Websites:
http://www.lifesciencesite.com
http://www.sciencepub.net

Emails:
editor@sciencepub.net
sciencepub@gmail.com

Life Science Journal

MARSLAND PRESS
Multidisciplinary Academic Journal Publisher

Improving the ultimate capacity of loaded strip footing using additional contact area under excessive loads

M.N. EL Siragy

Assistant Professor of Geotechnical Engineering, Department of Structural Engineering, Faculty of Engineering – 6 October University, Egypt
Email: siragy2000@yahoo.com

Abstract: The purpose of this paper is to adopt an alternative strategy for strengthening of existed strip footing by increasing the bearing area instead of using the previous methods of soil reinforcement technique. These techniques are rather than prohibitively expensive and restricted by the conditions of the site. The main objective of this strengthening is to improve the bearing capacity under the loaded strip footing to resist additional loads. It also aims to study the effect of the increasing the footing size on the bearing capacity factor (N) and failure mode of the footing. A series of Loading tests on the modified model footing are carried out at different footing widths on sandy soil. The results show that the bearing capacity of widen footings at double side significantly increased. In addition to, the resulting settlement can be decreases. The ultimate load capacity is increased by as much as 140, 218% for additional area $\Delta B/B = 0.4$ and 1 with remarkable reduction in settlement around 45%. The bearing capacity factor affected by the footing size as comprised with different investigators.
[M.N. EL Siragy. **Improving the ultimate capacity of loaded strip footing using additional contact area under excessive loads.** *Life Sci J* 2019;16(12):147-153]. ISSN: 1097-8135 (Print) / ISSN: 2372-613X (Online). http://www.lifesciencesite.com. 19. doi:10.7537/marslsj161219.19.

Keywords: Improving; ultimate; capacity; loaded strip; footing; excessive loads

1. Introduction

A majority of foundations are adequately constructed and perform as designed, however, there are many instances where soil movement can cause damage and foundation failure. Common soil problems that causes foundation failure are heave or shrinkage from expensive soil, consolidation due to soft and organic soil and settlement from uncontrolled or deep fill (Greenfield and Shen, 1992), in addition the foundation subjected to excessive loads. Foundation can also be damage due to natural disasters such as earthquakes (Day, 1994 and Day, 1996) or fires.

On the other hand, a variety of methods of soil reinforcement is known and is well developed. However, they are sometimes prohibitively expensive and restricted by the conditions of the site. In some conditions they are difficult to apply to existing foundations. (Basset and Last 1978, Verma and Char 1986, Mahmoud et al, 1988, Verma et al., 1992 and Mandal, 1995 and Bahloul et al., 2004) studied the possibility of using vertical reinforcement along each side of existed footing as a technique of soil reinforcement. While Masoud and Ehsan 2017 used a soil reinforcement technique by geotextile to improve the ultimate bearing capacity of footing with the same area. It is therefore suggested that an alternative approach is required for improving the bearing capacity of the loaded footing soil system instead of excavate the site and placing a layer of reinforcement. This approach is based on the increasing the contact area under the loaded footing, the foundation of the building under reconstruction or of technological equipment can be strengthened by various methods. Selection of the method depends on the type of the existed foundation, quality of its performance, characteristics of engineering-geological stratification, ground water level, construction of the building and acting load on the foundation etc. If the foundation material is in an unsatisfactory condition (mechanical failure, presence of settlement cracks and cracking of foundation body), it is appropriate to strengthen such foundation by the method of injecting cement slurry, synthetic resins etc. But if no failure in reinforced concrete footing, in order to decrease the contact stress in the subgrade layer it is preferable to increase only the bearing area. When the bearing capacity of the soils under the base is not sufficient, the foundation area has to increase. In this case additional area of the foundation provided may be one sided when the foundation load is eccentric or double sided when the load is central.

The paper will be limited and focus to study the strengthening process by increasing the contact area along each side of loaded strip footing to increase the bearing capacity and control the settlement. Also, it presents the identification of the failure pattern under strengthens footing.

