



Response of Square Footing on Geocell-Reinforced Sand Bed Under Static and Repeated Loads

Chirajyoti Doley¹ · Utpal Kumar Das¹ · Sanjay Kumar Shukla²

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Abstract

This paper describes the behaviour of a square model footing resting on a geocell-reinforced sand bed subjected to static and repeated loads. The static load tests were conducted to investigate the performance improvement of reinforced soil in terms of bearing capacity and settlement. The repeated load tests were carried out with varying initial static pressures to simulate the structures wherein the live loads change slowly and repeatedly such as oil or water storage tanks do. The ultimate bearing capacity, effect of initial static pressure as well as the number of load cycles without and with the use of geocell reinforcement were the main parameters to be investigated in this study. The results showed that with the provision of geocell reinforcement, the bearing capacity of reinforced soil increased by 2.4 times as compared to unreinforced soil, and the settlement decreased by 68% at the measured settlement level, $s/B = 10\%$ (s = settlement of footing, B = width of footing). It has also been observed that the total settlement reduces by 56% in case of geocell-reinforced sand after the application of 20 load cycles. Further, the results show that the total settlement increases at a gradually decreasing rate with an increase in initial static pressure and the number of load cycles.

Keywords Geocells · Sand bed · Bearing capacity · Settlement · Static loading · Repeated loading

Introduction

There are several field projects that include pavements, embankment, oil or water storage tanks, shipyard, etc., in weak foundation soil areas, where static and repeated loadings cause undesirable foundation problems. Geocells, which are three-dimensional interconnected cells, can be laid over the weak foundation soils to enhance the bearing capacity and reduce the settlement of such structures subjected to static as well as repeated loadings.

In the recent past, several model-scale tests have been carried out to understand the behaviour of geocell-reinforced

soils under static loads [1–11]. Previous scholars have also reported the use of geocell reinforcement as a cost-effective method for increasing the ultimate bearing capacity and reducing the settlement values of shallow footings. This improvement was achieved by using the semi-rigid slab behaviour of the geocell-reinforced soil which redistributes the incoming load over a wider area onto the underlying soil [12, 13]. In spite of its beneficial effects, only a few studies have been conducted to investigate the behaviour of geocell-reinforced soil under repeated loading. Moreover, the studies reported earlier mainly focused on traffic loads or machine foundation loads [14–20]. However, structures such as petroleum tanks and shipyard have higher live loads, which vary with time, as compared to the self-weight of the structure. In oil (diesel/petrol) tanks, oil is shifted and kept in the storage tanks before it is transferred to the petroleum stations. Consequently, the foundation soil experiences a repeated load whose frequency and load amplitude are dependent on the rate of filling and emptying of the tanks. Although there has been a potential of geocell reinforcement in foundation of such structures, not many studies have been made on the behaviour of geocell-reinforced sand foundation subjected to a slowly repetitive loading [21, 22]. Thus,

✉ Chirajyoti Doley
chirajd@tezu.ernet.in; chirajyoti5@gmail.com

Utpal Kumar Das
ukrdas@tezu.ernet.in; ukrdas@gmail.com

Sanjay Kumar Shukla
s.shukla@ecu.edu.au; sanjaykshukla1@gmail.com

¹ Department of Civil Engineering, Tezpur University, Napam, Sonitpur, Assam 784028, India

² School of Engineering, Edith Cowan University, Joondalup, Perth, WA 6027, Australia

the present study was aimed to develop an understanding on the performance of geocell-reinforced sandy soils in terms of load-carrying capacity and settlement under static and repeated loads. Contrary to the use of factory-manufactured geocell (generally available in one geometric dimension) in many previous studies, the geocell used for this work was made from strips of woven geotextile (i.e. curtain blind, to obtain the desired geocell dimensions). The soil used as a base and infill material was Brahmaputra river sand (BRS), which was easily available within the river valley in India.

Laboratory Model Tests

Test Tank and Footing

The internal dimensions of the steel tank that was fabricated for the experimental study were 1200 mm × 980 mm × 1010 mm (length × breadth × height). Structural steel angle sections were welded to connect the test tank side plates to achieve negligible lateral deformation. A reaction steel frame, designed to support a 100-kN hydraulic jack, was attached to the steel tank (Fig. 1). A square steel plate of size 150 mm × 150 mm × 20 mm was placed as the model footing. A thin layer of sand was pasted to the bottom face of the steel plate to make it rough. Chummar [23] suggested that in case of cohesionless soil, the failure wedge is likely to be extended to a maximum of about $3B$ (B is the width of footing) distance on either side of the footing centre line and a depth of about $1.1B$ from the footing bottom. Therefore, in the present study, the foundation bed width/length (980 mm/1200 mm) of $6.533B/8.0B$ and depth (880 mm) of $5.867B$ has been considered as large enough to avoid the boundary effects and hence the experimental results. The model tests were performed by manually operated hydraulic loading. The model footing was subjected to a reaction load applied vertically through a steel ball. The reaction load applied through the hydraulic jack to the square footing was controlled manually and was measured with a proving ring. The settlement of the footing was measured with two dial gauges. The loading arrangement is illustrated in Fig. 2.

