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

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

MARSLAND PRESS
Multidisciplinary Academic Journal Publisher

Strengthening of subgrade layer underneath loaded strip footing using reticulated root piles in sand

M.N. EL Siragy

Assis. Prof. of Soil Mechanics & Foundation, Structural Eng. Dept. 6 October University, Egypt
Email: siragy2000@yahoo.com

Abstract: The major aim of this research is to investigate the ability of using root piles as a vertical reinforcement to increase the bearing capacity of the subgrade layer under loaded shallow strip footing. The present investigation aims to study the possibility of strengthen the subgrade layer under the existing foundation by using reticulated root piles (micro piles) along each side of loaded footing. A series of loading tests on the model footing on reinforced subgrade by rough piles were conducted. The effect of the spacing and location of the reinforcement in addition, pile diameters on the both bearing capacity behavior and settlement are investigated. The experimental results were compared to the work of previous investigators. The results indicate that the bearing capacity of strip footings on vertically reinforced subgrade by piles can be significantly increased by as much as 183% of its initial value in case of (L/D =16, XlB =0.25 and S/B =0.25). More over, the existence of the root piles were modified the bearing capacity failure and controlled the settlement under the existed loaded footing for general shear failure to punching shear failure.

[M.N. EL Siragy. **Strengthening of subgrade layer underneath loaded strip footing using reticulated root piles in sand.** *Life Sci J* 2019;16(8):88-97]. ISSN: 1097-8135 (Print) / ISSN: 2372-613X (Online). http://www.lifesciencesite.com. 11. doi:10.7537/marslsj160819.11.

Key words: Bearing capacity, strengthening, reticulated root piles, vertical reinforcement, and settlement.

1. Introduction

Reticulated root piles RRP is a kind of in situ reinforced soil acquired by introduction in the soil, before any kind of excavation (also called in dissimilar country root piles) are the primary model of micropiles, used in 1952 and at the present mainly applicable in the troubles of footings and underpinning. The significance and the great prospect of applications, in variety fields, for the RRP are stressed; among others: Schlosser, (1979), Mitchell et al., (1981) and Lizzi, (1983). In the current study it could be used as a perpendicular reinforced element to amplify and improve the bearing capacity performance of the subgrade stratum. While, the enhancement of the bearing capacity of subgrade by utilization of horizontal reinforcement is notified before. In addition to, investigated by lots of researchers, Binquet and Lee (1975), illustrated that the existence of tensile reinforcing strips beneath foundation enlarge and enhance the bearing capacity of supporting soil and reduces the stress over weakly soil layer. Abdrabbo (1979), Giroud (1981) and Mahmoud, (1988). It verified that the presence of a definite type of horizontal enclosure has a good effect on improvement the bearing capacity of subgrade layer. The furthermost draw back modus operandi are presented during removal the in situ soil from the site to desired depth and in the need to backfill in horizontal layers compacted to desired density and with the reinforcement placed in between as presented by Abdel-Baki et al., (1993, 1994) Mandal and Manjunath (1994), studied the method of improving the bearing capacity of strip footing resting on sand subgrades, Watn et al. (1997) and Saleh (2002), explained the improvement of the bearing capacity of strip footing by using geosynthtic reinforcement placed in horizontal manner. Where, Basset and Last (1978), Verma and Char (1986 -1992) used a steel vertical bars as a vertical inclusions, Mahmoud and Abdrabbo (1988) were used vertical aluminum strips in addition, Abdrabbo, El-Hansy (1993) studied the ability of strengthening of circular foundation reinforced by vertical steel bars. Mandal (1994) notified and investigated the option of using variety of vertical reinforcement in the shape of geogride and bamboo sticks. Conversely, in (2003), Al-Aghbari debate the bearing capacity of shallow square foundation with structural skirts resting on sand in the vertical form. It is found that this type of reinforcement enlarges the bearing capacity of subgrade. Azzam and Basha (2018) investigated the connected micro-piles for raising the sub-grade under the presence strip footing. In this research, micro-piles are used in parallel lines each aspect of the loaded strip foundation under the increased recently used region. This technique can be improved the ultimate bearing capacity by 260% and decreased the foundation settlement by 45%. Based on the paper in literature there are verity of reinforced technique used to improve the bearing capacity under loaded footing in the form of inextensible and extensible reinforcement some of this technique are expensive difficult in construction and restricted by conditions of the site. Therefore the present paper tries to use and economic and easy installation method to enhance the loaded footing subgrade system. This approach can be assisted to the possibility of using vertical reinforcement as root piles as an outstanding way for increasing the bearing capacity of subgrade and control the settlement of the existence foundation to resist any extra loads.

