Strengthening of Cohesionless Soil Using Basalt Fibre Geogrids

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Abstract. Modern soil reinforcement uses more durable materials and advanced methodology in increasing the bearing capacity of feeble soils. Basalt fibre geogrids can be characterized as a green nonpolluting material used in stabilizing the week foundation soils by the interaction of frictional forces that develops at the soil reinforcement interface. This revolutionary fibre obtained from volcanic extrusive basalt rock possess high tensile strength than steel fibres and even effectively replaces glass and carbon fibres in terms of cost-efficiency and performance. Tests have been carried out to determine the effectiveness of basalt fibre geogrids in cohesionless soil. Cellular arrangement of geogrid with coir fibre inclusions at different confinement depth ratios (CD/B=0.25, 0.75, 1.5 and 2) and variation in number of geogrid cells (N=1, 5 and 9) are performed. Results show that maximum strength can be attained within the zone of influence at optimum coir fibre content.

Keywords: Basalt Fibre Geogrid, Cellular Arrangement, Coir Fibre Inclusions.

1 Introduction

The principle of reinforced earth has been effectively utilized more than three thousand years ago by the babylonians in the construction of ziggurats. A part of the Great Wall of China is also an example of soil reinforcement. Reinforcement can be provided to the soil by using either physical methods like vibration or by using chemical methods utilizing enzymes and resins or by adopting mechanical methods involving geogrids, geonets and geocells. Geogrids can be classified into three categories as punched and drawn type, flexible textile geogrids consisting of polyester fibres as reinforcing elements and laser geogrids including polyester fibres or straps bonded ultrasonically into geogrid meshes. Basalt fibre geogrids can well be designated as nonpolluting green material of twenty first century and a sustainable product as it does not require any chemical additives, solvents or enzymes during its production process. Basalt products have no noxious reaction with air or water and have proven to be non-carcinogenic in nature with minimum moisture absorption capacity. They possess high tensile strength and resistance to fire and ultraviolet radiations and its excellent damping properties makes it useful in acoustic insulation. Present study focusses on utilization of basalt fibre geogrid cells in improving the bearing capacity of week soils.

The effect of coir fibre in combination with the geogrid cells have also been studied at various fibre contents of 0.4%, 0.6%, 0.8% and 1%.

2 Materials Used

2.1 Cohesionless Soil

The soil sample was collected from nearby the campus of RIET, Attingal. The sample was properly cleaned from impurities, oven dried and sieved using IS 4.75mm and IS 0.075mm sieve as per IS 2720 (Part-4)-1985 to attain the desirable gradation. The properties of soil are discussed in Table 1.

Table 1. Properties of Cohesionless Soil

Properties	Values
Specific gravity, G	2.64
Effective size, D10 (mm)	0.16
D60 (mm)	1.18
Uniformity coefficient, Cu	7.37
Maximum dry density (g/cm3)	1.82
Mininum dry density (g/cm3)	1.45
Emin	0.45
Emax	0.84
IS classification	SW

2.2 Basalt Fibre Geogrid

The properties of basalt fibre geogrid as shown in Fig 1 of grade 350gsm are listed in Table 2.

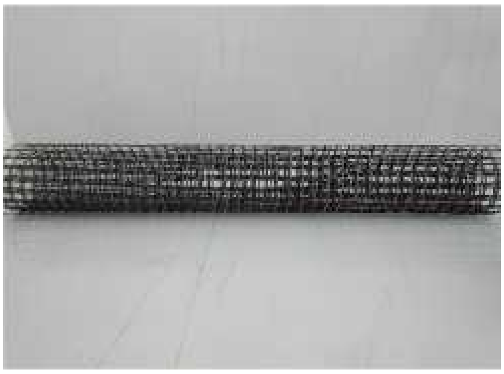

Fig. 1. Basalt fibre geogrid

Table 2. Properties of Basalt Fibre Geogrid

Properties	Values
Opening size (mm)	25
Thickness (mm)	0.08
Weight (g/m^2)	350
Max load –warp (N/m)	80780
Max load –weft (N/m)	78900
Elongation at break –warp (%)	6.67
Elongation at break –weft (%)	3.53

3 Methodology

A test tank made of mild steel with dimensions of 600x600x600mm and a mild steel plate of size 100X100mm with a thickness of 20mm was used as the square footing. The footing is placed in such a way that the axis of loading coincides exactly with the center of the plate. The dimensions of the tank were designed as per IS: 1888-1982 such that the size of the tank was always kept five times the width of the footing. The experimental setup used is shown in Fig 2.

