Assessment Behaviour of Cojointed Footings System Placed on Sands Encased by Geocell Reinforcement: Experimental Study

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ABSTRACT

Previous experiences indicate that employing cellular reinforcements (such as geocell) in the weak sands beneath footings has significant influence on the bearing pressure and their settlement. The increased structures' height and loads intensity lead to enhancement in the dimension of the footings and their spacing, thereby causing them to get closer to each other. Existing footings near each other creates interaction problem tends to changing failure mechanism, ability of load carrying capacity and deformability. The behavior of nearby footings resting on sandy soils reinforced with 2D polymeric reinforcements has been elucidated in the literature, however, it has been not attended for cellular reinforcements. By keeping optimum geometry and location for cellular reinforcement embedded in the soil, the effect of spacing between footings on bearing capacity and settlement was studied. The results show that coupled effect of reinforcement and footing interference can enhance load carrying capacity more than 300% and improve the settlement more than 60% compared with single isolated footing on unreinforced bed. Maximum bearing capacity is attained when two footings are besides. Spacing between footings more than three times of footing diameter represents substantial reduction in the interference effect and each footing almost acts as a single isolated footing.

KEYWORDS

Weak sands, Footings interference effect, Cellular reinforcement, Bearing capacity and settlement, Failure mechanism

1. Introduction

In the last decades, using polymeric reinforcements with cellular shapes such as geocell to improve load carrying capacity of weak soils supporting shallow footings has been attended by the scientists. Many researchers have studied the behavior of single isolated shallow footings on geocell-reinforced soils using different methods [1-3]. The results showed that geocell enhance the bearing capacity and reduce the settlement of footings significantly.

In practice, footings are constructed close to each other due to applied heavy loads. The interference effect of the footings can change the bearing pressure, failure mechanism and footings tilt [4-7]. The interference influence of two nearby footings on planar reinforced soils (e.g. geogrid, geotextiles and etc.) is investigated by several scientists [8-12]. However, interference effect of multiple footings on reinforced sand with 3-dimensional cellular reinforcement [13] has not been greatly highlighted.

In the present study, two symmetric circular footings subjected to equal loads on geocell-reinforced sand are modeled using experimental tests. The impact of spacing between footings and geocell reinforcement on the performance of twin footings is evaluated.

2. Methodology

Poorly graded sand (SP) with average grain size 0.25 mm, internal friction angle φ=36° at relative density D_r=68% and prefabricated geocell reinforcement

(HDPE) with dimensions of 1050×1050 mm and average cell diameter 183 mm were used in this study. Physical and mechanical properties of the geocell are depicted in Table 1.

Table 1. Geocell characteristics

Geocell properties	Values
Geocell material	Polyethylene
Size of cell, (mm)	250×210
Thickness of Strip, (mm)	1.5
Height of cell, (mm)	150
Short term yield resistance, (kN/m)	21
Density, (gr/cm^3)	0.94
Elastic modulus, (MPa)	270

Plate load tests were conducted on unreinforced as well as geocell-reinforced sand. A rigid square steel box with dimensions of 1100×1100 mm in plan and 1000 mm in height was manufactured for all tests. The tank was supported by a stiff reaction frame to distribute equal loads over two footings. The load with the rate of 10 mm/min was applied using pneumatic jack connected to loading frame. Two rough base circular Teflon with diameter D=150 mm and thickness 100 mm was used as footings. The raining technique was used to reach required relative density for sand bed. To ensure uniform density, the sand in the test tank was filled in 100 mm thick layers up to 900 mm. Geocell was placed at depth of 0.1D which is optimum location to achieve the maximum performance [14]. The applied load and footings displacement was measured respectively using a pre-calibrated load cell and two Linear Variable Differential Transducers (LVDTs) installed on each footing. Both load cell and LVDTs were connected to a data logger. The pressure-settlement curves were generated from the average settlement of the footings. The ultimate bearing capacity was measured from the curves corresponding to 10% footing width (S/D=10%).

Generally, 11 tests were conducted on single and twin footings. Four tests were conducted on unreinforced and four experiments were also performed on geocell-reinforced sand. To verify the accuracy of the test data, three tests were repeated two times resulted in 4% deviations in the results.

3. Results and discussion

The bearing pressure curves for two closely spaced footings on unreinforced sand are presented in Figure 1a. As can be observed, bearing capacity of twin footings is larger than that of single footing due to the interference effect. Maximum bearing capacity occurs when two footings are besides (e.g. Δ/D=1 in which Δ is distance between two footings from center-to-center). At Δ/D=1 bearing capacity of twin footings is approximately 77% greater than those obtained from single footing at the same condition. By increasing spacing between footings the impact of interference reduces. When Δ/D=3 each footing almost acts as a single isolated footing without interference effect.