2. Model experiment arranging and methodology

A wooden tank was used to contain the soil that was tested. The testing tank has inside dimension of 900 mm (long), 900 mm (wide) and 1200 mm (height). The element of test setup and loading system are shown in Fig. (1). the tested soil in the present investigation was obtained from Quesna sands, in Egypt. For every experiment an identical bed of dry silica sand was created. The grain size distribution curve illustrated in Fig. (2). The mean grain size $D_{50\%}$ 0.33 mm and the consistency coefficient is 26. The physical and mechanical properties of tested sand are shown in Table 1. To prepare, the compacted sand bed, the Japanese method used. The relative density stayed constant. An extensible vertical inclusions was used a steel sheets its thickness 1.5 mm as a reinforced element. Loading tests have been performed on the footing surface up to predetermined percentage of the failure load (after reaching 50% of failure load). Then, the sand is reinforced by vertical pile reinforcement and the test is completed up to failure in footing-soil system. At failure it is noticed that the extreme settlement happens at almost a constant load.

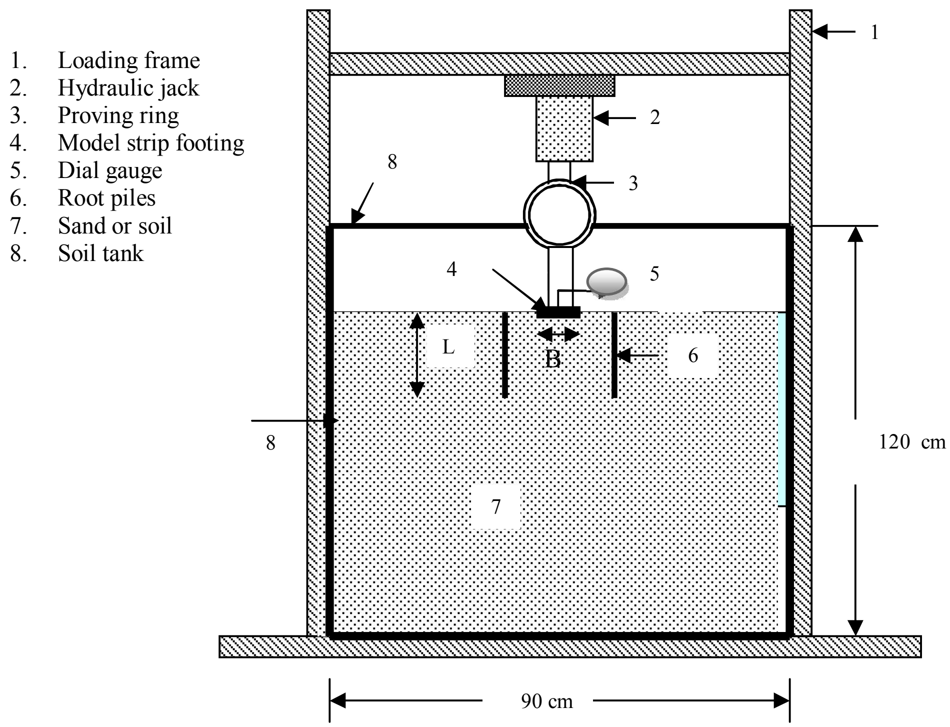

Fig. 1 Test setup and loading system

Table 1: Physical and mechanical properties of tested sand

Property	Value
Specific gravity	2.65
Compacted dry density $_{d\ max}$ (g/cm^3)	1.8
Min dry density - soft case $_{d\ min}$ (g/cm^3)	1.56
Max. shear angle $_{tri}$	40^o
Max. voids ratio e_{max}	0.699
Min. voids ratio e_{min}	0.472
Relative density Dr	85%

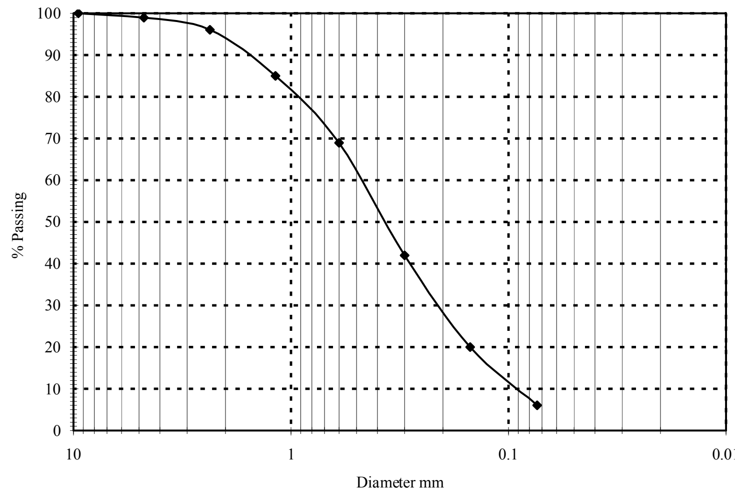

Fig. 2: Grain size distribution curve for tested sand.

