BEARING CAPACITY IMPROVEMENT OF SAND USING COIR GEOGRID TUBES INFILLED WITH COCONUT SHELL CHIPS

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Abstract - *The growing prevalence of problematic soils presents significant challenges in construction. Geosynthetics play a pivotal role in improving soil properties, particularly in enhancing the bearing capacity of structures built on sandy terrain. This research looks into the bearing characteristics of sand when reinforced with Geogrid tubes filled with Coconut Shell Chips (CSC). Experimental analyses were conducted to evaluate the enhancement in bearing capacity achieved by sand installed with Coir Geogrid Tubes (CGT) filled with Coconut Shell Chips (CSC). Laboratory plate load tests were carried out to study bearing capacity behavior and settlement reduction in the soil. The study investigates how varying the vertical distance between the surface and the first layer of geosynthetic of geogrid tubes, impacts sand behavior through experimentation. It examines the bearing capacity effect of CSC-filled CGT with diameter 2cm at different u/B ratios of 0.5, 0.75 and 1, where B is the footing width. The potential of using coir geogrid in reinforcement form is studied.*

Key Words*: *Bearing capacity, Plate load test, Coir, Geogrid tubes, Coconut shell chips.

1. INTRODUCTION

Civil engineers face daunting tasks when constructing over weak soils, as these soils are prone to problems like differential settlements, low shear strengths, and high compressibility. Coir, a 100% organic fiber derived naturally from coconut husks, is a renewable resource sourced from the coconut tree. When employed in grids or mats, various factors such as the grid's aperture size, the thickness and shape of rib cross-sections, as well as the strength of knots, become significant. Numerous studies have explored the modification and enhancement of soil reinforcement properties and their shapes. The form of reinforcement plays a crucial role in design, as the same quantity of reinforcement can yield different beneficial effects. Geosynthetics can be transformed into tubular elements for reinforcement purposes. Crushed coconut shells are well-suited as soil stabilizers due to their durability, high toughness, and abrasion resistance. This suitability arises from the coconut shell's excellent weather resistance, making it suitable for construction materials. However, it lacks economic value, and its disposal process is costly, leading to potential environmental problems.

Shear strength characteristics of coir mat in sand was studied by Sridhar et al. [6] in 2014. Direct shear tests were done on coir mat reinforced sand. Size opening of coir mat was varied and it was found that, the maximum value of angle of internal friction was observed corresponding to smaller size of opening. The study also showed that, with increase in size of opening, value of angle of internal friction decreased due to reduction in interlocking effect. Lal et al. [4] in 2017 conducted a study to determine the effect of reinforcement form on behavior of coir geotextile reinforced sand. Coir in the form of geotextile and geocell was used and plate load tests [2] were conducted. Results showed that the use of coir in geocell form enhanced the performance of sand more. For the same amount of reinforcement used, coir geocell offers higher performance characteristics compared to planar forms. Al-Subari et al. [1] in 2020 performed a study to understand the effect of reinforcement of different material on the bearing capacity of sand. It was observed that inclusion of coir showed higher bearing capacity and it also improved friction angle by 2° compared to steel and polypropylene reinforcement.

In a series of CBR tests, Jelani et al. [3] (2023) looked in the effect of varying percentage of crushed coconut shell in silty sand. According to the study, the soil sample with 10% of crushed coconut shell recorded considerable increase in CBR of 2.3 times compared to unreinforced sample. Comparison study between the bearing capacities of strip footing on soil slope reinforced by planar and tubular form of braid and geogrid elements was conducted by Satvati et al. [5] in the year 2016. From the study, it was observed that the increase in bearing capacity ratio (BCR) of soil slope with braid reinforcement from planar to tubular was 39% and the BCR increase for reinforcement with geogrid from planar to tubular was 53%.

The present research focuses on the behavior of soil with and without reinforcement. Coir geogrid was fabricated into tubes, Coir Geogrid Tubes (CGT) and Coconut Shell Chips (CSC) was used as the infill material. Effect of CSC infilled CGT by varying u/B ratios on the bearing capacity of sand is studied in this paper.

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2. MATERIALS AND EXPERIMENTAL SETUP

2.1. Soil

The soil used in this study was excavated 1.5m below the ground level. The soil was collected from Menamkulam, Trivandrum. The properties of the soil are summarized in Table 1. The values of coefficient of curvature and uniformity coefficient were obtained from the particle size distribution curve (Fig.1). After testing the soil, it was found that the collected sample was Poorly Graded Sand (SP) according to IS Specifications.