Test Materials

Sand

The experimental study was carried out using BRS as filling materials. The sample was thoroughly cleaned and air dried in the laboratory before it was used in the experimental work. The specific gravity (G) of the sand was determined as 2.66 [24]. The density in the densest state was found to be 1730 kg/m³ [25] and that in the loosest state was 1510 kg/m³

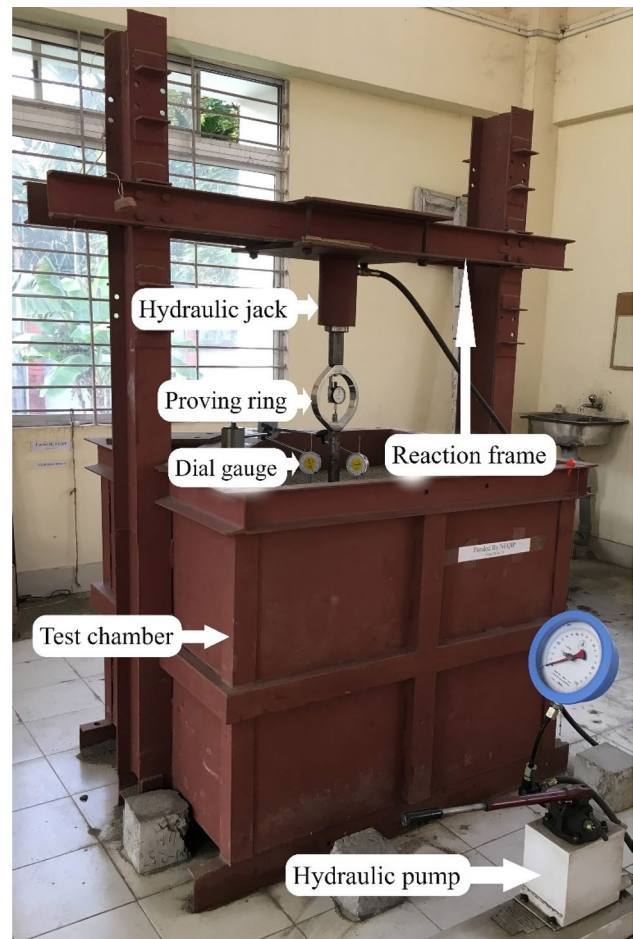


Fig. 1 Photograph of laboratory model test setup

[26]. The particle size distribution curve obtained from the sieve analysis as per ASTM standard [27] is shown in Fig. 3. The shear strength parameters of BRS at relative density (R_d) of 70% were determined in accordance with IS (Indian standard): 2720 (Part 13)-1986 [28]. The geotechnical properties of sand are listed in Table 1. The sand was classified as poorly graded sand (SP) as per the Unified Soil Classification System (USCS) [29].

Geocell Reinforcement

The geocell was prepared in the laboratory by stitching polyester-based woven geotextile. The geotextile was obtained from curtain blind generally used in office window. To fabricate the geocell of desired dimension, the paper templates were first made. The geotextile was then cut and stitched with nylon thread as per the template. Tensile stress–strain behaviour of the woven geotextile used for the geocell is shown in Fig. 4 [30]. The material properties of the geotextile used were tested in the laboratory and the results are shown in Table 2. The geotextile seam was also tested and

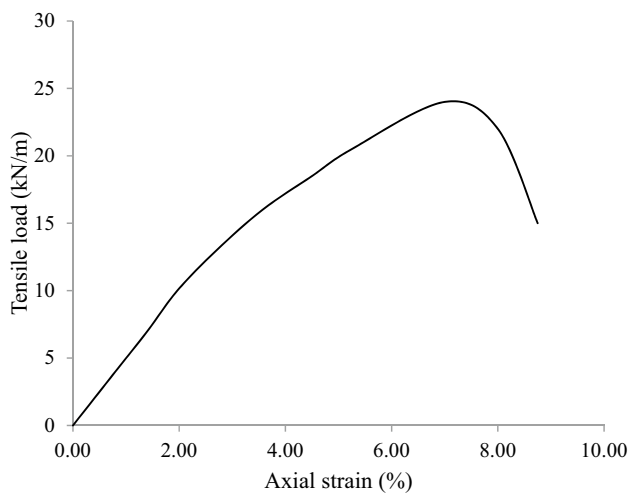


Fig. 4 Tensile stress vs strain response of the woven geotextile used for geocell

