Static behavior of ring footing based on geogrid-rubber reinforced sand bed

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ABSTRACT: Ring footings have been used in various industries, like oil and gas. So this kind of footings is very important and doing some works to improve their behavior can be very important. In the present study, the behavior of ring footings with a constant outer diameter of 300 mm based on reinforced bed with granular rubber particles alone and also in combination with a geogrid layer, subjected to static loads, has been investigated by experimental tests. The results showed in both unreinforced and rubber-reinforced bed, the ring footing with inner to outer diameter ratio of 0.4 had the maximum bearing capacity. Also, the optimum thickness of rubber-reinforced layer is equal to 0.5 times the outer diameter of ring footing; in this case, the bearing capacity can be increased by 41.5% compared with the unreinforced bed; more increases than optimum value, have reverse results and lead to decrease in bearing capacity and increase in settlement. Using the geogrid layer can activate reinforcing effects of rubber-reinforced layer with high thicknesses, but its value is not big enough to overcome the negative effects of using rubber-reinforced layers with higher thicknesses than optimum value. At last, using geogrid reinforcement in combination with rubber particles can be more effective than using each of them alone. In geogrid-rubber reinforced bed, the bearing capacity can be increased by 62.7% compared with the unreinforced bed.

1. INTRODUCTION

Finding some ways to improve the behavior of ring footing can be very important; because these types of footings are widely used in various industries like storage tank of oil, gas or other fluids, television antennas, food storage silos, atomic reactors, and communication towers. The results of previous researches showed that using the optimum ratio of inner to outer diameter of ring footing can increase the bearing capacity of footing and consequently decrease the footing settlement [1-3]. Applying geosynthetic layer(s) is another effective way for improving the behavior of ring footing. If optimal values of effective parameters such embedded depth of first geosynthetic layer (u), the distance between two consecutive layers (h), the width of the layers (L) and the number of layers (N), are used, the bearing capacity has a significant increase in comparison with that in an unreinforced bed [2-4]. Nowadays using cheap waste materials like rubber particles obtained from old tires, as soil reinforcement are very useful because of their economic advantages. The results of many researches showed that adding rubber particles to the soil can increase the shear resistance. Of course, the improvement in soil shear strength depends on various parameters like the type of rubber particle, the percentage of rubber, the unit weight of rubber-soil mixture, the size and aspect ratio of rubber particle [5-10]. Previous researchers found that using a rubber-soil mixture layer in the footing bed can increase the bearing capacity if the optimal values of effective parameters like percentage of rubber particle and thickness of rubber-soil mixture layer are used [11-14].

According to the above mentioned positive effects of using some reinforcements like rubber particles and geosynthetic layer, it has been expected that using these reinforcements simultaneously can be more effective. So the main objective of this paper is to investigate the behavior of ring footing based on unreinforced, rubber reinforced, geogrid reinforced and combined geogrid-rubber reinforced bed. During this investigation, the effects of some important parameters like inner (d) to outer (D) diameter ratio of ring footing and the thickness of rubber-soil mixture layer (h_{rs}) are evaluated by experimental loading tests on ring footing.

2. MATERIALS

A kind of well-graded sand (SW) with medium grain size, D_{50}, of 2.35 mm, moisture content of 5.4% and friction angle of 41.7° have been used in all tests for filling excavated test trench. The rubber type for using in rubber-soil mixture layer was granulated rubber particles that have major dimensions between 2 and 20 mm, a mean particle size, D_{50}, of 14 mm and a specific gravity, G_s, of 1.15. Also a geogrid layer of CE131 that had tensile strength of 5.8 kN/m and aperture size of 27×27 mm² , was used as a reinforcement layer in soil bed.