Physical modeling and tests

A wooden tank was used to contain the soil that was tested. The testing tank has inside dimension of 205 cm (long), 60 cm (wide) and 90 cm (height). Plain strain conditions were considered for all model tests. The rigid footing model was made of a steel box section with a width of 10 cm, 2 cm thickness and a length equal to the length of the tank to simulate a strip footing. In order to widen the footing model along each side, the two additional areas are connected rigidly to the footing model after reaching 50% failure load. These parts have width ratio $\Delta B/B$ = 0.2, 0.4, 0.0.6, 0.8 and 1. Where ΔB is the additional width connected to the existing footing along each side. The model footing is modified to carry out the loading tests at each new area. The new area connected rigidly to the footing model by two cross plates (200 x 50 x 20 mm) welded with the footing model as in Fig. (1). These plates are also used to transfer the load to the additional area and connect the footing with the new area by anchor bolts (10). For each test a homogenous bed of dry silica sand was formed with dry density 1.8 t/m^3 (R. D = 81%, = 40^o). The mean grain size $D_{50\%}$ = 0.33 mm and the uniformity coefficient is Uc = 26.

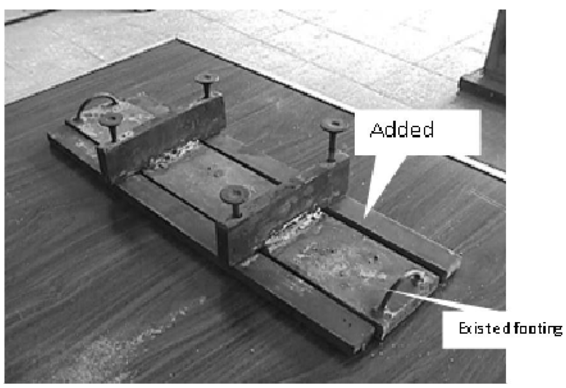

Fig. 1: General view for modified footing model.

Loading tests are carried out on the model strengthen footing, where the load is applied incrementally, and the displacement of footing under each incremental load is recorded until reaching equilibrium. When the load reaches 50% of the failure load, the new areas are connected with the footing, and then it is loaded up to failure. These tests are carried out at different values of ratio ($\Delta B/B$) and the resulting ultimate bearing capacity are obtained. The test parameter ($\Delta B/B$) is varied to evaluate its effect on the bearing capacity of the subgrade layer under the strengthened footing as shown in Fig. (2).

Table (1) gives a summary of the performed tests and the resulting ultimate bearing capacity and the load ratio (L_r) where $L_r = P_{ult}/P_o$ in case of compacted sand. Where,

P_{ult} ultimate load capacity in case of increasing the bearing area.

P_o ultimate load capacity of existing footing.

Test results and discussion

Load settlement relationships

The load settlement curves determined from last mentioned tests are shown in Fig. (3). This figure presents the load settlement curves after increasing the bearing area of the model footing at 50% failure load. The ultimate bearing capacity of the footing soil system of each test is assessed unambiguously from the load displacement curves. From these curves it can be seen that, the increasing in the contact area of loaded footing significantly modifies the load displacement curve as clearly shown in last figure. As the footing width increases, the resulting settlement decreases and the footing load capacity is increased. It is observed that the increase in the contact area leads to decrease the deformation of the soil under the loaded footing and decrease the plastic flow of soil particles. On the other hand, it has been found that for the ratio ($\Delta B/B > 0.4$), the load settlement curve is distinctly modified and the bearing capacity of the system is increased. For the ratio ($\Delta B/B < 0.4$), the load settlement curve is slightly enhanced and relatively increases the bearing capacity of the widening footing.

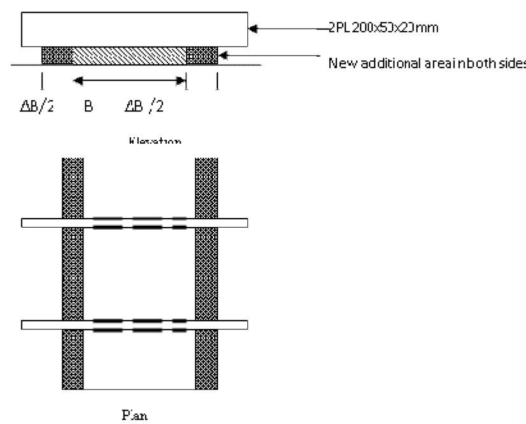

Fig. 2: Layout of the modified testing model for strengthening the foundation.