Table 2 Properties of the geotextile used to make the geocell

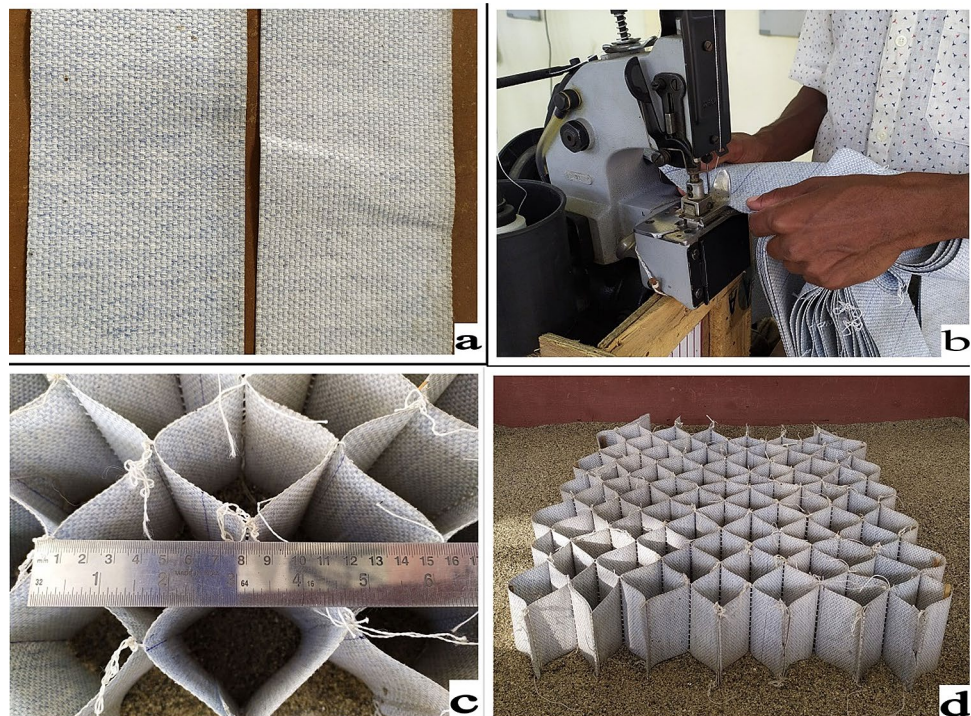
Parameter	Description
Geocell material type	Woven geotextile
Polymer	Polyester
Thickness, t (mm)	0.8
Ultimate tensile strength, T_u (kN/m)	24
Failure strain (%)	7.0

Fig. 5a–d. In this paper, the nomenclature used for geocell reinforcement is as follows: d —equivalent diameter of geocell pocket; h —height of geocell reinforcement; u —depth of placement of geocell reinforcement from the bottom of the footing; b —width of geocell reinforcement.

Preparation of Test Setup and Procedure

The laboratory model footing tests were conducted by loading the footing over BRS bed of 880 mm thickness. The pluviation procedure (raining of sand through air) was adopted to prepare the uniform test sand bed of 70% relative density (R_d). The density obtained through rainfall technique depended on the height through which the sand was allowed to fall. The system was calibrated by measuring the respective densities achieved for different preset heights of fall during a pluviation test series. The height of fall required to maintain 70% relative density of the soil in the test tank was read from the calibration curve (Fig. 6). By adopting this technique, an average density of 1660 kg/m³ ($\pm 2\%$) was achieved during the sand bed preparation of the test tank. In literature [1, 14] it was found that the optimum placement depth of geocell would be $0.1B$ (B = footing width) below the bottom of the footing. Therefore, after achieving the desired level of sand bed by the pluviation procedure, a geocell of intended size was placed at the depth of $0.1B$ below the footing. The same river sand was also used to fill the geocell pockets by the pluviation technique to maintain the uniform relative density. Once the geocells were filled

Fig. 5 Photographic view of: **a** woven geotextile (curtain blind); **b** stitching of geotextile to fabricate geocell; **c** size of geocell pocket; **d** woven geotextile geocell after complete stitching



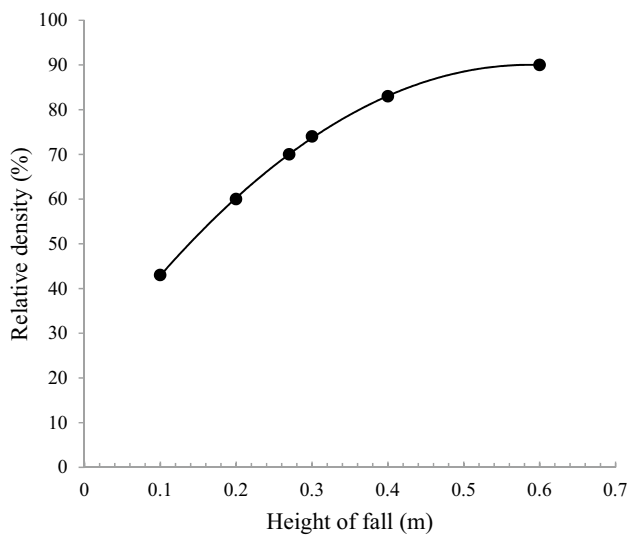


Fig. 6 Calibration curve for height of fall versus relative density

up, the fill surface was levelled with great care to avoid the change in the relative density of the top surface.

The footing was then placed at the top of the bed exactly at the centre of the test tank. Once the test setup was prepared, the load was applied on the square plate using a hydraulic jack. The footing settlements (s) were measured with two dial gauges touching the opposite edges of the steel plate. The settlement of the footing (s) was normalized with width of the footing (B) and expressed in a non-dimensional form s/B (%).

In this study, initially the ultimate load-carrying capacity of unreinforced and reinforced sand beds was determined. Thereafter, a fraction of ultimate load-carrying capacity of unreinforced and reinforced soils was applied on the footing as a repeated load. Loading was done in increments and the vertical displacements of the loading plate were recorded. A typical loading–unloading cycle was 30–60 min [31].

