Bearing Capacity and Settlement Characteristics of Circular and Square Footings on Reinforced Sand Beds with Lateritic Soil Layers

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Abstract - This study presents a comprehensive investigation into the bearing capacity and settlement characteristics of both circular and square footings positioned on reinforced sand beds that are underlain by lateritic soil layers. A series of meticulously controlled laboratory experiments were conducted to assess the performance of these footings, with geogrid reinforcement employed to enhance the structural properties of the sand bed. The research focuses on the combined effects of footing geometry, reinforcement configuration, and the integration of lateritic soil layers on overall foundation behavior.

The experimental results reveal that the inclusion of geogrid reinforcement leads to significant improvements in bearing capacity while simultaneously reducing settlement. These findings underscore the potential of reinforced soil systems to enhance foundation performance, thereby demonstrating their practical applicability in geotechnical engineering where improved load distribution and minimized settlement are paramount.

Keywords: Optics, bearing capacity, circular and square footings, reinforced sand beds, lateritic soil.

1.INTRODUCTION

The stability of footings is a critical consideration in foundation engineering, as it directly affects the safety and serviceability of structures. Sand beds, commonly encountered in construction sites, often require improvement to achieve desired load-bearing characteristics. Reinforcement using geosynthetics has emerged as a cost-effective method to advance the bearing capacity and control settlements of such foundations.

Lateritic soil, prevalent in tropical regions, poses unique challenges due to its heterogeneity and variable properties.

A study was conducted in laboratory tests to explore the behaviour of sandy soil foundations, assessing critical elements that influence their performance. The findings revealed that reinforcement greatly minimizes settling, particularly with numerous layers, and that a combination of geogrid and geotextile outperforms individual reinforcements. The analytical solution produced in prior investigations closely matched the experimental data, demonstrating its trustworthiness [1].

A study discovered that raft foundation carrying capacity diminishes with increased breadth but improves with depth, whereas settlement advances with size, pressure and depth. The Burland and Burbidge approach projected higher settlements than Harr, which aided early design [2].

The effect of energy absorbing materials and their impact on the capacity and different form of methods [3] also the experimental data with different method shows the variation of materials [4] and their inputs [5]. A study examines the effect of geogrid reinforcement on closely spaced square and circular footings. Despite the limitations, soil reinforcement greatly reduces the detrimental impacts of interference on footing performance [6].

A study experimentally analysed the settlement of strip foundations and concluded the particular foundation width as the most influential factors, with settlement increasing as both parameters increased [7]. Further a study examines the impact of cyclic loading on square footings. Results showed that increasing sand density enhances both bearing capacity and elastic coefficients [8].

A study was concluded to enhance the performance with different materials [9] and further improvement in the physical properties of energy materials and absorbing phenomenon [10]. A study investigated the impact of geogrid reinforcement and concluded that geogrid placement significantly enhances load-bearing capacity [11].

The study of geo-grid reinforcement increases bearing capacity and minimizes settlement while providing optimal performance. Higher soil density increases bearing capacity, consistent with prior research findings [12].

This study explores the influence of incorporating lateritic soil layers within sand beds on the overall performance of soil systems. The investigation seeks to bridge existing knowledge gaps by conducting a comparative analysis resting on geogrid-reinforced sand beds containing lateritic inclusions.

1.1 Objectives

1. To evaluate the bearing capacity of circular and square footings on sand beds reinforced with geogrids.
2. To analyse settlement characteristics under varying loads.
3. To study the effect of lateritic soil layers on the performance of reinforced sand beds.

4. To compare the performance of circular and square footings.

2. MATERIALS AND METHODS

2.1 Sand: The current work used a consistently graded clean sand, and its specific gravity and particle size distribution were meticulously examined in accordance with the American Society for Testing and Materials' (ASTM) standards. These characteristics were thoroughly tested to assure consistency and dependability in the experimental setting, resulting in a well-defined foundation for measuring the behaviour of the reinforced soil system.

2.2 Lateritic Soil: Soil samples were obtained from a tropical region and thoroughly analysed to determine their plasticity, compaction, and shear strength qualities. Detailed experiments were carried out to evaluate the soil's behaviour at various moisture levels, find the best compaction parameters for maximum dry density, and measure its resistance to deformation under shear stresses, resulting in a thorough profile of its geotechnical performance.

2.3 Geogrids: High-strength polymeric geogrids were used as reinforcement layers to improve the stability and load-bearing capability of the sand bed. These geogrids, known for their high tensile strength and durability, were strategically placed in the soil to improve mechanical qualities, facilitate load distribution, and reduce settling under applied loads. Their use improved the total reinforcing efficacy, making them an important component in optimizing foundation performance.