Effect of the widening the footing on the footing load capacity

The relationship between the increase in the bearing area and the load ratio (P_{ult}/P_o) is plotted as in Fig. (4). It is noticed that as the footing area increases the load ratio is increased. The load that applied to the footing before increasing the contact area, it improves the subgrade layer and compacts the soil particle under the footing. As the soil particles at both edge of the footing are activated and move upward, the new area connected to the footing over these activated particle prevent it form upward movement and the footing load capacity increases. For extent, as the footing area is increases the footing load capacity increases and over range of ($\Delta B/B$ > 0.4), the footing load capacity sharply increases. The ultimate load capacity is found to be increased by 40 and 218% at $\Delta B/B$= 0.4 and1 respectively.

Table 1: The testing program for the compacted sand for modified footing.

Test No	ΔB/B	$P_{ult\ kN}$	$q_{ult\ kN/m^2}$	Lr	N	PRS%
1	0	80	133	1	148	0
2	0.2	96	134	1.18	122	5
3	0.4	113.4	135	1.375	105	20
4	0.6	141	140	1.76	95	25
5	0.8	156	144	1.95	86	3.75
6	1.0	165	144.5	2.01	80	45

Effect of the widening the footing on ultimate bearing capacity

The relationship between the increase in the bearing area (ΔB) and the ultimate bearing capacity of the footing soil system is illustrated in Fig. (5). It can be seen that, as the area of the loaded footing increases, the bearing capacity increases. But for the value of ($\Delta B/B$ = 0.2, 0.4) respectively, the increase in the area from 20% to 40% of the footing width is not effective, because the value of ($\Delta B/B$ = 0.2 and 0.4) are not sufficient to rest on the heaved soil along each side of the main loaded footing. When the soil particles are activated and move laterally, the submitted area should be cover these zones. It is concluded that the footing should be strengthened with the additional area in both footing sides which not less than 0.5B along each side.

On the other hand, based on the bearing capacity criterion. The variation of the ultimate resistance of footing with size is plotted in Fig. (6). It presents a comparison of measured ultimate bearing capacity for strengthened surface footing with those of Vesic, 1969. It has been found that the ultimate bearing capacity increases with the increase of the footing width. Also, it is noticed that the values of the measured ultimate bearing capacity remarkably lower than of that obtained by Vesic, that is backed to the variation in the tested soil and the footing type. Where, Vesic uses the circular footing.

In addition, the investigation extended to study the effect of the width in the bearing capacity factor (N) of surface footing. Where, the bearing capacity factor (N qult/0.5 B) obtained from the general equation by the back calculation at different footing size is plotted in Fig. (7). In view this figure a decrease in apparent values of the bearing capacity factor (N) with size should be to a certain degree be expected in all soils. Probably, the most conspicuous of all is the decrease in (N) values with increased size of surface footings on sand. This decrease has been apparent in all major experimental studies of the problem of the bearing capacity of shallow footings, as comprised with different mentioned investigators for rectangular plate footing model and circular plates Fig. (7). Otherwise, It is noticed that the (N) values for arbitrary large footings may be much smaller than conventionally assumed as indicated in last figure.

Settlement reduction due to increasing the contact area

The extension of the investigation of using laboratory loading tests for loaded footing soil system strengthened by increasing the contact area is carried out in order to examine the effect of increasing the bearing area on reduction of the settlement under the loaded footing. The settlement reduction is generally expressed according to values of the percentage reduction in settlement (PRS%) as discussed before. The relationship between the (PRS%) and the increase in the contact area is presented in Fig. (8). It has been found that the increase in the footing width reduces the settlement. The percentage reduction in settlement is affected by the ratio ($\Delta B/B$) in linear relationship. The increase in the contact area reduces the settlement by 45% of its initial value. In addition, the increase in the contact area under loaded footing is a good method to prevent the plastic settlement at each side of the footing.

Failure mode identification

The bearing capacity failure mode identification for strengthened footing by increasing its contact area is illustrated in Fig. (9). It is observed that, the displacement field under the widen footing depend on the load level and the increase in width (ΔB). This figure shows the three different stages of failure pattern. The stage (I) presents the settlement under the existed footing along the width (B) at 50% failure load. The stage (II) shows the settlement of both the existed footing and the settlement under the added area. This stage is considered as a transition stage, which provides a significant increase in the bearing capacity and delays the bearing failure. Where the distribution of the contact stresses only under the added area induces the passive resistance along the wedge or elastic zone. Consequently, this stresses control and prevents the activation of the soil particles under the system and decreases the plastic settlement until the footing reaches to the ultimate load. And occurs the overlap in the settlement of the stage (I and II) then the failure is take place as plotted in stage (III) in the form of punching shear failure. The general view of failure is confirmed that as presented in Fig. (10). Where, this figure clarify the expected failure mode, it seems to imply that as the footing size increases the failure mode is significantly modified to punching shear failure. In other words, a very large footing fails exclusively in punching shear, as apparently all deep footings do. This should not be surprising because the relative compressibility of soils increases with footing size.