The schedule of model footing tests is described in Table 3. The test series A was carried out on unreinforced sand bed to quantify the improvement due to the inclusion

of the geocell. The test series B was conducted to quantify the ultimate bearing capacity of geocell-reinforced sand. The test series (C–D) was carried out to investigate the effect of the initial monotonic load level on the footing behaviour for both unreinforced and reinforced foundations. The study was conducted using different values of repeated load levels, expressed as a ratio of applied repeated pressure (q_d) to the ultimate bearing pressure (q_{ult}) of the unreinforced or reinforced soil, termed as repeated load ratio (q_d/q_{ult}). Four different repeated load ratios (q_d/q_{ult}), 20%, 40%, 70%, and 85%, were used to study the response of footing supported on unreinforced and reinforced sand beds.

Results and Discussion

Tests Under Static Load

To quantify the ultimate load-carrying capacity of the footing, static load tests were carried out through the experimental setup of square footing rested on unreinforced and geocell-reinforced sand beds. The results of ultimate load-carrying capacity were required to estimate the maximum value of applied repeated loads.

The pressure–settlement behaviors of a footing on unreinforced sand and that on reinforced sand with geocell with $d/B = 0.5$, $h/B = 0.66$, $b/B = 3$, $u/B = 0.1$ woven geotextile are presented in Fig. 7. The results show that the provision of geocell reinforcement increases the load-carrying capacity and decreases the settlement of the footing. The curve for unreinforced sand indicates that local shear failure had taken place within a well-defined failure surface. Moreover, the slope of the curve turns out to be almost vertical beyond $s/B = 14\%$, indicating the failure of the foundation bed. In contrary, the pressure–settlement curve for the geocell-reinforced sand bed showed no clear failure even up to large settlements of $s/B = 22\%$. Furthermore, the curve depicts that the ultimate load-carrying capacity is about 91 kPa for unreinforced sand and about 214 kPa for reinforced sand at measured settlement $s/B = 10\%$. The

Table 3 Schedule of model-scale tests

Test series	Parameters	
	Constant	Variable
A	Static load, unreinforced sand, $R_d = 70\%$	
B	Static load, reinforced sand, $d/B = 0.5$, $h/B = 0.66$, $b/B = 3$, $u/B = 0.1$, Woven geotextile	
C	Repeated load, unreinforced sand, $R_d = 70\%$	$q_d/q_{ult} = 20\%, 40\%, 70\%$ and 85%
D	Repeated load, reinforced sand, $d/B = 0.50$, $h/B = 0.66$, $u/B = 0.1$, $b/B = 3$, woven geotextile	$q_d/q_{ult} = 20\%, 40\%, 70\%$ and 85%

Remark: the parameters h , B , d , u are defined in Fig. 2. Square footing width (B) = 150 mm, depth of top geocell layer (u/B) = 0.10, geocell height (h/B) = 0.66, and relative density (R_d) of footing bed = 70% were taken in this test series

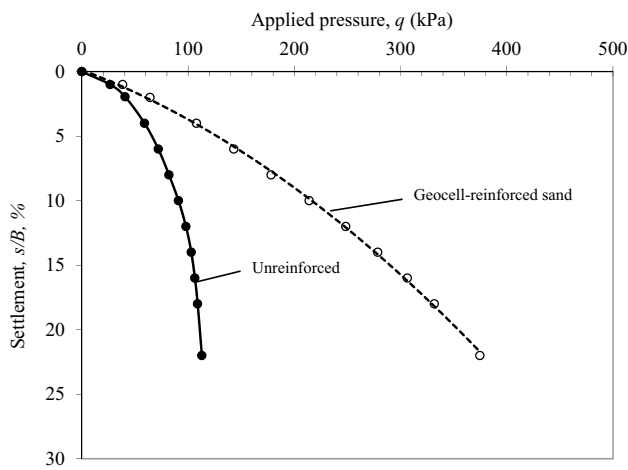


Fig. 7 Variation of footing settlement with bearing pressure for unreinforced and geocell-reinforced sand beds

performance improvement due to provision of geocell reinforcement is quantified in terms of improvement factor, *IF*, which compares the bearing pressure of the geocell-reinforced soil (q_R) to that of the unreinforced soil (q_U) at a given settlement level, as defined below:

$$IF = \frac{q_R}{q_U} \tag{1}$$

The variation of bearing capacity improvement factor (*IF*) with footing settlement is shown in Fig. 8. In literature [14, 32, 33], it was found that the ultimate bearing pressure of unreinforced soil would be at a settlement ratio of 5–10% of the footing width. Therefore, in this study the *IF* due to inclusion of reinforcement was considered at $s/B = 10\%$. Figure 8 illustrates that *IF* increases by 2.4-fold due to the inclusion of geocell reinforcement for geocell pocket opening ($d/B = 0.5$) at the measured footing settlement level $s/B = 10\%$. Figure 9 indicates the comparison between the present study and experiments performed by Dash et al. [3] and Hegde et al. [7]. The result of the figure demonstrate that the *IF* values of the present study are lower than the value obtained by Dash et al. [3] and higher than that of Hegde et al. [7]. This difference might be due to the variation of test parameters assumed in the past studies: such as, Dash et al. [3] conducted the tests on circular footing supported on geocell-reinforced sand underlain by soft clay beds and the geocell used in their study were fabricated from geogrids with $d/B = 0.8$, $u/B = 0.1$, $b/B = 3$, and $h/B = 0.66$; on the other hand, Hegde et al. [7] performed the study on square footing supported on geocell-reinforced sand beds, and factory-manufactured geocell with $d/B = 1.66$, $u/B = 0.1$, $b/B = 5.8$ and $h/B = 1$ were used for their work.