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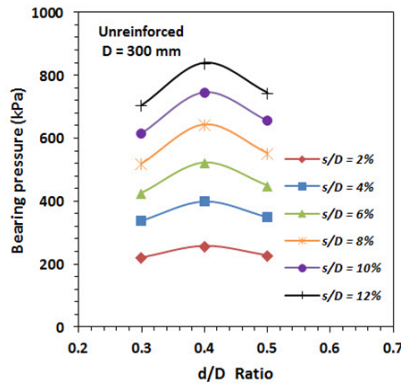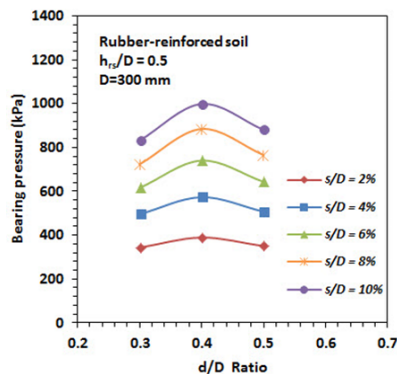
Fig. 1. Variation of bearing capacity with d/D ratio for ring footing on (a) unreinforced and (b) rubber-reinforced bed

Fig. 2. Variation of bearing capacity with h_{rs}/D ratio for ring footing on (a) rubber-reinforced and (b) geogrid-rubber reinforced bed
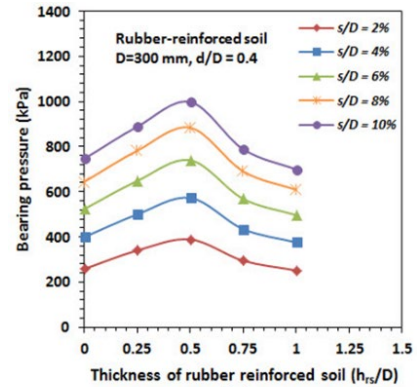
3. EXPERIMENTAL SETUP

The experimental setup consist of various parts like excavated test pit measuring 2×2 m² in plan and 0.99 m in depth, steel ring footing model with outer diameter, D, of 0.3 m and various inner diameters, d, (0.09, 0.12 and 0.15 m), hydraulic loading system (which consist of reaction beam, hydraulic pomp and hydraulic jack) and data acquisition system (load cell, LVDT, data logger and unit control). The soil and rubber-soil layers have been gained to their maximum densities by multiple passing of vibrating plate compactor.
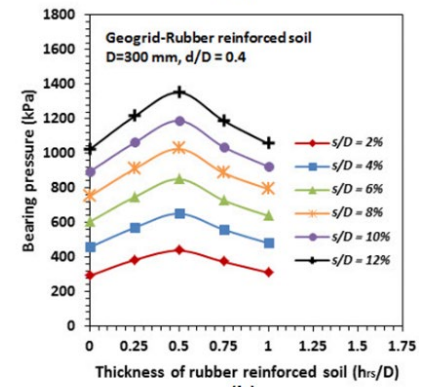
4. RESULT AND DISCUSSION

The results of experimental tests (showed in Fig. 1) on both unreinforced and rubber-reinforced bed introduce an optimum inner to outer diameter ratio (d/D) around 0.4, which delivers the maximum increase in the bearing capacity value, regardless of the footing settlement ratio, s/D. In fact, by using the optimal value, the soil density at the inside zone of the ring increases due to the interface effect of two sides of the ring. But with further increase in inner to outer diameter ratio, than optimal value, the interface effect get reduced and the ring behaves as thin strip ring footing [1, 15].

Figs. 2 a and b show that, regardless of the footing settlement level and also regardless of the presence or absence of geogrid layer, the improvement in bearing capacity value initially increasing when the thickness ratio of rubber-soil mixture (h_{rs}/D) increases from 0 to around 0.5, but that, after that, the value of bearing capacity decreases with h_{rs}/D

ratio and may tend to unreinforced bed. It can be due to the high compressibility of rubber-soil mixture layer with higher thicknesses than optimal value which leads to a decrease in stiffness of soil bed and consequently increase in settlement. Even adding a geogrid layer to the rubber reinforced system could not overcome the negative effects of using rubber-reinforced layers with higher thicknesses than optimum value.

Another important consequence that can be obtained from the comparison of Figs. 2a and b is that the bearing capacity of ring footing based on geogrid-rubber reinforced bed is greater than those of rubber reinforced or geogrid reinforced beds. For example at s/D ratio of 6% and h_{rs}/D of 0.5, the bearing capacity of ring footing was 605, 740 and 851 kPa for geogrid reinforced, rubber reinforced and geogrid-rubber reinforced bed respectively which show 15.7%, 41.5% and 62.7% increase in bearing capacity compared to unreinforced bed.