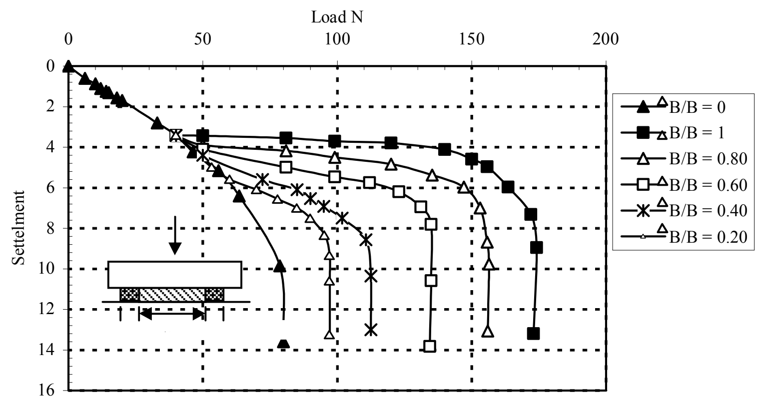

Fig.3: Load settlement curve for footing strengthened by increasing the bearing area.

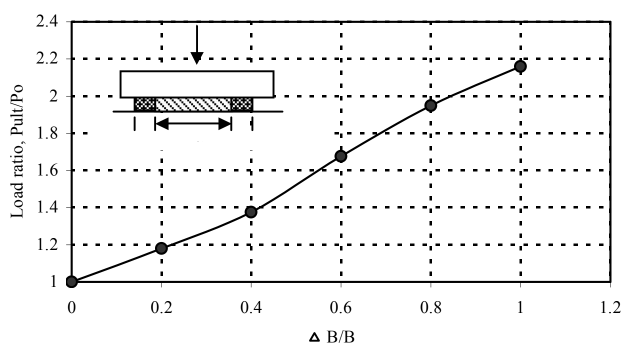

Fig. 4: The relationship between the increase in the bearing area and the load ratio.

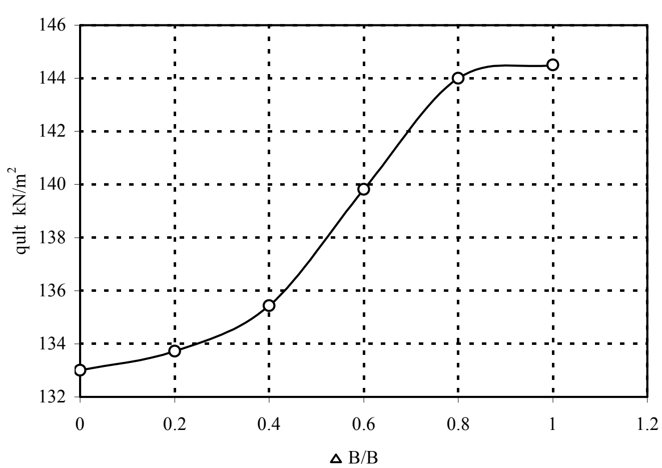

Fig. 5: The relationship between the increase in the bearing area and the ultimate bearing capacity.

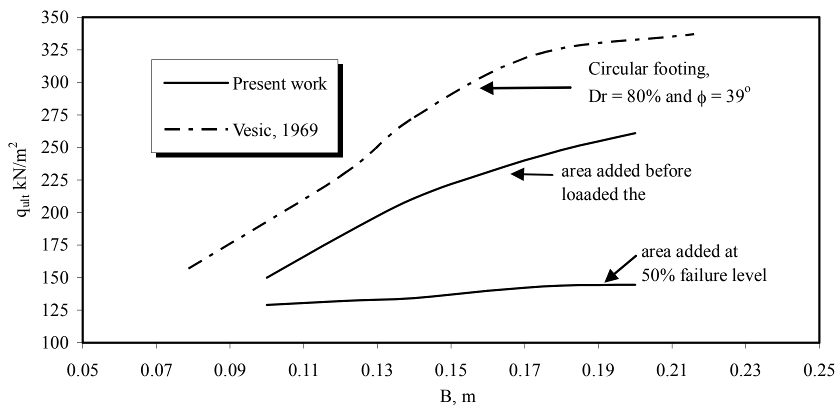

Fig. 6: The variation of the ultimate bearing capacity of footing with size.

