IRJIF. I.F. : 3.821
North Asian International Research Journal of Sciences, Engineering & I.T.
ISSN: 2454-7514 Vol. 8, Issue-7 July-2022
Index Copernicus Value: 52.88 Indian Citation Index Thomson Reuters ID: S-8304-2016
NAIRJC A Peer Reviewed Refereed Journal
DOI: 10.5949/nairjc_joe_00007.59

ENHANCEMENT OF BEARING CAPACITY OF SOIL USING GEOCELL REINFORCEMENT

PARTIK[1] & ER. BRAHMJEET SINGH[2]

[1]*M. Tech Scholar, Deptt. of Civil Engineering RIMT University Mandi Gobingarh Punjab India*
[2]*Assistant Professor Deptt. of Civil Engineering RIMT University Mandi Gobingarh Punjab India*

ABSTRACT

There are a variety of methods to increase the engineering properties of soil using different types of reinforcements. Over the last 30 years, the favorable effect of using reinforcements to enhance the bearing capacity of sand is clearly shown by a number of investigators. In this study, the laboratory model tests are conducted on a strip footing resting on a sand bed which is reinforced with a geocell mattress. The purpose of present study is to determine the Improvement in bearing capacity of soil by reinforcing it with geocell mattress. So the effect of various parameters such as height (h/B) and variation of depth (u/B) of the geocell mattress was investigate The depth of geocell mattress is kept 0.5B, 0.75B, 1.0B and 1.25B and it is observed that the gain in load carrying capacity starts reducing beyond 0.5B and the maximum increase of 388% is observed at a 0.5B depth of geocell layer. There is sufficient increase in the bearing carrying capacity by the using of geocells and the optimum depth of geocell layer was found to be 0.5B below the footing. It was also observed that the increase in height of geocells affects the load carrying capacity in a positive way. So, the geocell mattress can be used efficiently in geotechnical applications to enhance the strength characteristics of the sand bed.

KEYWORDS: *Geocell, Reinforcement, Enhancement, Soil*

INTRODUCTION

General

Earth reinforcement is a well-organized technique of improving the load carrying capacity of the soil. From the last 30 years, the geosynthetics are being used extensively in order to increase the strength of weak soils. Geocells are the 3-dimensional honeycomb-like structure of cells and are connected together, which helps to confine the soil layer and improve the load carrying capacity.

GEOSYNTHETICS

Geosynthetics are the synthetic material commonly used for the stabilization of slope, embankment and lose soils. They are usually polymeric products used to find a solution of many civil engineering problems, apart from reinforcement there are some other applications of the geosynthetics such as separation of the layer, fluid purification, barriers etc. Basically, these are the synthetic fabrics, which are being broadly used in geotechnical and construction engineering works for the last almost 30 years. Major groups in geosynthetics are geotextile and geomembranes and are generally and are by-products made-up of petroleum products like polyesters, poly–ethylene, and poly–propylene. In the case of temporary structures such as diversions etc. natural fibers may also be used as reinforcement such as sisal, jute, coir, cotton, even camel hair etc. Geosynthetics includes seven main products; geo-grids, geocells, geonets, geotextiles, geo- membranes, geo-composites, and geo-foams. The products having a huge range of application and are currently used in various geotechnical, geoenvironmental, dams, highway/railway, embankment, erosion control, mining and landfill covers etc. Different types of geosynthetic are shown in Figure 1.

GEOCELL HISTORY

Types of Geosynthetic

United States Army Corps of Engineers investigated the cellular confinement system in September 1975, to check its suitability for the construction of bridge approach road on soft soils. The engineer discovered that confining action of sand (fine grained) successfully bring the better strength than existing crushed stone system (coarse grained). They also concluded that the sand confinement techniques are more effective and may be successfully used for various civil engineering projects such as buildings, dams, highways, embankments, and railways if the weak soil is encountered at the site. The geocell reinforcement system was made up of high-density polyethylene (HDPE), which is considered as strong, durable and light in weight. Geocells were used in the United States since 1980; for the enhancement of load carrying capacity of the soil. The basic mechanism is the confinement of soil which attributes for the strength increase. The other applications such as slopes, deterioration control and lining for water channel was also introduced in the United States in the year 1984. It was also reported in the literature that geocells were used in earth retaining structures in Canada since 1986. Geocell reinforcement Cellular confinement systems are mostly used to control erosion, soil stabilization and retaining wall reinforcement. Geocells are a 3-dimensional honey-combed cellular type structure that creates an overall confinement system to the soil, which helps to retain the soil particles within the confining area. Geocells are made by polymeric materials which are cut into strips and then it is welded in series. The cellular confinement decreases the lateral displacement of soil particles, so it permits to continue the compaction and forms a strong mattress that distributes the load over the whole area. Large size geocells are also made from stiff geotextiles which are used for the safeguard of bunkers and walls. In the current study, the geocell were formed by using waste PVC pipe pieces of selected height collected from a big construction project having diameter 63mm. These cells were further tied together in a series with steel wires to arrange in it similar order