The pressure-settlement response for two adjacent footings on geocell-reinforced sand is showed in Figure 1b. As expected, the footing bearing capacity on the reinforced bed is greater than those obtained from the unreinforced bed. No clear failure point is seen in reinforced soils due to distributing footings load by the geocell over a wider surface and linear behavior of the geocell even at higher pressure. In reinforced cases, the ultimate bearing capacity (s/D=10%) of twin footings at Δ/D=1 is approximately 85% greater than single footing on the same bed.

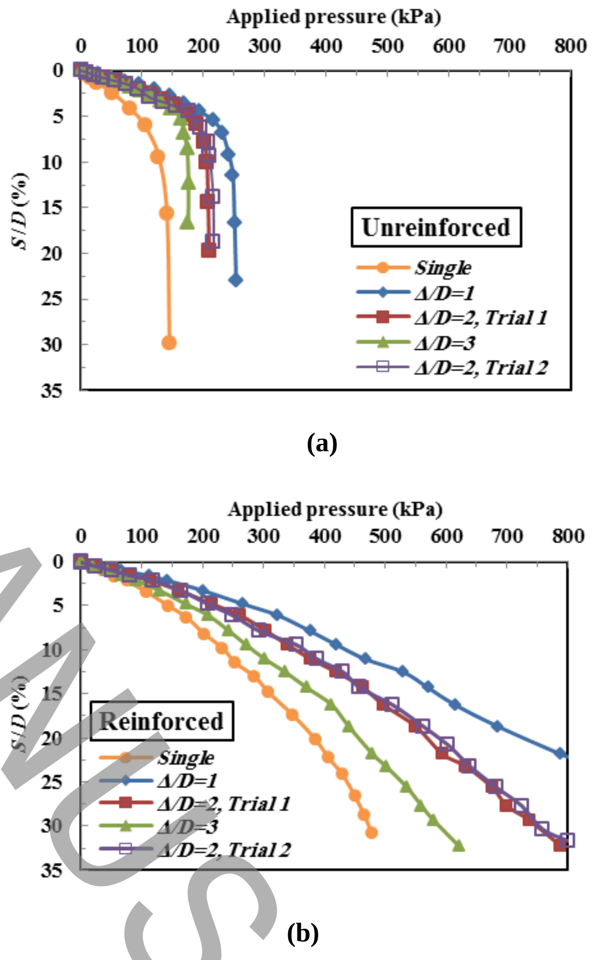

Figure 1. Pressure -settlement variation of two closely-spaced circular footing on sand bed for various d/D ratios; (a) unreinforced, (b) reinforced

To elucidate the interference effect on the bearing capacity of two nearby footings, following non-dimensional factor can be defined as:

$$\zeta = \frac{q_{u-\text{int.}-N}}{q_{u-single-N}} \qquad (1)$$

where, $q_{u\text{-int.-}N}$ is ultimate bearing capacity of a footing in the presence of other footing on unreinforced/reinforced sand, $q_{u\text{-single-}N}$ is ultimate bearing capacity of a single isolated footing on the same bed and N is the number of reinforcements. To study the influence of reinforcement on the ultimate bearing capacity of single/twin footings, following non-dimensional factor is introduced as:

$$BCR = \frac{q_{u-Rein.b}}{q_{u-Unrein.b}} \tag{2}$$

where, $q_{u\text{-Rein.b}}$ and $q_{u\text{-Unrein.b}}$ are respectively ultimate bearing capacity of single/twin footings on reinforced and unreinforced bed. Table 2 presents test results and non-dimensional factors for single and two nearby footings.

Table 2. Summary of laboratory test results for single and two circular footings on unreinforced and geocell-reinforced sand

Reinforcement	Δ/D	BC*(kPa)	BCR	ζ
Unrein. N=0	Single	137	-	-
	Δ /D=1	242	-	1.77
	Δ /D=2	206	-	1.50
	Δ /D=3	173	-	1.26
Rein. N=1	Single	232	1.69	-
	Δ /D=1	433	1.79	1.87
	Δ /D=2	352	1.71	1.52
	Δ /D=3	287	1.66	1.24

*BC=ultimate bearing capacity at S/D=10%

4. Conclusion

In the present study the behavior of two closely spaced shallow circular footings subjected to equal loads over geocell-reinforced sand was investigated. Using laboratory tests the impact of spacing ratio (S/D) and geocell reinforcement on the efficiency and load carrying capacity of single and twin footings was elucidated. The following conclusion remarks may be extracted from this study:

1) Geocell reinforcement can enhance the bearing pressure of two interfering circular footings beyond 80% compared to the same condition on unreinforced bed. It depends to soil characteristics, geocell reinforcement and spacing ratio of the footings.

2) Combination influence of interference and geocell reinforcement raise the bearing capacity more than 300% compared to those obtained from single isolated footing on unreinforced sand.

3) Maximum bearing capacity of twin circular footings on geocell-reinforced soil takes place when two footings are next to each other (Δ/D=1). The interference effect disappears at approximately Δ/D=3. This result is also presumable for unreinforced cases.

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