JSS Mahavidyapeetha

JSS SCIENCE AND TECHNOLOGY UNIVERSITY

SRI JAYCHAMRAJENDRA COLLEGE OF ENGINEERING

JSS Technical Institutions' Campus, Mysuru – 570006

"EXPERIMENTAL INVESTIGATION ON BEHAVIOUR OF CIRCULAR FOOTING RESTING ON SAND, REINFORCED WITH PLASTIC GEOCELL"

Thesis is submitted in partial fulfillment of curriculum prescribed for the award of the degree of

BACHELOR OF ENGINEERING
IN
CIVIL ENGINEERING

by

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DEPARTMENT OF CIVIL ENGINEERING
July 2023

JSS MAHAVIDYAPEETHA

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Date: 10-06-2023

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DECLARATION

We do hereby declare that the project titled **"EXPERIMENTAL INVESTIGATION ON BEHAVIOUR OF CIRCULAR FOOTING RESTING ON SAND, REINFORCED WITH PLASTIC GEOCELL"** is carried out by the project group, under the guidance of **Prof. Prasad Pujar,** Assistant Professor, Department of Civil Engineering, JSS Science and Technology University, Mysuru, in partial fulfilment of requirement for the award of Bachelor of Engineering by JSS Science and Technology University, Mysore, during the year 2022-2023.

We also declare that we have not submitted this dissertation to any other university for the award of any degree or diploma courses.

Date: 10-06-2023
Place: Mysore

JEEVITH KUMAR. J

ABSTRACT

This study presents an experimental investigation conducted to assess the behavior of circular footings supported by reinforced sand and reinforced with a practical geocell system. The geotechnical engineering community has shown a growing interest in the use of geocells as a reinforcement technique to improve the performance of shallow foundations. However, limited research has been conducted on the behavior of circular footings with geocell reinforcement in conjunction with sand.

The experimental program consisted of constructing a series of circular footing models on a rigid container filled with sand. The sand was reinforced with a practical geocell system, which involved the placement of interconnected geocells beneath the footing. Various geocell configurations and reinforcement densities were considered to investigate their influence on the footing's load-carrying capacity, settlement characteristics, and overall stability.

A comprehensive set of load tests was conducted on the model footings to measure the load-settlement response and failure behavior. The experimental results were compared with control footings without geocell reinforcement to evaluate the effectiveness of the geocell system in improving the footing's performance. The data obtained from the tests were also used to analyze the load distribution, stress transfer mechanisms, and deformation patterns within the reinforced sand.

This study contributes to the understanding of the behavior of circular footings supported by reinforced sand and provides insights into the effectiveness of geocell reinforcement in practical applications. The findings can aid geotechnical engineers in designing and optimizing the use of geocells to enhance the performance of shallow foundations, especially in sandy soils. Further research is recommended to investigate the long-term behavior and durability of the reinforced sand and geocell system under various loading conditions.

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INTRODUCTION

1.1 GENERAL

The value of excellence in building social infrastructure has long been highlighted in the profession of civil engineering. Due to improvements in science and technology, the building sector has seen substantial expansion in the twenty-first century. It has been discovered that strengthening the soil can improve its engineering properties. Retaining walls, embankments, foundations, slopes, highway and airport pavements, and railroad tracks are just a few of the places where soil reinforcement is used. A practical, adaptable, and repeatable method for ground improvement in shallow foundations is geosynthetic reinforcement, particularly fiber-reinforced soil. [1-5].

This study investigates the behavior of circular footings under vertical stresses in civil engineering projects such as transmission towers, storage tanks, and building foundations. By subjecting the circular footing to vertical loads, the research intends to recreate real-world settings and examine the circular footing's behavior under these circumstances. The goal of the study is to comprehend the load-bearing capacity, structural performance, and deformation traits of circular footings in real-world applications.

In the current work, recycled plastic bottles that have been processed and arranged to form geocells are used to strengthen the soil. These made-in-house geocells are utilized to strengthen sand. To understand how a circular footing responds to loads both with and without sand reinforcement, as well as the effects of combined loads on sand footings with various densities and reinforced spacing, experimental research was conducted.

The major objective of this work is to investigate the load-bearing capability and settlement behavior of a circular foundation reinforced with plastic geocells in a sand-based medium. The goal of the study is to learn more about how the recycled plastic debris used to build the geocell structure interacts with the soil. The results of this study can aid in a better comprehension of the interaction between the geocell reinforcement and the soil, opening the door to future applications in real-world circumstances. The study's ultimate goal is to investigate whether using plastic geocells to improve the performance of circular foundations in sandy soils is feasible and effective.