OBJECTIVES

- To examine, the effect of depth (u/B) of a geocell layer on bearing capacity of sand.
- To examine, the effect of height (h/B) of the geocell mattress on the bearing capacity of sand.
- To optimize the effective use of geocells.

LITERATURE REVIEW

Dash et al. (2001) conduct laboratory model tests on sand bed using geocell as reinforcement and the type of footing was strip footing. Authors studied the effect of geocell pattern, opening size, height, and diameter of geocells. The relative density of sand was also varied during the experimentation. It was observed that reinforced sand bed could bear a load equal to 8 times the failure load for unreinforced sand even at a very high settlement of 50% of the width of footing. The study also highlighted the effect of placement depth and size of geocells on the improvement of bearing capacity of the soil. The optimum width of the geocell layer was found about 4 times and optimum height of geocell was found 2 times the width of footing, beyond this value there was a marginal enhancement in the bearing capacity of the soil. The optimum aspect ratio of the geocell pocket was approximately 1.67 times the height of the geocell.

Zhang et al. (2006) recommended a new idea of soil reinforcement, in which soil was reinforced with the 3D reinforcing elements. The horizontal, vertical and 3D reinforcing elements were inserted at pre-decided locations in the soil. A series of triaxial tests were performed on sand deposit using 3D reinforcement and stress – strain behavior for different tests was analyzed. Authors concluded that 3D reinforcing patterns not only improved the apparent cohesion but there is a noteworthy increase in the frictional angle also. Several configurations and patterns of 3D reinforcing elements were compared and discussed.

Gill et al. (2010) presented that load bearing capacity at the surface of the flyash slope was less, but with the placement of a geogrid reinforcement layer at a appropriate location, a significant increase was observed. Authors also noticed that increase in edge distance of footing, the number of reinforcing layers, and change in slope angles led to increase in the bearing capacity for any size of footing. It was also concluded that when the slope angle is 45° there is a noteworthy gain in the load-carrying capacity of the soil, up to an edge distance of2B. Similarly, if the slope angle increased up to 60°, the bearing capacity of the footing showed better results at an edge distance more than 3B.

Pokharel et al. (2010) concluded that the circular shaped geocells had a higher stiffness than that of elliptical shaped and the performance of geocell mattress was dependent upon the elastic modulus of the mattress. It was also concluded that with an increase in the height of the mattress, bearing capacity decreases as compared to the smaller size geocell mattress. With the inclusion of geocell layer in the Kansas River sand significant improvement was observed under static loading as compared to quarry dust due to its less apparent cohesion. If the multi reinforcement was used in the sand, a further increase in bearing capacity was recorded.

Tafreshi et al. (2010) in this study author make an effort to study the combined effect of planar reinforcement along with geocells on the settlement behaviour and bearing-capacity of the sand bed. Equal weight of geotextile materials was used at settlement level of 4% to the width of footing, the maximum increase in bearing capacity of the geocell and planar reinforcement was 2.73 and 1.88 times that of unreinforced soil. Similarly, reduction in settlement of footing was observed as 63% in case of geocell and 47% in case of planar reinforcement. With the higher stiffness, the load carrying capacity of geocell reinforcement was observed to be higher whereas settlements start decreasing than the planar reinforcement system when the weight of geotextile material was kept same. It was suggested that bearing capacity and settlement behavior of footing can be improved more by reducing the quantity of geocell material than planar geotextile.

lal et al. (2012) used cellular reinforced mattress made up from waste water bottles of different diameters as reinforcement material in the fly ash. The diameter of the bottle was kept 50mm in the first case with a height of 10mm and 20mm. Similarly, the diameter of the bottle in the second trail was kept 70mm and heights were 15mm and 30mm. Further, these cells were tied together with the help of tie wire pieces to form a cellular mattress. Laboratory model test results show that cellular reinforcement with an optimum diameter of 70mm and height of 30mm gives a better result as compare to other sizes of cellular reinforcement.