Fig. 2. Experimental setup

The test tank is filled with soil using sand raining method at relative densities of 35% and 85% respectively with geogrids cells placed at different confinement depth ratios (CD/B). A Loading frame was set to work as per the lever arm principle. After applying the balancing load on one side of the lever arm, the load is applied at equal increments and the corresponding settlements were observed using two 50mm dial gauges. The final settlement is obtained by calculating the average of the two values. Loading is continued until failure occurs due to excessive settlement.

4 Results And Discussion

Load settlement analysis have been carried out to determine the effectiveness of basalt fibre geogrids in cohesionless soil. Following results have been obtained.

4.1 Unreinforced State

Load settlement curve was plotted for the soil under natural condition with a relative density of 35%. The curve shows a general shear failure with a failure load at 5.2 kg.

The soil was then compacted in the influence zone of footing that is 1.5B at a relative density of 85% and the load settlement curve was plotted as shown in Fig 3.

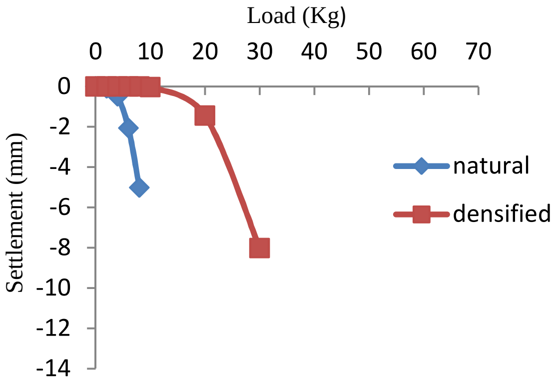

Fig. 3. Load settlement curve in unreinforced condition

With the increase in relative density from 35% to 85% the load carrying capacity has increased by 240% as the soil particles get rearranged to more denser state with less number of voids.

4.2 Reinforced State - Coir-Geogrid Cellular Composites

In cellular composites, the geogrids are placed in the form of cells encasing the soil and coir fibres at varying fibre content and confinement depth of geogrid. The top view of a 3x3 cell arrangement with the length of one side as 3B, where B is the width of footing is shown in Fig 4.

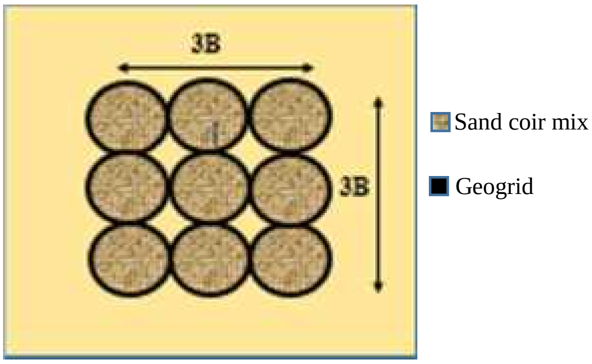

Fig. 4. Top view of cellular model with 9 cells

A graph is plotted between BCR and settlement ratio for the reinforced soil with constant number of cells as N=9 at optimum fibre content and confinement depth as shown in Fig 5.

