the bearing capacity of footing on soft clay with sand pile with/without skirts “, Alexandria Engineering Journal (2010) 49, 371-377

[5] B.B. Ajitha, P. Sandhya, B. Aswin, V. Merin, G.M. Reshma, K. Rohit and P.A. Thansila, 2014, “Behavioral study of skirted foundations on sand”, Proceedings of Indian Geotechnical Conference, 43-49

[6] Kazuo Tani and William H. Craig, 1995, “Bearing Capacity of circular foundations on soft clay of strength increasing with depth”, Soils and Foundations, Japanese Geotechnical Society, Volume 35, No. 4, 21-35

[7] M.Y. Al-Aghbari, 2007, “ Settlement of shallow circular foundations with structural skirts resting on sand”, The Journal of Engineering of Research, Volume 4, No. 1, 11-16

[8] M.Y. Al-Aghbari and Y. E-A. Mohamedezein, 2004, “Bearing capacity of strip footing with structural skirts “, Geotechnical and Geological Engineering, 22, 43-57

[9] M.Y. Al-Aghbari and Y. E-A. Mohamedezein, 2007, “Model Testing of strip footings with structural skirts”, Proceedings of the Institution of Civil Engineers Ground Improvement, 7, No.1,1-7

[10] Gupta, R. and Trivedi, A., 2010, “Behavior of model circular footings on silty soils with cellular supports”, International Journal of Engineering Vol. 23, No. 1, 21-35

[11] Rajeev Gupta and Ashutosh Trivedi, 2009,” Bearing capacity settlement of footing resting on confined loose silty sands, Electronic Journal of Geotechnical Engineering, 14, 1-14

[12] S. Golmoghani-Ebrahani, M.A. Rowshanzamir, 2013, “Experimental Evaluation of bearing capacity of skirted footings”, Civil Engineering and Architecture 1(4):103-108

[13] S.P Singh, S. Tripathy and B. Srikanth, 2013, “Horizontal load carrying of circular skirted footings embedded in sand”, Proceeding of Indian Geotechnical Conference, 1-4

[14] Sareesh Chandrawanshi, Rakesh Kumar, Dr. Suneet Kaur and Dr. P K Jain, 2014, “Effect of skirt on pressure settlement behavior of model circular footing in medium dense sand”, International Journal of Advanced Engineering Technology, Vol. V, Issue II,01-05