The problem under investigation and the used parameters are seen in the Fig. 4. The non-dimensional test factors are varied to calculate the following effects:

1. The ratio of the horizontal distance between the pile and the edge of the footing to the footing width (X/B).
2. The ratio of the pile length to the footing width (L/D).
3. The spacing between piles (S/D)

The resulting ultimate bearing capacity and the bearing capacity ratio BCR = $q_{ult\ rein}/q_{ulto}$ was presented for different tested parameters. Where,

$q_{ult\ rein}$ ultimate bearing capacity in case of reinforcement

q_{ulto} ultimate bearing capacity in without reinforcement

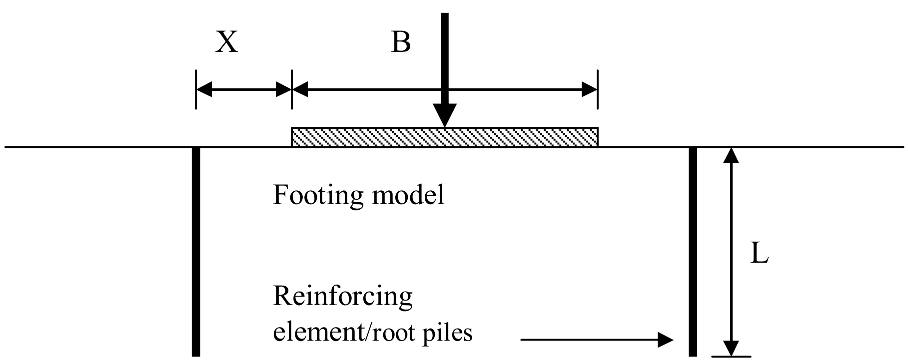

Fig. 3: The investigated parameters for the problem statement in case of extensible technique, root piles

3. Results and analysis

General

This paper presents the analysis of using piles as a vertical reinforced element for strengthening the subgrade layer. Therefore, the main aim of the present research is to investigate the potential of strengthening the subgrade layer under the existence of footings by using reticulated piles. Loading experiments on model footing reinforced by rough piles which have slenderness ratio (L/D = 25, 20 and 16) were conducted at different spacing between piles. Also, some of loading tests are accomplished on the sand bed model after and before pile reinforcement. The piles placed in the soil when the load reaches 50% of the failure load. The effect of both pile stiffness and spacing between piles on the bearing capacity behavior were discussed. In addition, the effects of location of pile row from footing edges were submitted. The effect of the pile reinforcement on the failure mode is also distinctly explained.

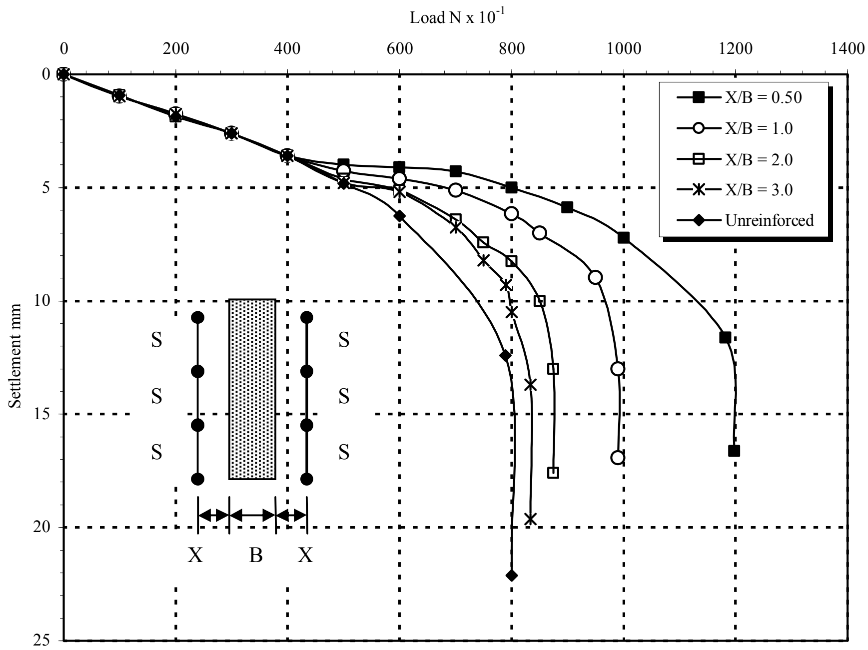

Fig.4: Load settlement curve for reinforced subgrade with pile technique in case of (L/ D = 25, pile spacing S = 0.25B)