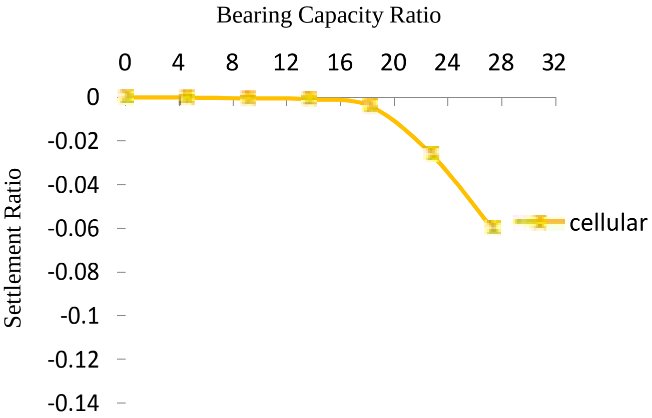

Fig. 5. Cellular form of geogrid at N=9 cells

An increment in bearing capacity was observed with the addition of coir fibres to the geogrid cells as shown Fig 6 as fibre strands holds the soil particles without being displaced off at the time of loading.

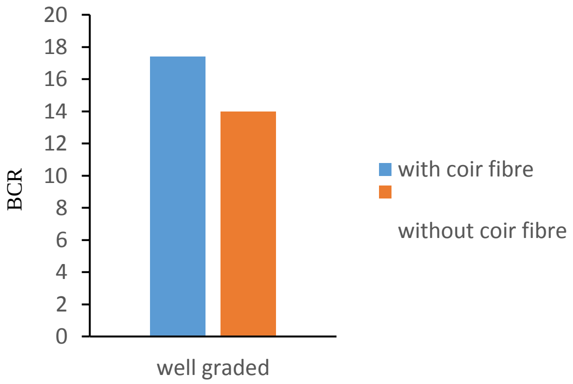

Fig. 6. Cellular form of geogrid with and without coir fibre

4.3 Optimum Fibre Content

Basalt fibre geogrids were placed in the form of cells filled confining the sand-coir mix with varying number of geogrid cells and percentage of coir fibre from 0.4 to 1% with confinement depth of cells extending upto the zone of influence A graph was plotted between BCR and percentage fibre content as shown in Fig 7.

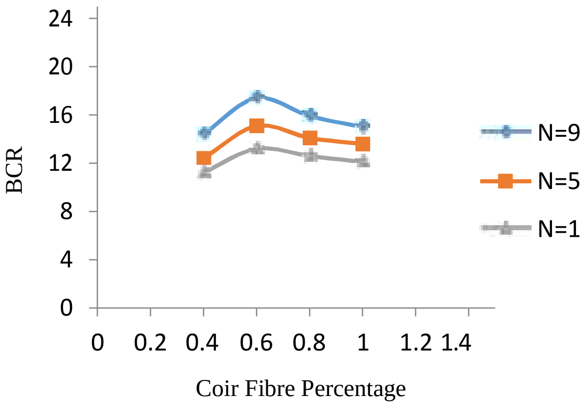

Fig. 7. Variation in BCR at different percentages of coir fibre

It was observed that the optimum coir content was observed to be at 0.6% with a maximum number of geogrid cells arranged in a 3x3 form. Beyond the optimum point the fibre content exceeds the percentage of soils particles for which a decrement in bearing capacity was observed.

4.4 Optimum Confinement Depth

A cellular form of geogrid has been placed with varying confinement depth ratios of 0.25B, 0.75B, 1.5B and 2B at optimum fibre content of 0.6% as shown in Figs 8 to 11.