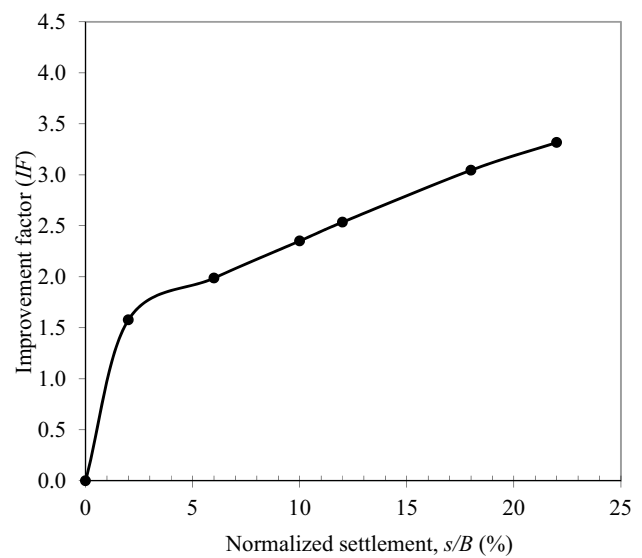


Fig. 8 Variation of bearing capacity improvement factor (*IF*) with footing settlement

The performance improvement in respect to settlement of a geocell-reinforced sand bed can also be quantified in terms of the percentage reduction of settlement, *PRS*, which compares the settlement of the geocell-reinforced bed (s_R) to that of the unreinforced bed (s_U) at the same level of bearing pressure, defined as:

$$PRS = (1 - s_R/s_U) \times 100. \tag{2}$$

Figure 10 illustrates the percentage reduction of settlement (*PRS*) due to the provision of geocell reinforcement at different footing settlement levels. Since the improvement is assessed with respect to the unreinforced sand, and past studies of several small-scale model tests [14, 32, 33] suggest an

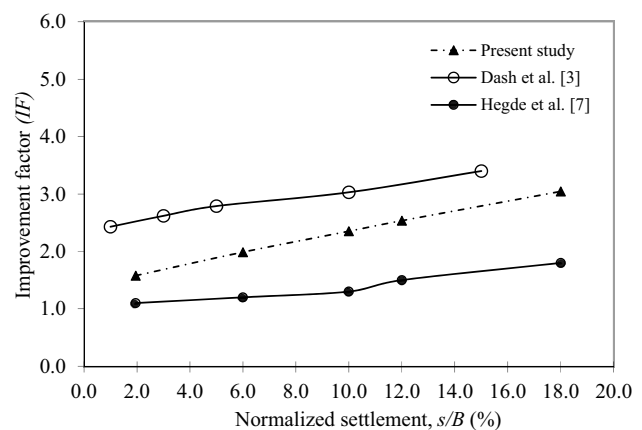


Fig. 9 Comparison of *IF* obtained from this study with that reported in the literature for geocell reinforcement

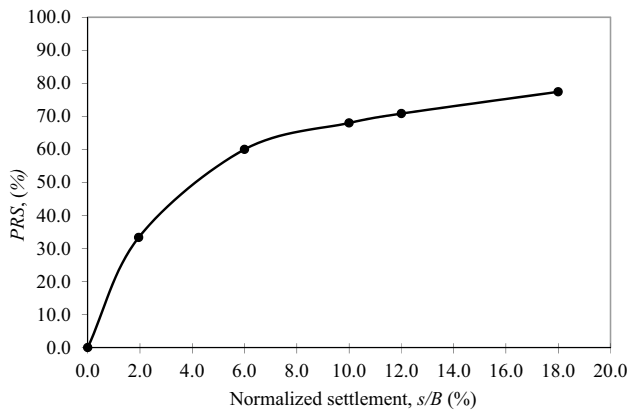


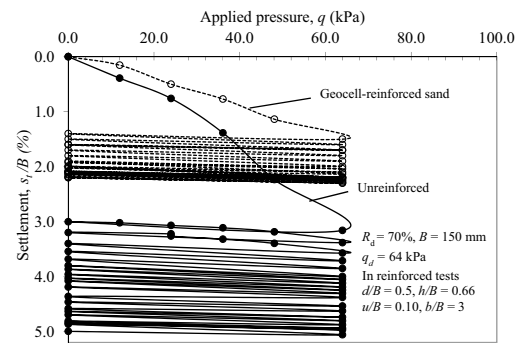
Fig. 10 Variation of PRS with normalized settlement of footing

ultimate bearing capacity of unreinforced soil at a settlement 5–10% of the foundation width, the settlement investigated in Fig. 10 is considered as 10% of the footing width. The test result illustrates that PRS increases by approximately 68% due to the inclusion of geocell reinforcement at $s/B = 10\%$, i.e. 68% reduction in settlement of the geocell-reinforced sand beds as compared to unreinforced sand bed.