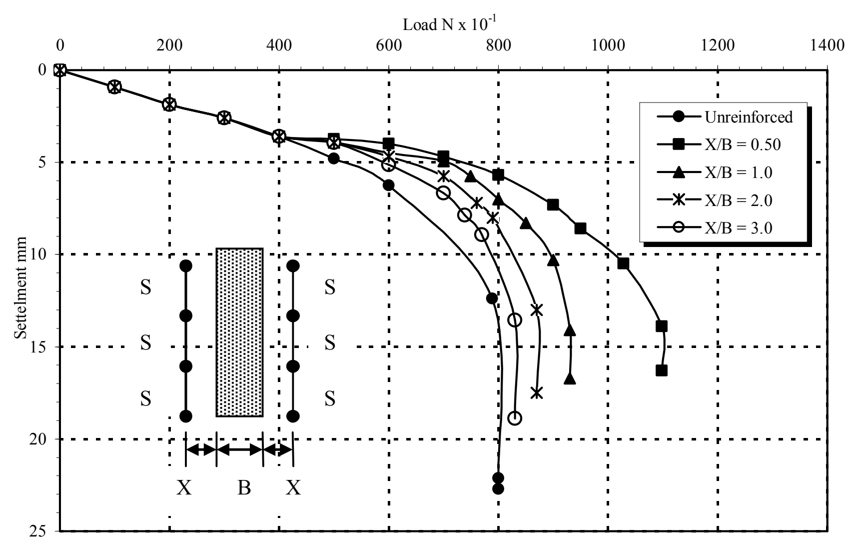

Fig. 5 : Load settlement curve for reinforced subgrade with pile technique in case of (L/ D = 25,pile spacing S = 0.5B)

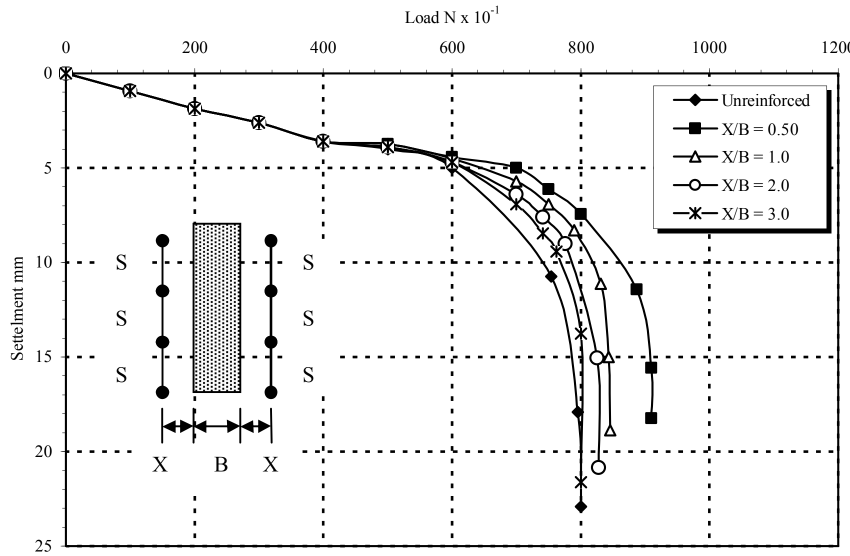

Fig. 6 : Load settlement curve for reinforced subgrade with pile technique in case of (L/ D = 25, pile spacing S = B)

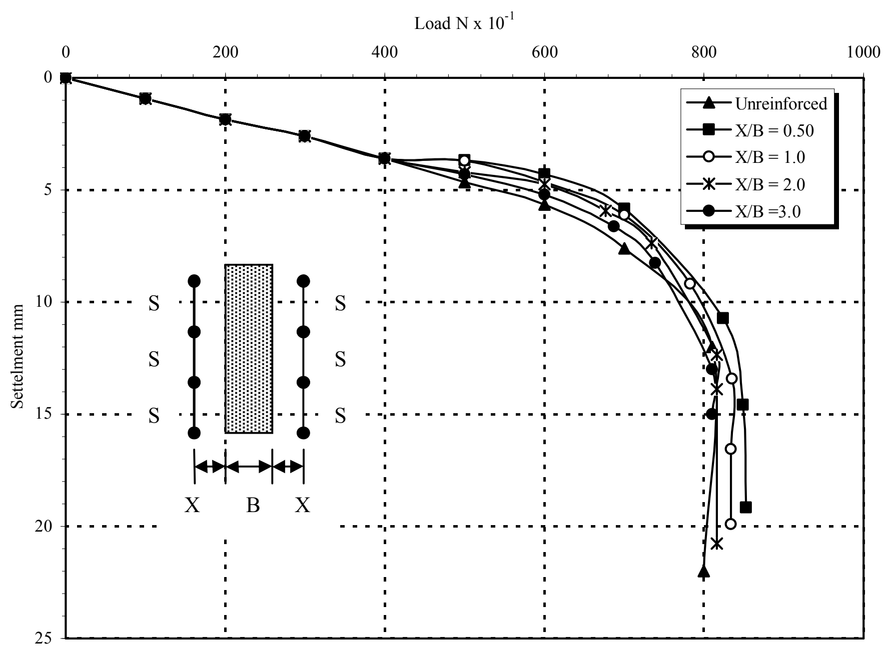

Fig. 7 : Load settlement curve for reinforced subgrade with pile technique in case of (L/ D = 25, pile spacing S = 1.5B)