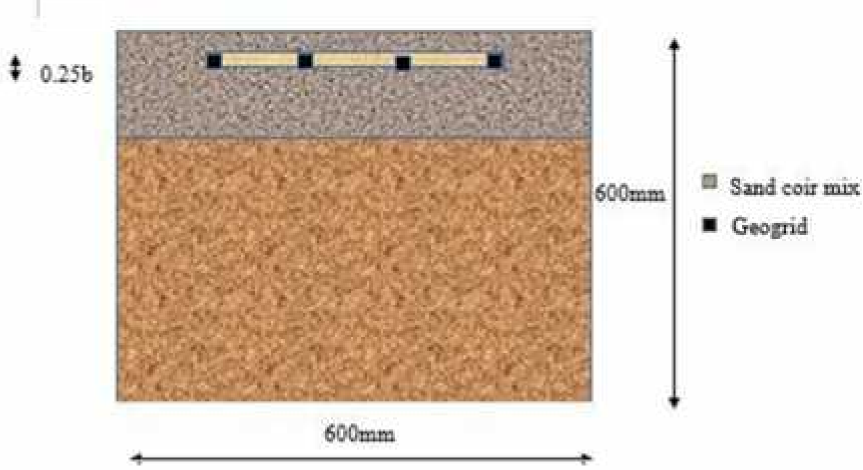

Fig. 8. Crossection of cellular model at CD/B= 0.25

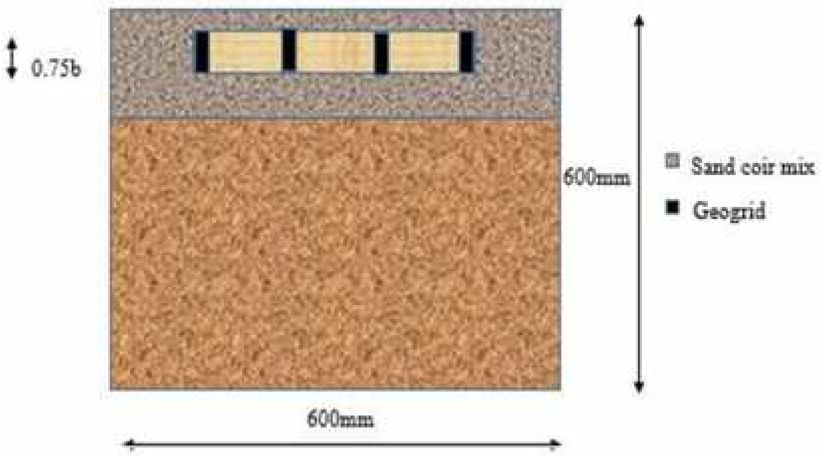

Fig. 9. Crossection of cellular model at CD/B= 0.75

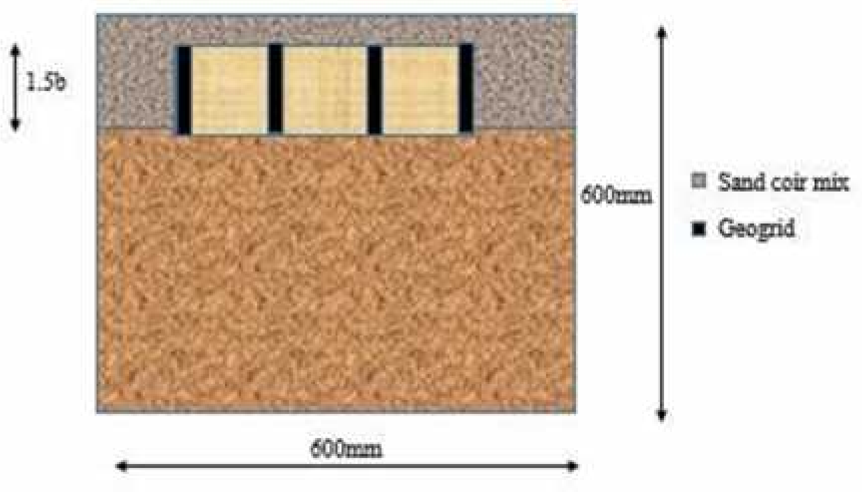

Fig. 10. Crossection of cellular model at CD/B= 0.75

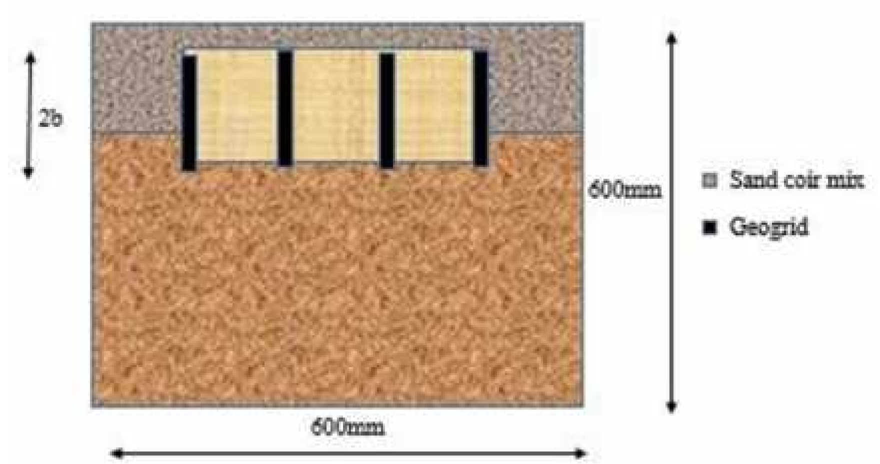

Fig. 11. Crossection of cellular model at CD/B= 2

It can be observed that in the first three cases, the cellular geogrid was placed in the compacted fill whereas at CD=2B the cellular geogrid was placed penetrating into the loose fill by 0.5B. All the cells were placed at 0.25B below the bottom surface of the footing.

Settlement curve was plotted by varying the CD/B ratio of geogrid cells at optimum coir fibre content as shown in Fig 12. BCR ratio increases with increase in confinement depth ratio in the reinforced area with a relative density of 85% due to the all-round confining action of the geogrid cells and maximum benefit could be achieved in a 3x3 cellular form. It was also observed that there is no increment in BCR beyond the zone of influence that is at CD/B=2 which penetrates into loose fill with relative density of 35%.

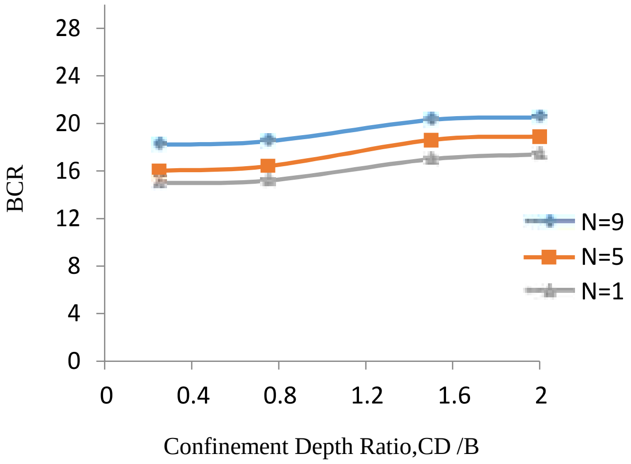

Fig. 12. Cellular model of geogrid with varying confinement depth ratios (CD/B)

5 Practical Significance

Rising cost and decreased availability of areas for urban infill has forced the mankind to take up construction in undeveloped areas which possess weak underlying foundation material. This has set a great challenge for the geotechnical engineers especially in utilizing cohesionless soil for construction activities. In sandy soils the settlement occurs when the soil gets too wet causing an increase in pore pressure and thus with low friction between the sand particles it smoothly shifts out of place resulting in the collapse of the structures built on it. Studies have been carried out over the past decades for improving the performance of shallow foundations using geosynthetics. Researches have been carried to the present era to attain an economical and environment friendly product which can be more effectively utilized in strengthening soils of low bearing capacity. Basalt fibre geogrids have been successful in satisfying this criteria to a certain extend.

6 Conclusion

- The load bearing capacity of the soil increased with the introduction of coir–geogrid cells and the settlement reduced with the increase in cells from N=1,5, and 9 due to the increased stiffness of the corresponding cells.
- Maximum benefit can be achieved in cellular model at CD/B=1.5 due to the all-round confining action of the geogrid.
- Lesser settlement is observed at CD/B=1.5 beyond which there is less influence of the restraining action of the geogrid.
- Optimum percentage of coir fibre added is at 0.6% beyond which the effect is negligible.

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