Table – 1: Properties of soil

PROPERTY	VALUE
Initial Moisture content (%)	1.67
Specific Gravity, G	2.65
Coefficient of Uniformity (Cu)	1.62
Coefficient of Curvature (Cc)	0.99
Angle of internal friction (degree)	38
Cohesion (kg/cm^2)	0.19
Density (g/cc)	1.78
IS Classification	SP

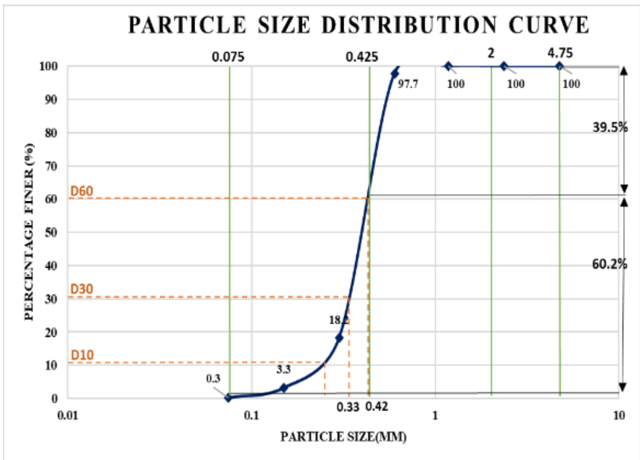

Fig - 1: Particle size distribution curve

2.2. Coir Geogrid Tubes (CGT)

Coir geogrid was collected from National Coir Mills, Alappuzha. Coir geogrid was fabricated into tubes and used as reinforcement. Properties of coir geogrid (Table 2) was obtained from National Coir Research and Management Institute, Trivandrum.

Table – 2: Properties of Coir Geogrid

Properties	Values
Thickness (mm)	8.56
Tensile strength (N/m)	14971.47
Puncture resistance (mm)	17.33
Mass per unit area (GSM)	900

2.3. Coconut Shell Chips (CSC)

Crushed coconut in the form of chips was collected from Easy and Fresh, Anayara, Trivandrum. The properties of coconut shell were studied and the values are tabulated in Table 3.

Table – 3: Properties of CSC

Properties	Values
Size (mm)	1-10
Specific Gravity	1.28
Porosity (%)	55
Bulk density (g/cc)	0.57
Shell thickness (mm)	2-6

2.4. Experimental Set Up

The experimental setup for this research includes a loading frame, a test tank, a hydraulic jack, and additional instruments for load and settlement measurement (Fig 2). In this study, a test tank measuring 50x50x50 cm and a plate of size 20x20 cm were utilized, with the loading plate having a thickness of 10mm. Manual application of load was carried out, with observations of settlement recorded for each load increment, and subsequent settlement calculations were performed. Furthermore, a proving ring and deflection gauges were arranged to apply load and determine settlement.

Fig – 2: Plate load setup

3. EXPERIMENTAL PPROGRAM

The necessary materials were gathered for the study. The test tank was filled with the appropriate amount of sand. The loading plate was positioned centrally, and load application to the sample was facilitated using the loading frame. Throughout the loading process, the settlement of the sample was monitored using a dial gauge with a precision of 0.01mm. Load was applied at a consistent strain rate of 1.2 mm/min. Initially, a test was conducted on unreinforced sand (Fig 3) followed by an analysis of the load-settlement behavior of sand reinforced with 2cm diameter CGT infilled with CSC, at varying u/B ratios of 0.5, 0.75, and 1. The horizontal spacing between tubular geogrids was maintained constant to ensure equal area of reinforcements between tubular and planar forms. Thus, a single layer comprised 8 reinforcements with a center-to-center spacing equivalent to πD. Soil is then filled up to the top surface and loading setup is placed as shown in Fig 4.

Fig – 3: Load test on unreinforced sand

Fig – 4: Plate load setup before loading

4. RESULTS AND DISCUSSION

4.1. Unreinforced sand

Plate Load Test was carried out following the IS procedure to analyze the load settlement characteristics of CGT infilled CSC under various placement depths. Two dial gauges were positioned on the footing plate, positioned opposite each other, to record the readings.

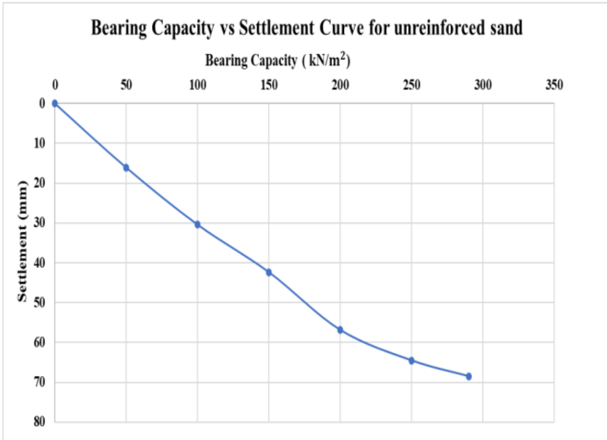

Fig – 5: Bearing capacity graph of unreinforced sand

The bearing capacity settlement graph of sand without reinforcement is shown in Fig 5. The maximum bearing capacity of sand was found as 290 kN/m² and the maximum settlement was obtained as 68.52 mm.