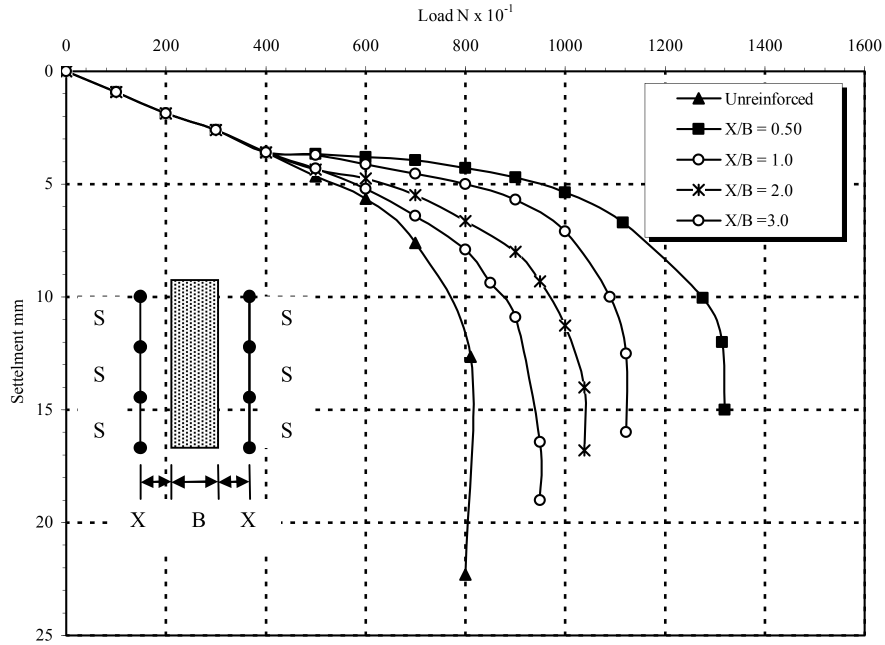

Fig. 8: Load settlement curve for reinforced subgrade with pile technique in case of (L/ D = 20, pile spacing S = 0.25B)

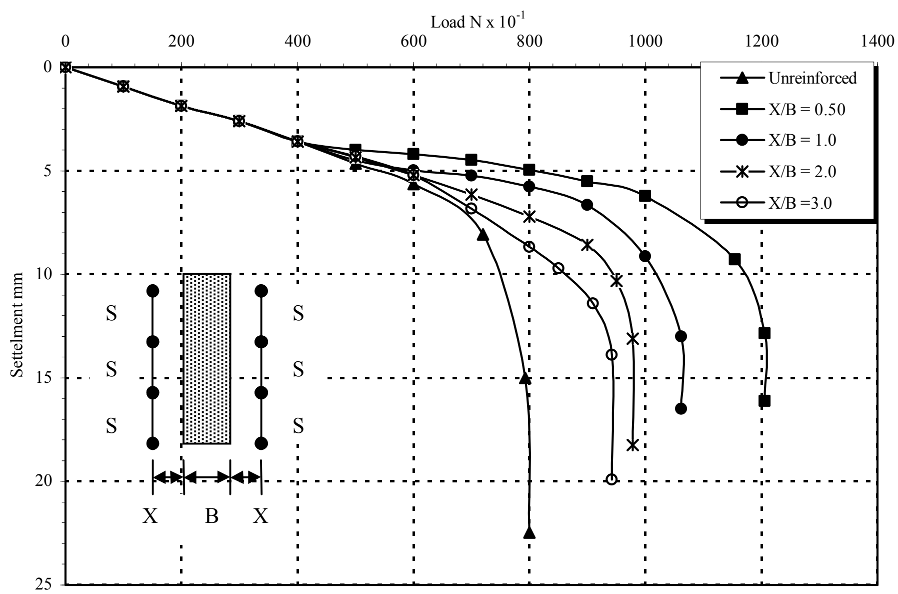

Fig. 9 : Load settlement curve for reinforced subgrade with pile technique in case of (L/ D = 20, pile spacing S = 0.5B)

The load settlement relationships in case of using pile reinforcement

The load settlement curves obtained from variety of loading experiments for different (L/D) ratio and location from the footing edges (X) were shown in Fig. (4 to 9). These figures presented the load settlement curves at different spacing (S) between pile row. The ultimate bearing capacity of the foundation soil system of every test is assessed unambiguously from the load displacement curves for both reinforced and unreinforced cases. It can be seen that, the presence of the pile reinforcement had adjusted the load settlement curves and amplified the bearing capacity under the footing. On the other hand, the embedded pile in soil along each side of the footing is providing additional shear strength. The bonding between the pile and the soil due to friction stress can cause strengthening in subgrade layer and increase the confinement zone. For all figures, the (X/B) ratio affects the bearing capacity of the footing soil system. It is apparent that the piles modified the load settlement behavior of the foundation. For situation of (X/B < 2), the general shear mode of failure of the foundation soil system is entirely eradicated, on the contrary, through the unreinforced case in which a typical punching shear failure plane is noticeable. Also, it is attention-grabbing to note that when the piles are dragged out while the foundation is loaded, a general plane of failure developed and the footing experienced an abrupt settlement. Moreover, as the distance among the piles (S) reduces the bearing capacity of foundation soil system augments where, the piles rows act as an equivalent plate or tends to extensible reinforcement because of the interlocking among the soils in the region of the piles.