Sitharam et al. (2013) observed that with the inclusion of geocells and geogrid (as a single reinforcing unit) into the soil, the bearing capacity of the sand bed increases by 4 - 5 times as compared to the unreinforced soil. The interlinked cells help to transfer the load to a large area, which gives a better result. The solution was established with the help of three mechanisms: vertical stress dispersion effect, lateral resistance effect. The author validated the analytical result with the experimental study and the variation in both the result was within permissible limits. More experimental tests were suggested by the authors using footing of different geometry to calibrate the analytical model and also suggested to incorporate suitable shape factors.

Badakhshan et al. (2015) conducted a number of tests on a footing of different shapes such as square or circular having equal covered area, resting on granular soil which was reinforced with geosynthetics. The effect on the load-carrying capacity of soil varied with the variation in depth of placement and the number of geosynthetic layers and was investigated by applying central and eccentric loading over the footing. The ultimate load-carrying capacity value of unreinforced soil was almost same for both footings. But with an increase in the number of geosynthetics layers, the effect is maximum in case of footing of circular geometry and the increase is relatively at a higher rate compared to the other shapes. When the load was applied to the footing in eccentric and centric manner.

Moghaddas et al. (2015) in this study number of cyclic plate load tests were conducted using a 300mm diameter circular plate on the sand bed with reinforced geocell layers. It was observed that with an increase in the layers of geocell led to decrease in the settlement due to the equal load distribution. The optimum depth of the first layer was obtained as 0.2 times the plate diameter. Under the last cycle of loading at 800 kpa, stress starts decreasing about 30.40 % & 40.70 % for single or double layers of geocell reinforced soil respectively.

Cicek et al. (2015) performed number of laboratory tests on stiff strip footing resting over un– reinforced and reinforced sand bed and the effect of reinforcement length was studied. The length of reinforcement was increased as multiples of footing width B in various tests, namely B, 2B, 3B, 5B and in some tests even 7B was also used. The type and number of reinforcements were also varied to determine whether these parameters show any influence on the optimum reinforcement length. Authors observed L = 3B as an optimum length.

Tafreshi et al. (2016) observed that optimum vertical spacing of geocell reinforcement layers and planar geotextile reinforcement layers are approximately 0.36 and 0.4 times diameter of the footing. The use of the geosynthetic material as geocell layers at optimum depths always gave better results as compared to that of the planar layers at their optimum depths. No improvement was seen beyond three geocell layers, but when the reinforcement was increased by the use of geotextile it was concluded that by adding more layers of geotextile reinforcement the bearing capacity improves. Authors concluded that when the layers of geocell and geotextile are placed at optimum depths, maximum enhancement in bearing capacity and subgrade modulus can be attained.

Biabani et al. (2016) in this study authors conducted repeated load test on sub blast reinforced with geocells. A number of laboratory large-scale triaxial tests were performed by applying a low confining Stress of the order of 10 – 20 kPa and frequency of 10 Hz. A commercial finite element based software ABAQUS was used for numerical modeling. It was observed that results of the numerical study are in good agreement with the experimental data which highlights that geocells could be effectively used to minimize the vertical and lateral deformations. The study also revealed that increase in stiffness of geocells could further reduce the lateral deformations significantly.