1.2 ABOUT GEOCELL REINFORCED SAND FOUNDATIONS

To increase the ability of poor soils to support loads, geotechnical engineers frequently use geocell-reinforced sand foundations. High-density polyethylene (HDPE) or materials similar to it are frequently used to create geocells, which are three-dimensional structures resembling honeycombs. They are frequently used to contain and stabilize granular materials like sand. Geocells increase the soil's overall strength and stiffness, enabling it to withstand greater loads by containing the granular material. Geocells have benefits including simple installation, low cost, and eco-friendly building materials. In conclusion, geocell reinforcement improves the performance of granular materials while confining and stabilizing weak soils.

The exact type of geocell utilized, among other things, has an impact on the load-carrying mechanisms of geocell-reinforced sand foundations. Geocell types can differ in terms of features including cell size, height, form, and junction layout. These changes have an effect on the geocell's stiffness, strength, and confinement, which in turn affects how the reinforced sand foundation carries and distributes stresses. It is essential to comprehend these variables since they affect how well the geocell will increase the foundation's load-bearing capability.

Through confinement, interlocking, and arching mechanisms, geocells increase the load-bearing capacity of sand foundations. Limitation reduces lateral deformation, increasing rigidity. Through mechanical engagement, interlock increases shear resistance. By creating arch-like structures, arching redistributes loads and encourages more even load distribution. These mechanisms work together to fortify the reinforced sand mass, enhancing overall performance.

Depending on the particular application and site circumstances, the impact of geocell type on load-carrying mechanisms can vary. The performance of the geocell is affected by variables such cell size, height, shape, and junction layout. Larger cell sizes and shorter heights encourage arching and load redistribution, whereas smaller cell sizes and taller heights often offer more confinement and interlock. The geocell's shape and junction design also have an impact on how stress and strain are distributed throughout the reinforced sand foundation. For choosing the best geocell for a given application and optimizing the design of geocell-reinforced sand foundations, it is essential to understand the impact of geocell type on load-carrying mechanisms. Numerous research has investigated the effectiveness of various geocell forms in various applications.

1.3 ABOUT CIRCULAR FOOTING ON REINFORCED SOIL

To improve the stability and load-bearing capacity of foundation soils, soil reinforcing techniques frequently use materials including geocells, geogrids, and geotextiles. In this work, circular footings were placed on both unreinforced and reinforced sand beds for laboratory experiments. The research examines the effects of several elements, including the number of reinforcement layers, the placement of the reinforcement layer inside the soil bed, and the distance between the layers when geosynthetic materials are employed as reinforcement. The study seeks to obtain insights into how geosynthetic reinforcement affects the performance of circular footings and to provide useful information for enhancing the design and efficacy of soil reinforcing techniques in foundation engineering.

The work focuses on analyzing the behavior of a circular footing on a reinforced sand bed, which is important for developing and improving geotechnical constructions for many engineering applications. The results of the research are anticipated to develop effective and long-lasting geotechnical solutions, ultimately increasing the security and dependability of civil infrastructure. Geotechnical engineering must fully comprehend how circular footings behave on reinforced soil. Reinforced soil delivers increased strength and stiffness by integrating geosynthetic materials like geotextiles, geogrids, or geocells. Reinforced soil is becoming more and more common because to its affordability, simplicity in construction, and environmental friendliness.

For this investigation, a footing and reinforced soil system laboratory model will be built. In order to simulate real-world situations, the model will be subjected to a variety of loading circumstances, including static and dynamic loads. Different measurement devices, including strain gauges, displacement transducers, and accelerometers, will be used to observe and document the behavior of the model. It is predicted that the study's findings would offer important guidance for the construction of reinforced soil structures such retaining walls, bridge abutments, and embankments. The results will also improve our knowledge of how reinforced soil and structures interact, assisting in the creation of long-lasting and affordable solutions to geotechnical engineering problems.

1.4 ABOUT BEARING CAPACITY AND SETTLEMENT OF CIRCULAR FOOTING

Bearing capacity and settlement are important factors to consider in the design of foundations for various structures such as buildings, bridges, and towers. In this experimental study, the behavior of a circular footing resting on a reinforced sand bed will be investigated with a focus on bearing capacity and settlement.

Due to its increased rigidity and strength, reinforced sand has become more common as a foundation material. This paper focuses on the usage of geotextiles and geogrids as reinforcement materials, which are frequently used in geotechnical engineering applications. The research entails building a lab model with a circular footing and a reinforced sand base. In order to simulate real-world situations, the model will be subjected to a variety of loading circumstances, including static and dynamic loads. A variety of measurement devices, including strain gauges, displacement transducers, and load cells, will be used to track and record the behavior of the model. These measurements will offer insightful information on the reinforced sand system's behavior, assisting in the comprehension and improvement of its functionality in real-world applications.