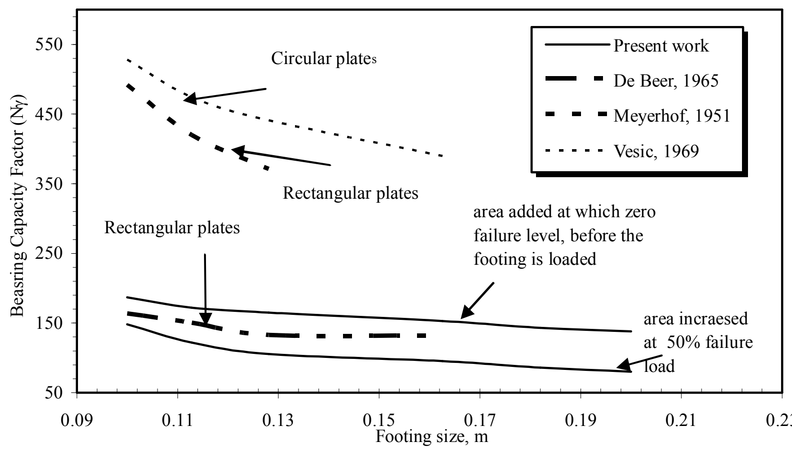

Fig. 7: The effect of footing size on the bearing capacity factor of surface footing on

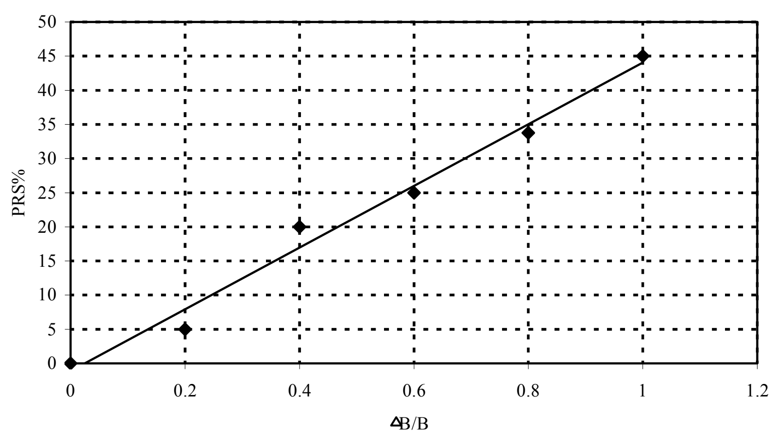

Fig. 8: The relationship between the increase in the bearing area and the percentage reduction in settlement.

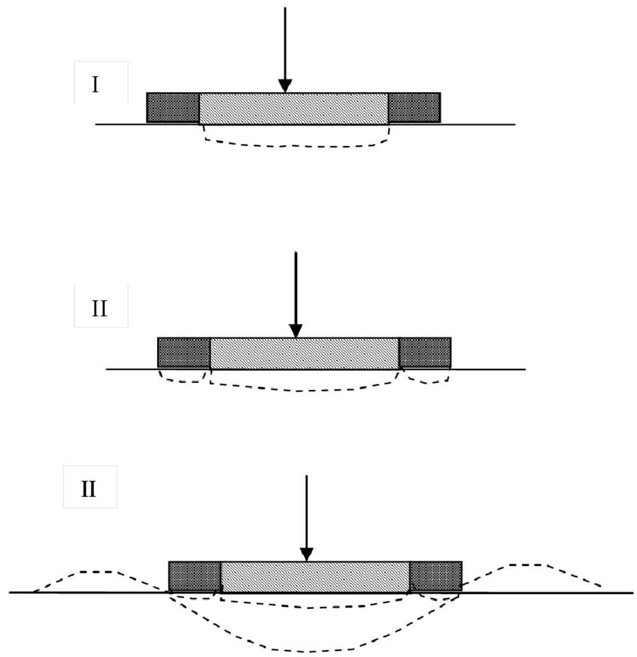

Fig. 9: The stages of failure under strengthened footing.
I -The settlement under the existed footing.
II- The settlement at both side under the added area at different stages of loading.
III- The overall settlement for the footing system at failure.