METHODOLOGY

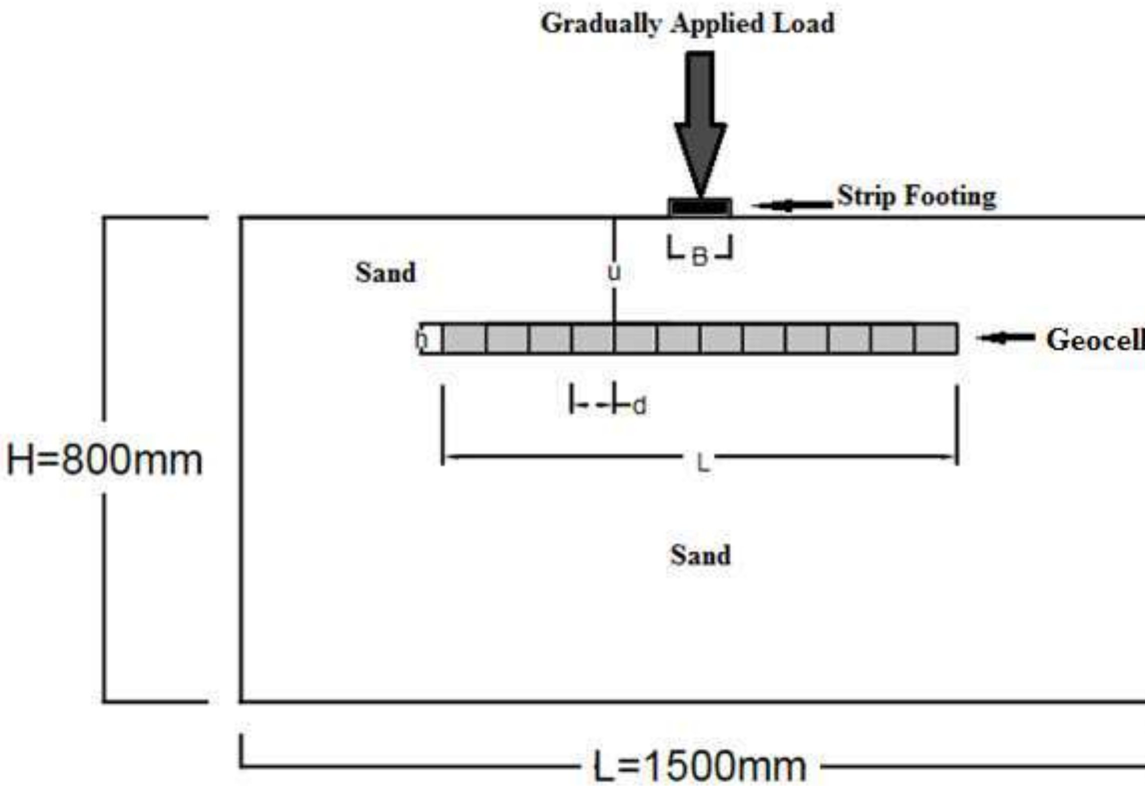
Sample preparation

Before filling the test tank with sand, rainfall technique was used for pouring the sand into the mould of known size (150mm×150mm×150mm) and weight to decide the final compaction level of sand in the test tank in terms of relative density. After several trails, it was finalized that 60% relative density of sand can be achieved by pouring sand from 50 cm height and the unit weight of sand at 60% relative density was found to be 17.90kN/m 3 . Now to prepare the test bed in the large size test tank sand was filled in three equal layers by maintaining the fall of 50 cm with the help of hopper which can be moved in both horizontal and vertical direction. To confirm whether the desired level of relative density is attained or not, five cylindrical density pots of 80mm height and diameter of known weight were placed in the model tank following a zig-zag pattern before filling each layer of sand as shown in Fig. 10. After the pots are filled with sand, they were collected and average unit weights of five cylinders were determined. By adopting the above-specified procedure during filling of test tank relative density of 60±2 % could be achieved. In reinforced cases, geocell layers were placed at pre-decided depths after leveling the fill surface and sand filling was done over geocell layer by same technique up to the top surface of the tank. Test procedure

The tank was filled up to the desired level and the sand was leveled properly and then stiff footing was placed according to the test programme. Proper care was exercised during the loading to avoid any type of eccentricity.

The base plate was placed on the footing to support the load cell and then a small cylindrical column was placed over the load cell to transfer the load on the footing. Finally, the hydraulic jack was placed over a cylindrical column to make a contact with horizontal reaction frame in order to apply the load.

Two LVDT's were placed on the surface of the footing on opposite sides. The load cell was placed between the actuator and footing using the appropriate arrangement as shown in the Fig.



The axial load was applied at a displacement rate of 2mm/min gradually and the load and settlement readings were recorded in the data logger system.

The footing was loaded at a constant incremental loading up to failure or maximum settlement of 40 mm whichever is earlier.