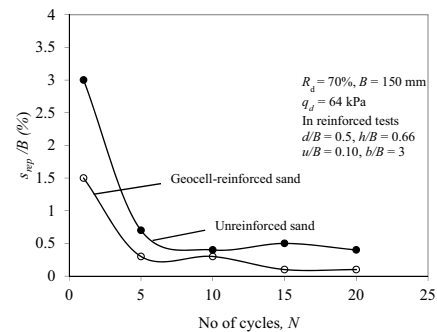
Tests Under Repeated Load

To carry out the repeated load tests, at the beginning (in case of the first cycle of loading), the load was increased in five small increments (steadily from zero) until reaching the predetermined value (loading). Each load increment was maintained at a value until the dial gauge readings of footing settlements had stabilized, i.e. up to a time when the rate of settlement (dial gauge readings) gets appreciably reduced to a value of 0.02 mm/min. The applied load was then decreased to zero value (unloading) in 15 min. This process of first cycle of loading–unloading took about 300 min. Thereafter, subsequent cycles of reloading and unloading were applied on the footing which was termed as repeated loading. The deformation of soil beneath the footing due to repeated load only (i.e. the difference in settlement under the last cycle and first cycle of loading) is denoted as (s_{rep}) and was normalized with footing width (B) to express it in a non-dimensional form as s_{rep}/B (%).

To assess the performance improvement of geocell-reinforced sand as compared to unreinforced sand under the same magnitude of repeated loading, a repeated loading test was conducted up to a predetermined pressure of 64 kPa, which is 70% of the ultimate bearing capacity of unreinforced sand. The load was applied on the footing supported on both unreinforced and geocell-reinforced sand. The test results plotted in Fig. 11a, b show that the rate of change of both total and the repeated settlement of the loaded surface decreases as the number of cycles of load increases, and



(a) Variation of s_t/B with applied repeated pressure (q) for unreinforced and geocell-reinforced soil beds at equal intensity of repeated load



(b) Variation of s_{rep}/B with no. of cycle (N) for unreinforced and geocell-reinforced soil beds at equal intensity of repeated load

Fig. 11 a Variation of s_t/B with applied repeated pressure (q) for unreinforced and geocell-reinforced soil beds at equal intensity of repeated load. **b** Variation of s_{rep}/B with number of cycles (N) for unreinforced and geocell-reinforced soil beds at equal intensity of repeated load

their response became almost stable after the first ten load cycles, especially for the geocell-reinforced sands. Suku et al. [20] have also reported a similar trend of observation for both reinforced and unreinforced soils under repeated loading. Figure 11(a) also illustrates that the total settlement (s_t) under repeated loading reduces by 56% with inclusion of geocell reinforcement, which may be due to upsurge in stiffness of the reinforced sand bed compared to the unreinforced sand. The upsurge in the stiffness of geocell-reinforced sand may be attributed to three factors, namely lateral confinement effect due to three-dimensional interaction between the encapsulated soil and the cellular structure, vertical dispersion effect due to introduction of stiffer materials, and membrane effect because of an anchorage on both sides of the loaded soil [13, 34]. These three factors influence the distribution of the applied load over a wider area, instead of directly transferring them at the point of contact, and provide a composite slab with high flexural stiffness and load support capability within the geocell reinforcement [15, 16].

Since there is substantial increase in the ultimate bearing capacity of the sand bed with the inclusion of geocell reinforcement, it is of practical interest to study the behaviour of the geocell-reinforced sand bed under repeated loading up to the same percentage of respective ultimate bearing capacities under unreinforced and reinforced conditions. With this in view, a series of repeated load tests were carried out up to 20%, 40%, 70% and 85% of the respective ultimate bearing capacities, both for reinforced and unreinforced conditions of the sand bed as obtained from Fig. 7.

The variation of total settlement (s_t/B) with bearing pressure for initial static pressure amount (q_d/q_{ult}) equals to 70% of the ultimate bearing pressure for footing rested on unreinforced and geocell-reinforced sand subjected to repeated loads (i.e. $q_d = 64$ kPa for unreinforced, and $q_d = 150$ kPa reinforced sand) is presented in Fig. 12. The figure clearly indicates that as the vertical stress increases monotonically, the vertical settlement increases rapidly. Moreover, after completion of each load cycle, the vertical settlement increased and somewhat surpassed the previous maximum value. It is also noticed that some recoverable settlement (elastic rebound) upon decreasing the load to zero (unloading) occurs. However, the settlement did not bounce back to its earlier value while unloading, and some permanent settlement remained in the footing. The settlement that occurred up to the final cycle of loading including all stages of loading was termed as cumulative or total settlement (s_t). The permanent total settlement was also observed to increase with the increase of number of load cycles and it was more prominent for the first few cycles of loads. The test results of total settlement of footing resting on unreinforced and geocell-reinforced sand are discussed in the following sections.

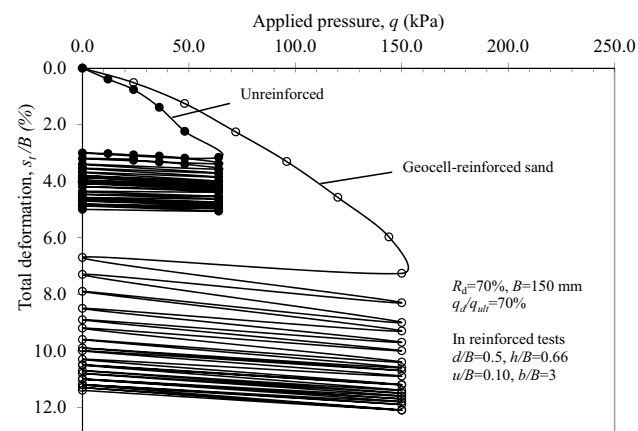


Fig. 12 Variation of s_t/B with applied pressure (q) for equal $q_d/q_{ult} = 70\%$, and 20 cycles