4.2. Effect of CSC infilled CGT

The settlement and load-bearing capacity of CSC infilled CGT in sand were investigated. CSC infilled CGT with diameters of 2 cm and varying u/B ratio of 0.5, 0.75 and 1 were tested. Fig 6 illustrates the changes in the settlement and bearing capacity. Analysis of the graphs revealed that maximum bearing capacity was obtained for CSC infilled CGT at u/B=0.75 and minimum settlement was also observed at this case.

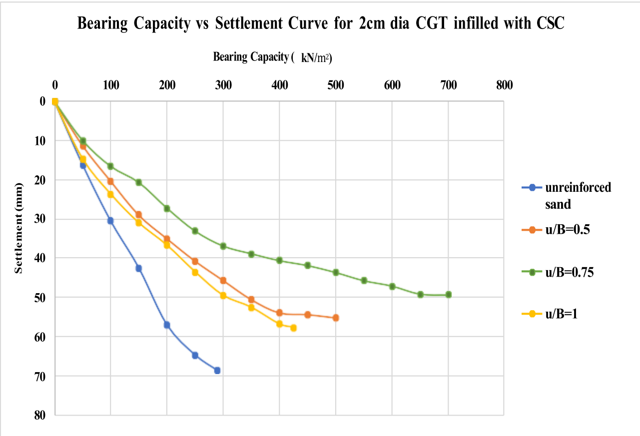

Fig – 6: Bearing capacity graph of unreinforced sand

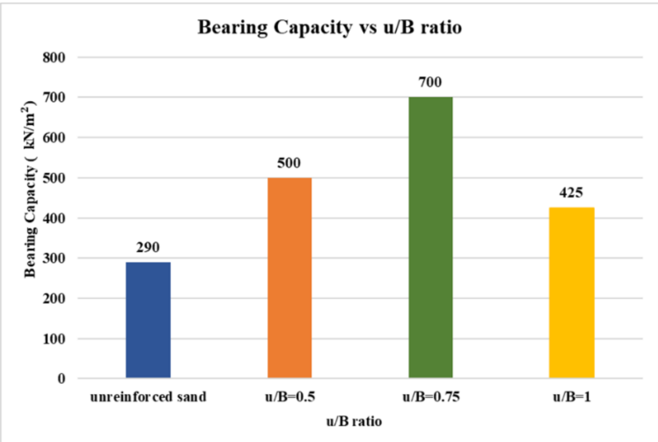

Fig – 7: Bearing Capacity vs u/B ratio for 2cm diameter CGT infilled with CSC

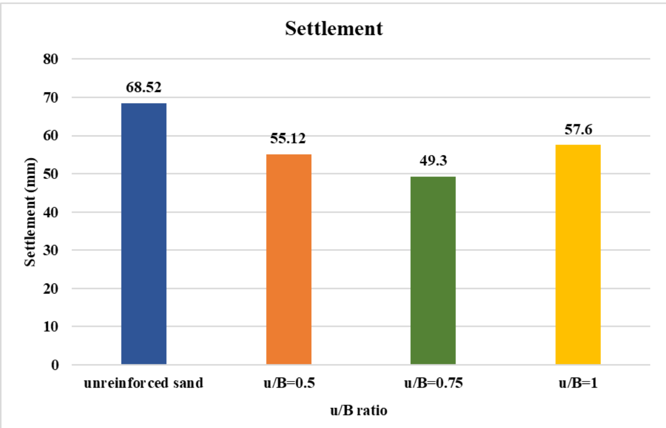

Fig – 8: Settlement vs u/B ratio for 2cm diameter CGT infilled with CSC

Fig 7 and 8 shows the comparison of bearing capacity and settlement for different u/B ratios respectively. The results show a considerable reduction in bearing capacity and increase in settlement when CGT was placed at u/B=1. The study also shows the improved effect in strength of soil by utilizing reinforcement in different form and shape.

5. CONCLUSIONS

The study investigates the impact of coconut shell chips infilled coir geogrid tubes on soil behavior. Bearing capacity and settlement values were calculated. Several observations were drawn from the study:

– Unreinforced sand exhibits lower bearing capacity compared to sand with coconut shell chips infilled coir geogrid tubes.

– Sand reinforced with CSC infilled CGT showed bearing capacity improvement of 1.4 times and 28% settlement reduction when placed at u/B = 0.75 compared to unreinforced sand.

– A reduction in bearing capacity was observed in case of CSC infilled CGT at u/B = 1 due to occurrence of lateral displacement of reinforcement.

– Strength of soil improved with the inclusion of geogrid in tubular reinforcement form and beneficial disposal of coconut shell waste was achieved by using it as infill in coir geogrid tubes.

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