The Effect of pile location on the bearing capacity ratio BCR

Loading tests were carried out to investigate the best location of the tested piles, to get the most beneficial effect of their existence on the bearing capacity of footing soil system. The relationship between the pile location (X/B) and the bearing capacity ratio BCR for both different (L/D) ratio and pile spacing (S), were shown in the Fig. (10 to 12). As mentioned above, the increase of the bearing capacity of the footing was due to sand confinement created by reinforcing elements and the interruption in the velocity discontinuities planes. Once the reinforcing elements were placed in soil, a velocity discontinuities planes were created, in addition to prereinforcing planes. As the spacing between piles and distance from the footing edge increased, the confined zone underneath footing increases and the length of the created planes of velocity discontinuities by piles decreased. Generally, it was noticed that the value of the (BCR) prominently decreased at the value of (X/B > 1.5). But for ratio (L/D = 16), the bearing capacity ratio sharply decreases at the value of (X/B > 2). In summary, the increase the value of (X/B) leads to increase in the confinement zone which causes un-stability for soil particles under the footing. Obviously, when the ratio (X/B) increases the particle movement activated and the resulting settlement is increased.

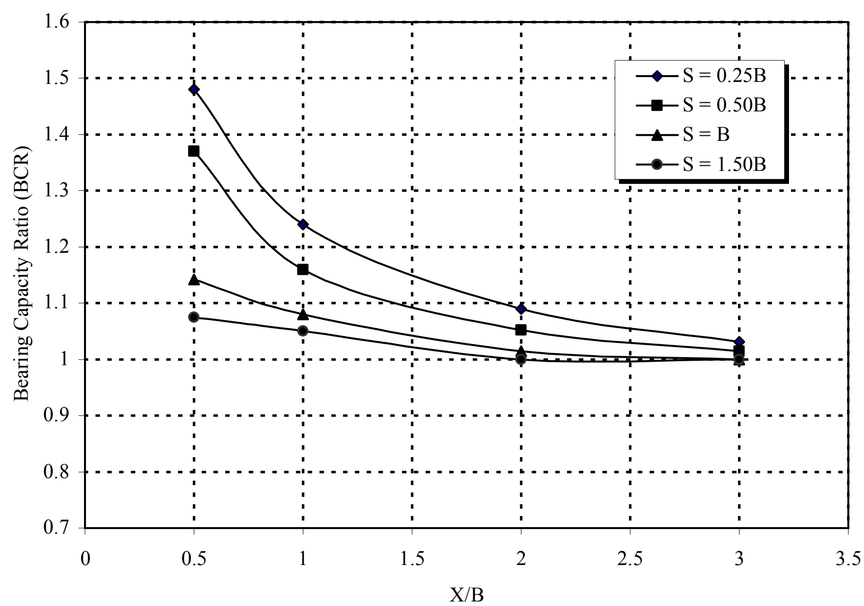

Fig.10 : The relationship between the location of the pile (X/B) and the bearing capacity ratio (BCR) for L/ D = 25.

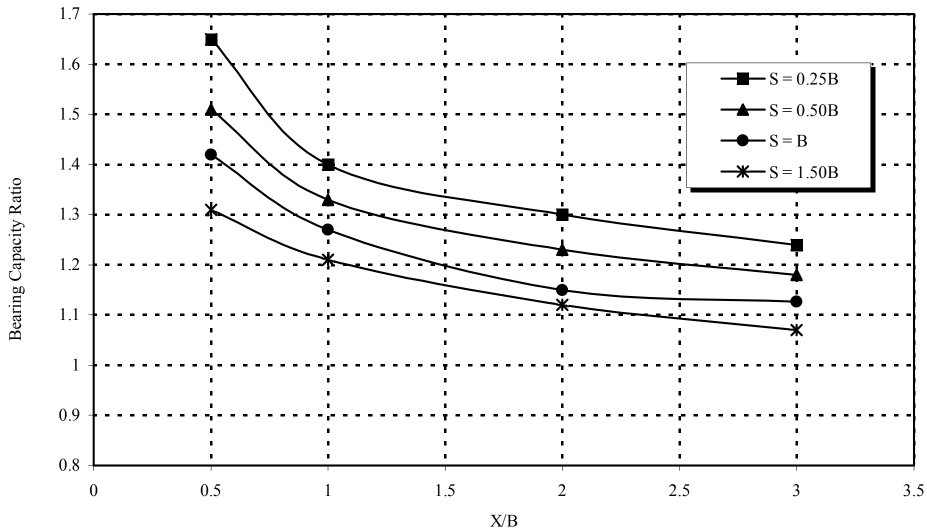

Fig. 11 : The relationship between the location of the pile (X/B) and the bearing capacity ratio (BCR) for L/ D = 20.