Effect of Initial Static Load Level

The test series C was conducted on unreinforced medium dense sand ($R_d = 70\%$) while the test series D was performed on geocell-reinforced sand at the same density. One layer of geocell made from woven geotextile with $d/B = 0.50$, $h/B = 0.66$, $u/B = 0.1$ and $b/B = 3$ was used as a reinforcement material. Figure 13 presents the variation of repeated settlement, (s_{rep}/B), with repeated load ratio, q_d/q_{ult} , for the case of unreinforced and geocell-reinforced sand after the application of 20 cycles of load. It can be seen that with increasing repeated load ratio, q_d/q_{ult} , the repeated settlement increases. It is also observed that a higher value of repeated settlement, (s_{rep}/B), is obtained for q_d/q_{ult} of 70% and 85%, as compared to q_d/q_{ult} of 20% and 40%. Furthermore, it is noted that a higher repeated settlement of the geocell-reinforced bed than that of the unreinforced bed for the same initial repeated load ratio takes place. This can be attributed to the fact that for both the cases of reinforced and unreinforced beds, the repeated load tests were conducted at the same normalized repeated load ratio, q_d/q_{ult} . Since the ultimate bearing capacity for reinforced sand is much higher than that of unreinforced sand (i.e. 2.35 times the ultimate bearing capacity of unreinforced sand), both the initial static load and the repeated load levels are much higher than those in unreinforced sands.

Effect of Number of Load Cycles

Figure 14a shows the variation of total settlement against the number of load cycles for a square footing resting on unreinforced and geocell-reinforced sand beds. The repeated load ratio, q_d/q_{ult} , was maintained at 70% for both the tests. In the reinforced test, one layer of geocell made from woven geotextile with $d/B = 0.50$, $h/B = 0.66$, $u/B = 0.1$ and $b/B = 3$ was

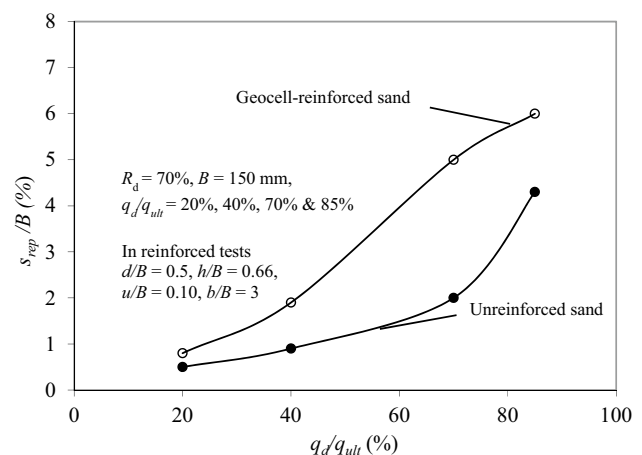


Fig. 13 Variation of repeated settlement, (s_{rep}/B), with repeated load ratio, (q_d/q_{ult})

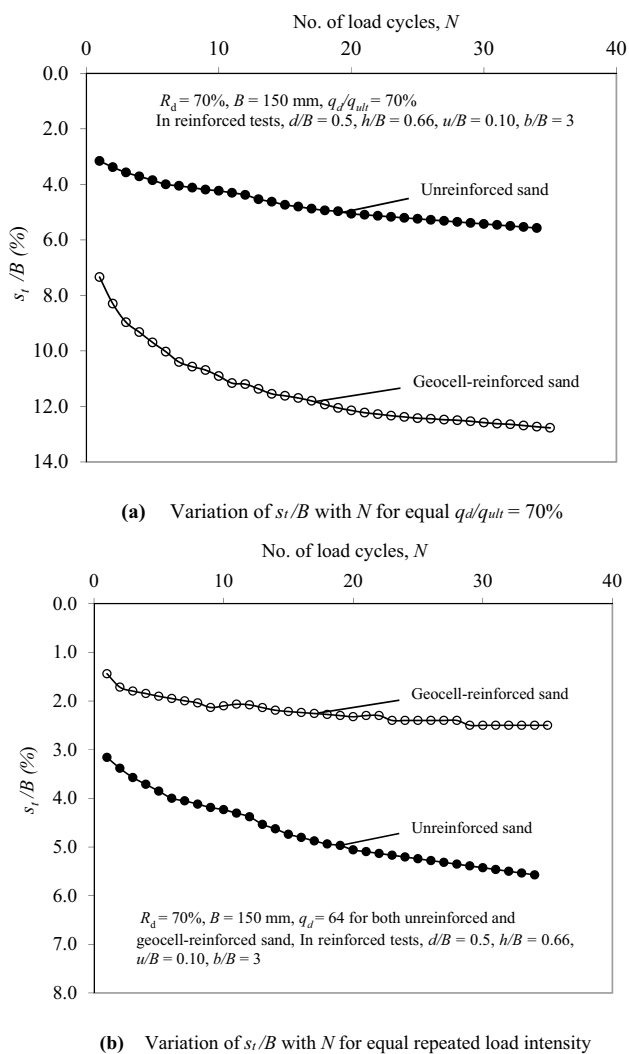


Fig. 14 **a** Variation of s_t/B with N for equal $q_d/q_{ult} = 70\%$. **b** Variation of s_t/B with N for equal repeated load intensity