Figure : Line Diagram Shows the Experimental Setup

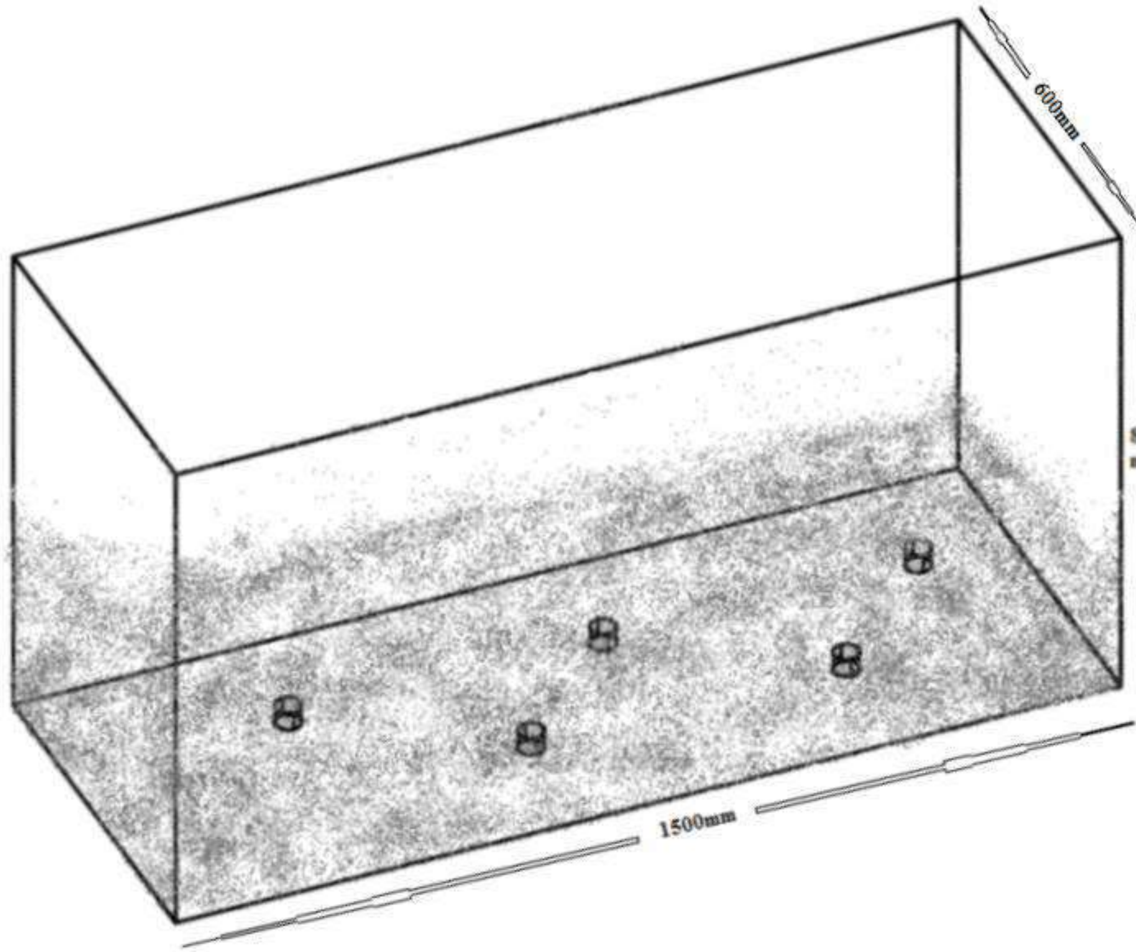


Figure : Shows the Zig-Zag Pattern of Test Pot to Check the Desired Density

PARAMETRIC STUDY

Studied parameters such as height (h/B) of the geocell mattress, depth of geocell layer (u/B) where, B - width of footing (10cm) and the diameter of the geocell is kept constant at d =63mm. The relative density of the sand used ID = 60%. The experimental study has involved 13 numbers of laboratory model tests by changing different parameters as explained below. Out of which 1 test was unreinforced sand and 12 tests were of reinforced sand. Constant parameters were chosen based on the literature survey. Parameters that are studied in this work are given in the Table

PARAMETER STUDIED

Sr. No.	Tests Performed	No. of Tests	Constant Parameters	Variable Parameters
1	Unreinforced soil	1		
2	Soil reinforced with geocell (h=1.02cm)	4	d/B=0.63, h/B=0.1, b/B=6, ID=60%	u/B= 0.6, 0.85, 1.1, 1.26
3	Soil reinforced with geocell (h=2.03cm)	4	d/B=0.63, h/B=0.2, b/B=6, ID=60%	u/B= 0.6, 0.85, 1.1, 1.26
4	Soil reinforced with geocell (h=3.01cm)	4	d/B=0.63, h/B=0.3, b/B=6, ID=60%	u/B= 0.6, 0.85, 1.1, 1.26

CONCLUSIONS

In this present study, bearing capacity of strip footing reinforced with geocell mattress subjected to centric loading with varying the height of reinforcement is investigated. From the research work, following conclusions are drawn,

1. From the set of experiments conducted in this study, it has been observed that 0.5B is the optimum depth of placement. Significant improvement of bearing capacity of the order of 245%, 283% and 388% was observed respectively for h = 1cm, h = 2cm and h= 3cm.