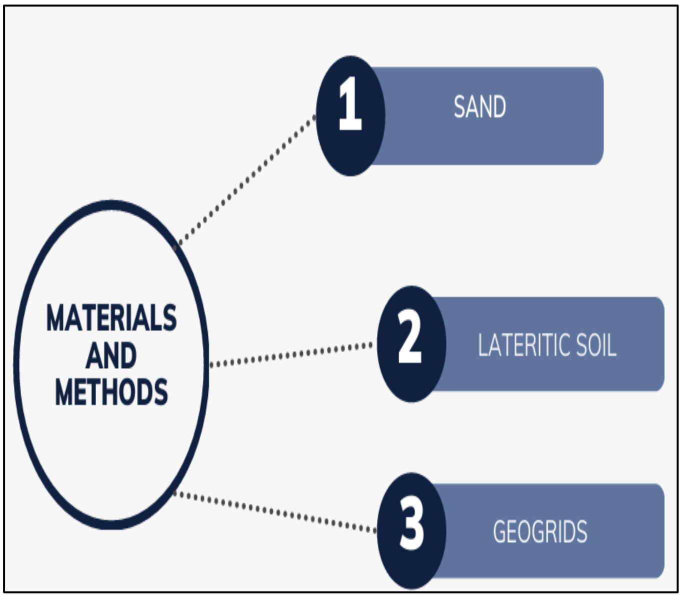

Fig. 1: Implementation of materials and methods.

3. EXPERIMENTAL SETUP

To evaluate the effectiveness of reinforced soil systems., a controlled model testing setup was created in a rectangular test tank measuring 1.5 m × 1.5 m × 1.0 m. Circular and square model footings with diameters and widths of 100 mm were used. The sand base was rigorously compacted to achieve uniform density, and the lateritic soil layer was strategically placed at predefined depths to exactly simulate real-world field circumstances.

3.1 Methodology

(a) **Preparation of Sand Bed**: The preparation of sand was compacted in layers to achieve the desired density. Reinforcement layers were embedded at predetermined intervals.

(b) **Placement of Lateritic Soil**: Layers of lateritic soil were introduced at various depths (e.g., 0.5B, B, 1.5B) below the footing base.

(c) **Loading Tests**: Incremental static loading was applied using a hydraulic jack, and load-settlement data were recorded.

(d) **Test Variations**: Tests were conducted for varying the number and placement of geogrid layers.

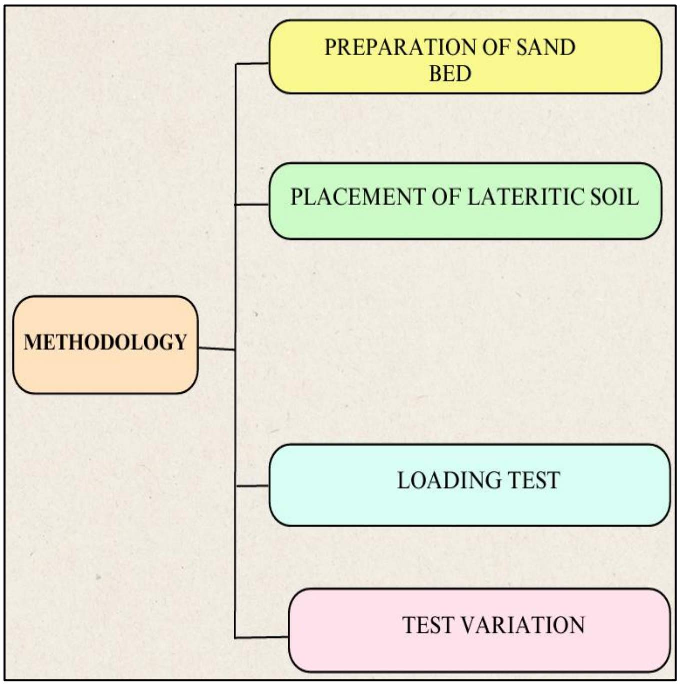

Fig. 2: Flow process for the methodology of circular and square footing.

4. RESULTS AND DISCUSSION

4.1 Bearing Capacity

The integration of geogrid reinforcement led to a substantial enhancement in the bearing capacity. As more reinforcement layers were added, the bearing capacity of the soil steadily improved compared to unreinforced soil. However, after three layers of reinforcement, the rate of improvement began to level off, showing little further increase, indicating diminishing returns with further layering.