used. The figure clearly illustrates the increases of the total settlement with gradually declining rate with the increase of the number of load cycles. Moreover, the effect was more prominent in case of reinforced sand as compared to unreinforced sand. This can be attributed because of higher repeated load ratio in reinforced sand than the unreinforced sand. In Fig. 14a, it can also be seen that the increase of the settlement rate is very rapid for the first 10 cycles, and thereafter the rate is lower until the number of load cycles become 30 cycles. Figure 14b represents the variation of cumulative or total settlement with number of load cycles for the same initial repeated load intensity on unreinforced and geocell-reinforced sand beds. It is also observed that the cumulative settlement significantly reduced after introduction of geocell reinforcement.

The benefits of using geocell-reinforced sand foundation subjected to repeated loadings are observed in this paper

through increase in the bearing capacity of footing and reduction in the footing settlement. The results obtained in the present study provides a basis to support the behavior of the repeatable loads in several areas, such as oil or water storage tank, and parking yard.

Scale Effects

Small-scale model test results are prone to scale effect. However, the scale effect can be reduced by carefully controlling the test parameters [35]. The particle size of foundation soil, size of model footing and geocell size contribute to the scale effect in model tests on sand [32, 36, 37]. In case of prototype footing, the width of the footing (B) is usually very large in comparison to mean particle size (d_{50}) of the soil. However, in model footing although the width of the footing is small, d_{50}/B ratio may still be low enough to nullify the scale effect due to particle size. Cerato and Lutenegeger [32] suggested that the bearing capacity does not get affected if d_{50}/B is kept smaller than $1/200$. Considering this recommendation, the particle size effect will be negligible as the ratio of d_{50}/B for this study is $1/250$. The response of a granular foundation under small model footing is not directly representative of that under prototype footing because of the different mean stresses under footings with different widths at a given relative density [32]. Tests performed by Cerato and Lutenegeger [32] on sand with footing sizes ranging from 0.0254 to 0.914 m showed appreciable scale effect up to footing width of 0.25 m after which the scale effect was significantly reduced.

Results of a study on load–settlement characteristic of large square footings (150 to 600 mm) investigated by performing large-scale loading tests on unreinforced and geocell-reinforced ($d/B = 1.66$ to 0.416 , $h/B = 1$ to 0.25 , $u/B = 0.33$ to 0.083 , tensile strength of geocell material = 15 kN/m) granular soils have shown that the effect of footing width on scale effect has the same trend at 65% relative density for both unreinforced and reinforced conditions [37]. This indicates that the model footing size has a much more dominant role than geocell parameters in the scale effect of the tests conducted. The parameters of the present study ($d/B = 0.5$, $h/B = 0.66$, $b/B = 3$, $u/B = 0.1$, tensile strength of geocell material = 24 kN/m, relative density 70%) are in the same range as seen in this study.

To have a closer representation of behaviour of full-scale footing, the model-scale tests are suggested to be performed on looser state of sand than the density of the sand in full-scale test [32]. In view of this, in the current study, the model tests were carried out in medium dense sand. The relative density of the sand bed in the present study was adopted at 70% so as to avoid punching shear failure of the unreinforced sand. The foundation

soil particle size and relative density, size of model footing plate and geocell dimensions adopted in the present study are sufficient enough to reduce, but not eliminate, the scale effect on the performance of the model tests. Using the results of this small-scale test for larger footings is not conservative and this fact should be considered in the design and construction of footings.

Conclusions

The behaviour of a repeatedly loaded square footing resting on unreinforced and geocell-reinforced sand bed was investigated in this study. Static load tests were conducted to determine the ultimate bearing capacity of unreinforced and geocell-reinforced sand beds with varying repeated load ratio such as 20%, 40%, 70% and 85% of the respective ultimate bearing capacity values of unreinforced and geocell-reinforced sand beds to simulate the structures wherein live loads change slowly and repeatedly. The following conclusions can be drawn from this study:

- The inclusion of geocell reinforcement in a sandy soil bed enhanced the bearing capacity and reduced the settlement of the footing. The bearing capacity increased by 2.4 times and settlement reduced by 68% at $s/B = 10\%$ when it was reinforced with a layer of geocell with $d/B = 0.50$, $h/B = 0.66$, $u/B = 0.1$ and $b/B = 3$.
- In circumstances where structures are very susceptible to large settlement, geocell reinforcement could be effectively used to attain the same allowable load-carrying capacity at a much lower settlement for the same soil density.
- For the application of the same initial static load intensity and the number of load cycles, the amount of total settlement due to repeated loading decreased with the provision of geocell layer. It was evident that the total settlement of sand bed with the same relative density reduced by 56% with the inclusion of the geocell layer after the application of 20 cycles of loading.
- For the same number of load cycles, the total settlement due to repeated load increased with increasing initial static load. Therefore, for the better performance of the foundation, the initial repeated load level should be kept below 30% of the ultimate bearing capacity.
- The total settlement was found to be increased with the number of load cycles with a gradually decreasing rate. For all the tests, most of the total settlement was observed to have occurred due to the first 10 cycles, and thereafter the rate became slower until the number of cycle reached 30 cycles.

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