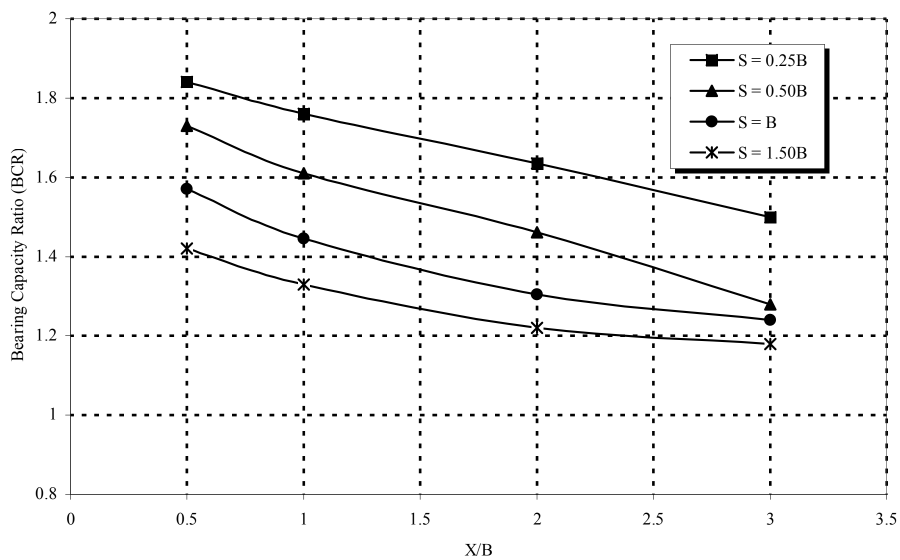

Fig. 12: The relationship between the location of the pile (X/B) and the bearing capacity ratio (BCR) for L/ D = 16.

The influence of pile intervals on the bearing capacity ratio BCR

The influence of spacing (S) between piles on the bearing capacity ratio (BCR) were also studied as in Fig. (10 to 12). These figures demonstrated that a significant decrease in (BCR) was gained when the pile spacing increases. Such reduction in bearing capacity is a consequence of failure of a besetment condition beneath the foundation. As the spacing among the piles amplifies the amount of reinforcing elements per unit length of the foundation reduces and consequently, the shear forces developed along the pile decreases. Decreasing the spacing leads to construct equivalent rigid plate or diaphragm, which achieved a soil confinement and an arching effect of soil is developed. Thus, it is preferable to install the piles at spacing equal or less than (0.5B) to get satisfactory performance.

The effect of pile rigidity on the bearing capacity ratio BCR

The bearing capacity ratio can be affected by the pile diameter. The relation between the ratio (L/D) and the bearing capacity ratio at different location and same spacing is shown in Fig. (13). It can be seen that the bearing capacity ratio increases linearly as the pile diameter increases. This may be due to the increase of the mobilized shear stresses around pile diameters where, the surface area or friction area increases with the increase of pile diameter. As the relation (L/D) reduces, the resulting pile stiffness raises hence, the bearing capacity of the subgrade layer increases. In general, as the ratio (L/D) decreases the bearing capacity ratio increases. Also, it is noticed that for the pile reinforcement installed close to the footing with the value of (L/D >20), the resulting bearing capacity ratio sharply decreases. Based on the best fitting, the relation between the (BCR) and the (L/D) ratio at (X/B = 0.5, S/B = 0.25) can be expressed by the following linear equation:

$$BCR = 2.46 - 0.039\,(L/D)$$

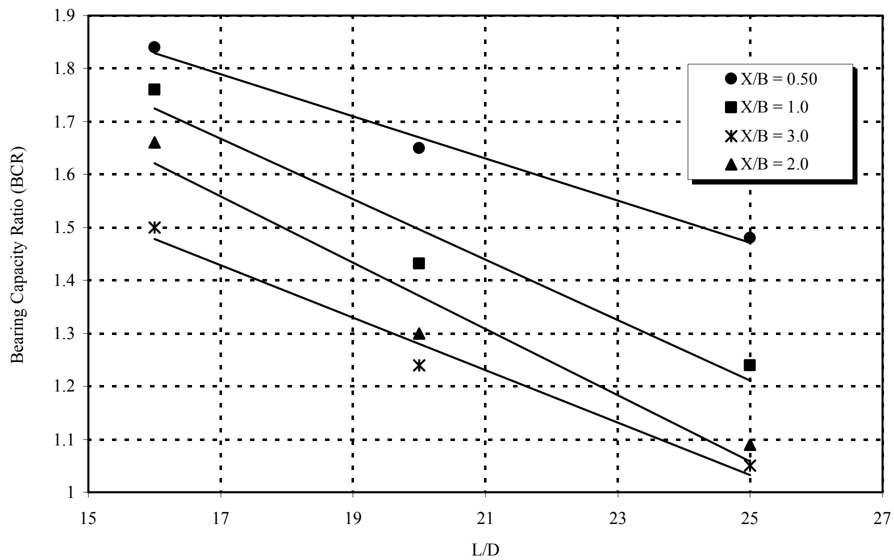

Fig. 13 : The relationship between the pile rigidity and the bearing capacity ratio (BCR) at different location.