4.2 Effect of Lateritic Soil Layers

The presence of lateritic soil layers within the sand bed resulted in a significant loss in bearing capacity, which was attributed to the lateritic soil's lower strength and weaker structural properties when compared to sand. However, the use of geogrid reinforcement substantially mitigated this loss by improving load distribution and soil stability. This revealed the importance of reinforcement in minimizing the negative effects of weaker soil layers, validating its efficiency in improving foundation performance under difficult geotechnical circumstances.

4.3 Settlement Characteristics

Reinforcement reduced the settlement of footings under identical loads. Circular footings exhibited slightly less settlement compared to square footings due to uniform stress distribution.

4.4 Influence of Reinforcement Configuration

The study found that closely spaced reinforcement layers markedly enhanced overall system performance. In particular, the optimal configuration was achieved when the spacing between reinforcement layers was maintained at 0.3B intervals, ensuring improved load distribution and increased stability in the reinforced soil system.

4.5 Comparison of Circular and Square Footings

Circular footings have a slightly better carrying capacity than square footings, most likely due to their design, which allows for a more efficient transfer of stress into the underlying soil. However, square footings had better load distribution characteristics because to their wider contact area, which helps to disperse applied loads more uniformly, reducing localized pressure and lowering the possibility of differential settling.

Table 1: Sample Table Bearing Capacity Improvement with Reinforcement

Test Case	Footing Type	Unreinforced Bearing Capacity (kPa)	Reinforced Bearing Capacity (kPa)	Improvement Factor
Sand Bed Only	Circular	120	180	1.5
Sand with Lateritic Soil Layer	Circular	100	150	1.5
Sand Bed Only	Square	110	160	1.45
Sand with Lateritic Soil Layer	Square	90	135	1.5

Table 2: Settlement Characteristics for Circular and Square Footings

Footing Type	Reinforcement Layers	Settlement (mm) - Unreinforced	Settlement (mm) - Reinforced
Circular	0	15	-
Circular	1	-	10
Circular	2	-	7
Square	0	18	-
Square	1	-	12
Square	2	-	8

Table 3: Effect of Lateritic Soil Layer Depth of Bearing Capacity

Lateritic Soil Depth (Relative to B)	Footing Type	Bearing Capacity (kPa) - Unreinforced	Bearing Capacity (kPa) - Reinforced
0.5B	Circular	90	135
B	Circular	80	120
1.5B	Circular	100	150
0.5B	Square	85	127
B	Square	75	112
1.5B	Square	95	140

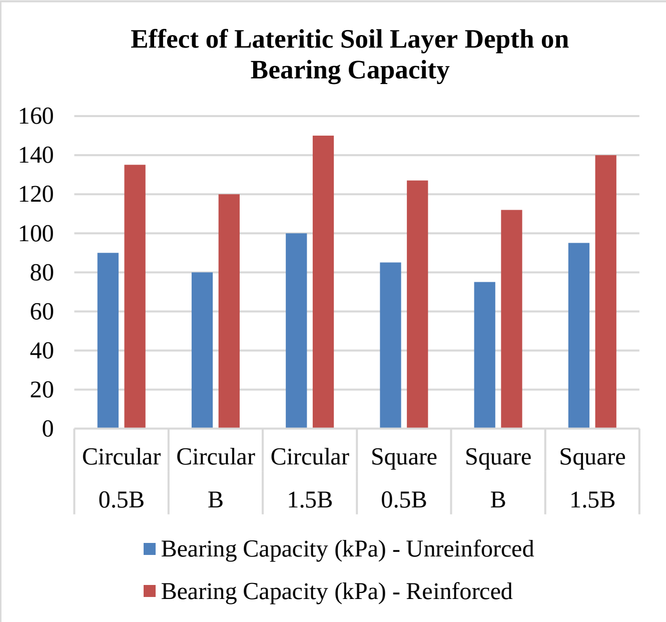

Fig. 3: Effect of Lateritic Soil Depth on Bearing Capacity

3. CONCLUSIONS

The experimental analysis highlights the significant role in enhancing the bearing capacity of footings on sand beds. The findings indicate:

1. Reinforced sand beds with geogrids perform effectively even in the presence of weaker lateritic soil layers.
2. Circular footings provide higher bearing capacity, whereas square footings excel in distributing loads.
3. Optimal reinforcement design can mitigate the adverse effects of lateritic soils, making the system suitable for diverse geotechnical applications.

Future work can focus on scaling these findings to prototype and field conditions, exploring the continuing performance of reinforced soil systems under cyclic and dynamic loading scenarios.

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