5. CONCLUSIONS

Based on the experimental load test by ring footing on geogrid reinforced, rubber reinforced and geogrid-rubber reinforced bed, the following main conclusions were made:

1. The optimum inner to outer diameter ratio of ring footing based on both unreinforced and rubber-reinforced bed is about 0.4.

2. In both cases of rubber reinforced and geogrid-rubber reinforced bed, with an increase in the h_{rs}/D ratio up to the value of 0.5, the bearing capacity increases, after which, with further increase in h_{rs}/D ratio, the value of bearing capacity

decreases.

3. Using geogrid-rubber system is more effective than rubber reinforced or geogrid reinforced systems for improving the behavior of ring footing.

REFERENCES

[1] M.L. Ohri, D.G.M. Purhit, M.L. Dubey, Behavior of ring footings on dune sand overlaying dense sand, in: International Conference of Civil Engineers, Tehran, Iran, (1997).

[2] J.H. Boushehrian, N. Hataf, Experimental and numerical investigation of the bearing capacity of model circular and ring footings on reinforced sand, Geotextiles and Geomembranes, 21(4) (2003) 241-256.

[3] M. El Sawwaf, A. Nazir, Behavior of eccentrically loaded small-scale ring footings resting on reinforced layered soil, Journal of Geotechnical and Geoenvironmental Engineering, 138(3) (2012) 376-384.

[4] M. Laman, A. Yildiz, Numerical studies of ring foundations on geogrid-reinforced sand, Geosynthetics International, 14(2) (2007) 52-64.

[5] P. Gotteland, S. Lambert, L. Balachowski, Strength characteristics of tyre chips-sand mixtures, Studia geotechnica et mechanica, 27(1-2) (2005) 55-66.

[6] A. Edincliler, A.F. Cabalar, A. Cagatay, A. Cevik, Triaxial compression behavior of sand and tire wastes using neural networks, Neural Computing and Applications, 21(3) (2012) 441-452.

[7] S. Bali Reddy, D. Pradeep Kumar, A. Murali Krishna, Evaluation of the optimum mixing ratio of a sand-tire chips mixture for geoengineering applications, Journal of Materials in Civil Engineering, 28(2) (2016) 1-7.

[8] D. Kyser, N. Ravichandran, Properties of chipped rubber roofing membrane and sand mixtures for civil engineering applications, Journal of Building Engineering, 7 (2016) 103-113.

[9] R.J. Chenari, B. Fatahi, M.A.A. Maroufi, R. Alaie, An Experimental and Numerical Investigation into the Compressibility and Settlement of Sand Mixed with TDA, Geotechnical and Geological Engineering, 35(5) (2017) 1-20.

[10] D. Rezazadeh Eidgahee, A. Haddad, H. Naderpour, Evaluation of shear strength parameters of granulated waste rubber using artificial neural networks and group method of data handling, Scientia Iranica, 26(6) (2019) 3233-3244.

[11] S.N. Moghaddas Tafreshi, A.H. Norouzi, Bearing capacity of a square model footing on sand reinforced with shredded tire–An experimental investigation, Construction and Building Materials, 35 (2012) 547-556.

[12] S.N. Moghaddas Tafreshi, N. Joz Darabi, G. Tavakoli Mehrjardi, A. Dawson, Experimental and numerical investigation of footing behaviour on multi-layered rubber-reinforced soil, European Journal of Environmental and Civil Engineering, (2016) 1-24.

[13] R.K. Mittal, G. Gill, Pressure settlement behaviour of strip footing resting on tire-chip reinforced sand, International Journal of Geotechnical Engineering, (2017) 1-7.

[14] S.M. Anvari, I. Shooshpasha, Influence of size of granulated rubber on bearing capacity of fine-grained sand, Arabian Journal of Geosciences, 9(18) (2016) 707.

[15] G. Ranjan, S. Saran, A.K. Gupta, Beaviour of ring footings on sand under vertical and horizontal loads, in: 9thAsian Geotechnical Conference, Bankok, Thiland, (1987).