Conclusions

The perception of improving the mechanical features of the sub grade stratum by inclusions of vertical reinforced element has been effectively practical in several techniques. The behavior of the reinforced subgrade along each side of existing footing is influenced by the relative stiffness of the reinforced elements with respect to the soil. Otherwise, the installation of a vertical reinforced element in the subsurface along each side of the existing foundation can be effective in increasing the bearing capacity of the footing soil system under certain conditions concerning the size and material properties of the root piles.

The inextensible vertical reinforced element used in this study in the form of spaced piles to be a high-quality technique of escalating the bearing capacity of the foundation soil system to resist any additional loads by 183%.

From this investigation the subsequent conclusions can be summarized:

1. Existence of the pile reinforcement also modifies significantly the load displacement behavior.
2. The most beneficial location to install the pile inclusions is found to be within a distance of (B) from the footing edges for case of (L/D = 25, 20) and within a distance of (1.5B) for case of (L/D = 16).
3. It is recommended to use the non-extensible reinforcing elements, one on each side, driven or pushed vertically with sufficient length, as close as possible to the footing.
4. A significant increase in bearing capacity ratio (BCR) is gained when the pile spacing decreases.
5. The most effective spacing (S) between the reinforced element is found to be within the limit (S = 0.25B to 0.5B).
6. The bearing capacity of the foundation soil system is increased with the increasing of the pile stiffness. The relation between the bearing capacity ratio (BCR) and the (L/D) ratio may be expressed by the following linear equation (this equation is valid for S/B = 0.25 and X/B = 0.5):

BCR = 2.46 - 0.039 (L/D)

References

1. Azzam, W. Basha, A (2018). " Utilization of micro-piles for improving the sub-grade under the existing strip foundation: experimental and numerical study." Innovative Infrastructure Solutions 3:44.
2. Abdel-Baki, S. and Raymond, G. P., (1993), " Soil Reinforcement for Shallow Foundation" Proceeding of 2nd Geotechnical Engineering Conference Cairo, pp. 488-499.
3. Abdel-Baki, S. and Raymond, G. P., (1994), " Improvement of the Bearing Capacity of the Footing by s Single Layer Reinforcement" Proceeding of Geosynthetics Conference Vancouver.
4. Abdrabbo, F. M., (1979), " Bearing Capacity of a Single Pile Embedded in Reinforced Earth" Alexandria Engineering Journal Vol. 6, pp. 165-175.
5. Abdrabbo, F. M., and El-Hansy, R. M., (1993), " Strengthening of Loaded Footing-Soil System" Alexandria Engineering Journal Vol. 32, No. 4, pp. 193-198.
6. 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.
7. Binquet, J., and Lee, K. L., (1975), "Bearing Capacity Tests on Reinforced Slabs" ASCE Journal of Geotechnical Engineering Division, 101, pp. 1241-1255.
8. Giroud, J. P., and Noiray, L., (1983), " Geotextile-Reinforced Unpaved Road design" ASCE Journal of Geotechnical Engineering Division, 107: 1233-1254.
9. Lee, K. L., (1976), " Reinforced Earth- An Old Idea In A new setting" New Horizons in Construction Materials, Vol.1, Envo Publishing Co. Pennsylvania, pp. 655-682.
10. Mahmoud, M. A., (1988), " Plate Loading Tests on Reinforced Choesionless Soil" Journal of the Egyptian Society for Soil Mechanics and Foundation Engineering Division, 3.
11. Mandal, J. N., and Manjunath, V. R., (1994), " Bearing capacity of Strip Footing Resting on Reinforcing Sand Subgrade" Construction and Building Materials, Vol.9, No.1, pp. 35-38.
12. Saleh, N. M., (2002), "Behavior of Footings Under Centric and Eccentric Loads Adjacent to Reinforced Slopes " Ain Shams University. Scientific Bulletin Vol., 37, No.4, pp. 41-63.
13. 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.
14. Watn, A. et al., (1997), " Geosynthtic Reinforced to Improve Bearing Capacity, Laboratory Testing and Numerical Study " The Fourth International conference on Soil Mech. and Found. Eng. Hamburg Balkema- Rotterdam Vol. 3, pp. 1789-1796.

8/18/2019