Fig. 10a: Failure mode for mdoel footing without strengthening.

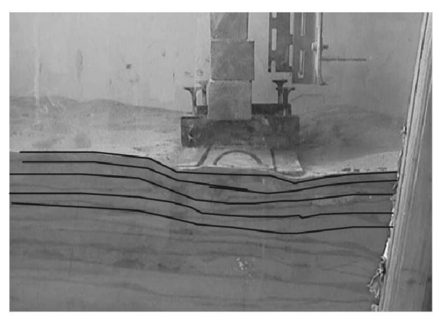

Fig. 10b:Failure mode for strengthen footing.

Conclusions

Based on the test results of the technique of strengthening footing by increasing its contact area, the following points can be mentioned:

1) The technique of increasing the contact area under the loaded footing modifies significantly the load displacement curves.

2) The increasing the footing width decreases both the deformation and plastic flow of soil particles under the loaded footing.

3) As the footing area is increases the footing load capacity increases and the resulting bearing capacity is increased.

4) The ultimate load capacity is increased by as much as 140 and 218% for additional area ΔB/B = 0.4 and 1.

5) The bearing capacity factor (N) decreases with the increase the footing size as comprised with different investigators.

6) It is suggested that, the footing should be strengthened with the increasing in the width which not less than 0.2B along each side of existing footing.

7) The percentage reduction settlement (PRS%) is found to be 20 and 45% of its initial value when the ratio ΔB/B = 0.40 and 1 respectively.

8) The bearing capacity failure mode for strengthened footing by increasing its contact area is considered to be punching shear failure and it takes place at three stages of failure pattern.

9) The increasing the footing size delays the failure and should not be surprising in occurrence.

References

1. Bahloul, M. M., et al., (2004) " Strengthening of Loaded Footing-Soil System by Vertical Extensible Reinforcement" 5th International Conference on: Ground Improvement technique, Malaysia.
2. Basset, R. H., and Last N. C., (1978), "Reinforcing Element Below the Footing and Embankment" Proceedings, Symposium on earth Reinforcement, ASCE Annual Convention, Pittsburgh, PA, pp. 202-231.
3. Day, R. W., (1994) " Performance of Single Family Houses During the Earthquake" Bull. Of Assoc. of Eng. Geologists, 31(a), pp. 507-515.
4. Day, R. W., (1996), "Repair of Damaged Slab on Grade Foundation" ASCE Journal of Structure Design and Construction Vol. 1 No.2, pp. 69-75.
5. De Beer, E. E. (1965) "Bearing Capacity and Settlement of Shallow Foundation on Sand" Proceeding of Symposium Held at Duke University, pp. 15-34.
6. Greenfield, S and Shen, C., (1992) "Foundation on Problem Soil" Prentice Hall, Inc., Englewood Cliffs.
7. Mahmoud, M. A., (1988), " Plate Loading Tests on Reinforced Choesionless Soil" Journal of the Egyptian Society for Soil Mechanics and Foundation Engineering Division, 3.
8. Mandal, J. N., and Manjunath, V. R., (1995), "Bearing capacity of Strip Footing Resting on Reinforcing Sand Subgrade" Construction and Building Materials, Vol.9, No.1, pp. 35-38.
9. Meyerhof, G. G., (1951), " The Ultimate Bearing Capacity of Foundation " Geotechnique, Vol. 1, No.2, pp. 301-332.
10. Verma, B. P. and Char, A. M., (1986), "Bearing Capacity Tests on Reinforced Sand Subgrades" ASCE Journal of Geotechnical Engineering Vol. 112. Pp. 701-706.
11. Masoud, M. and Ehsan, B. (2017), "Comparison of bearing capacity of footing with the same area resting on reinforced sand" International Journal of GEOMATE, Jan., 2017, Vol. 12, Issue 29, pp. 9-16 Geotec., Const. Mat. & Env., ISSN: 2186-2982(P), 2186-2990(O), Japan.
12. Verma, B. P. and Jha, J. V., (1992), "Three Dimensional Model Footing Tests for Improving Subgrade below Existing Footings " Proceeding of the International Symposium on Earth Reinforcement. Balkema, Rotterdam. pp. 677-682.
13. Vesic, A. S., (1969), "Effect of Scale and Compressibility on Bearing Capacity of surface Foundation" Proceeding 7th International Conference on Soil Mech. And Found. Eng. Mexico City, Vol. 3, pp. 45-71.

12/21/2019