2. When the height of geocell was increased to 2 cm, relative increase is 16% and a further increase of height to 3cm resulted in 60%, relative improvement in the bearing capacity with respect to h = 1cm. From these results, it

can be concluded that though with the increase in height bearing capacity increases but the relative increment is small as compare to the increase from unreinforced case to reinforced case with geocell of height 1cm and depth of geocell layer = 0.5B.

3. From this study, it can be concluded that geocells can be effectively used as reinforcement for weak sand deposits. The optimum depth of placement of geocell in the case of a single layer is 0.5B and optimum height is h/B = 0.1.

FUTURE SCOPE

The study can be further extended by using geocells of different material, of different pattern and of different pocket size. The effect of multilayers of geocells can also be investigated. The effect of relative density of sand may also be covered. The effect of cyclic load test if conducted on sand deposits reinforced with geocells may be of great use during the design of machine foundations so this aspect can also be considered for further study.

REFERENCES

1. Badakhshan, Ehsan and Noorzad, Ali et al. (2017) "Effect of footing shape and load eccentricity on the behaviour of geosynthetic reinforced sand bed", Journal of Rock Mechanics and Geotechnical Engineering, vol. 45, pp. 58-67.

2. Biabani, M. Mahd. and Indraratna, Buddhima et al. (2016) "Modelling of geocellreinforced sub-ballast subjected to cyclic loading", Geotextiles and Geomembranes, vol. 44, pp. 489-503.

3. Choudhary, A.K., Jha, J.N. and Gill, K.S. (2010) "Laboratory investigation of bearing capacity behavior of strip footing on reinforced fly ash slope", Geotextiles and Geomembranes, vol. 28, pp. 393-402.

4. Cicek, Elif and Guler, Erol et al. (2015) "Effect of reinforcement length for different geosynthetic reinforcement on strip footing on sand soil", Soil and Foundations, vol. 55, pp. 661-677.

5. Dash, S.K., Krishnaswamy, S. K. and Rajagopal, N. R. (2001) "Bearing capacity of strip footings supported on geocell-reinforced sand", Geotextiles and Geomembranes, Vol. 19, pp. 235-256.

6. Lal, B. Ram Rathan and Mandal, J.N. (2012) "Feasibility study on fly ash as backfill material in cellular reinforced walls", Electronic Journal of Geotechnical Engineering, Vol. 17.

7. Pokharel, Sanat K., and Han, Jie. et al. (2010)" Investigation of factors influencing the behavior of single geocell-reinforced bases under static loading", Geotextiles and Geomembranes, Vol. 28, pp. 570-578.

8. Sitharam, T.G. and Hegde, A. (2013) "Design and construction of geocell foundation to support the embankment on settled red mud", Geotextiles and Geomembranes, Vol. 41, pp. 55-63.

9. Tafreshi, S.N. Moghaddas and Dawson, A.R. (2010) "Comparison of bearing capacity of a strip footing on the sand with geocell and with planar forms of geotextile reinforcement", Geotextiles and Geomembranes, Vol. 28, pp.

72-84.

10. Tafreshi, S.N. Moghaddas and Khalaj, O. et al. (2015) “Repeated load response of soil reinforced by two layers of geocell”, World Multidisciplinary Earth Science Symposium, Vol. 15, pp. 99-104.

11. Tafreshi, S.N. Moghaddas, P. Sharifi and A.R. Dawson (2016) “Performance of circular footings on sand by use of multiple-geocell or -planar geotextile reinforcing layers”, Soil and Foundations,

12. Zhanga, M. X., Javadib, A. A. and Mina X. et al. (2006) **“**Triaxial tests of sand reinforced with 3D inclusions**”**, Vol. 24, pp. 201-209.