The purpose of this study is to investigate how reinforcement affects a circular footing's bearing capacity and settlement. To evaluate the efficiency of the reinforcement materials, results from a reinforced and unreinforced sand bed will be compared. Additionally, the study will look at how various elements, like footing diameter, embedment depth, and reinforcement spacing, affect the model's bearing capacity and settling. The results of this investigation will give an important new understanding of how circular footings behave on reinforced sand beds. They will improve the viability and cost-effectiveness of geotechnical engineering solutions and help create design recommendations for foundations on reinforced soils.

Chapter 2
LITERATURE REVIEW

2.1. LITERATURE REVIEW

Sankar Bose, et.al [2017][7] The purpose of this study is to investigate how reinforcement affects a circular footing's bearing capacity and settlement. To evaluate the efficiency of the reinforcement materials, results from a reinforced and unreinforced sand bed will be compared. Additionally, the study will look at how various elements, like footing diameter, embedment depth, and reinforcement spacing, affect the model's bearing capacity and settling.

The results of this investigation will give important new understanding of how circular footings behave on reinforced sand beds. They will improve the viability and cost-effectiveness of geotechnical engineering solutions and help create design recommendations for foundations on reinforced soils.

In the study, modeling analysis using the finite element technique (FEM) was done to simulate the behavior of the reinforced soil. By contrasting the FEM model's predictions with the experimental findings from the tests carried out on the reinforced soil, its validity was established.

M. Bala Maheswari and K. Ilamparidhi [2011][8] The study's main objective was to examine the behavior of a footing on a geogrid-reinforced soil bed. To assess the reinforced soil bed's performance under various loading scenarios, both experimental and computational modeling investigations were carried out. The experimental inquiry included the creation of soil samples with various geogrid reinforcement types, spacing between the geogrid layers, and the number of layers. These samples were subsequently put under various loading situations, and the outcomes were contrasted with those found in unreinforced soil samples. The test findings showed that adding geogrid reinforcement greatly boosted the soil bed's bearing capacity, decreased settlement, and improved overall performance.

D.M Dewaikar and et.al, [2009][1] The study concentrated on analyzing the behavior of a square footing on geogrid-reinforced soil. The primary goals were to assess the reinforced soil's bearing capacity, settling, and failure mechanism under various loading circumstances. In the experimental inquiry, soil samples were created with various geogrid spacing and layer counts. The samples were then put under various loading circumstances, and the outcomes were compared with soil samples that weren't reinforced. The test findings showed that adding geogrid reinforcement greatly boosted the soil's bearing capacity while lowering settlement, leading to an improvement in overall performance. The study also used the digital image correlation (DIC) method to examine how the reinforced soil fails. The distribution of strain in the soil was found.

Mr. Kiran and Prof. Nagraj Bacha [2015][2] In this study, the behavior of circular and square footings on a reinforced sand bed stratified with lateritic soil was examined. The main goals were to assess the reinforced soil's bearing capacity, settling, and failure mechanism under various loading scenarios. The experimental investigation required the fabrication of soil samples with various lateritic soil contents, geogrid spacings, and layer counts. These samples were subsequently put under various loading situations, and the outcomes were contrasted with those found in unreinforced soil samples. The test findings showed that adding geogrid reinforcement greatly boosted the soil's bearing capacity while lowering settlement. Using the digital image correlation (DIC) method to examine the reinforced soil failure mechanism.

Sujith Kumar Dash [2012][9] presented Geocell reinforced foundation beds are a type of geosynthetic reinforcement system used to enhance the load-bearing capacity of soils for various engineering applications, such as roadways, railways, and embankments. Past findings suggest that geocell reinforced foundation beds have proven to be an effective and efficient solution for improving the strength and stability of weak soils, reducing the amount of excavation needed, and increasing the overall lifespan of the foundation. This has led to an increase in their usage in various construction projects worldwide. Present trends indicate that there is a growing demand for geocell reinforced foundation beds in infrastructure development due to their versatility, cost-effectiveness, and environmental sustainability. Prospects for geocell reinforced foundation beds are promising, as they offer a reliable and efficient solution for infrastructure development while reducing environmental impacts. The industry is expected to see increased usage in transportation and infrastructure projects, and further developments in material science and design are likely to lead to even more efficient and effective solutions.

A. Hegde [2017][4] investigated that the effectiveness of various geocell designs in improving the bearing capacity of sandy soils was assessed in a study looking at the impact of geocell type on load-carrying mechanisms of geocell-reinforced sand foundations. The study showed that the load-carrying capabilities of geocell-reinforced sand foundations are strongly influenced by the choice of geocell type. The behavior of the reinforced soil system is greatly influenced by variables like the depth and width of the geocell and the type of connection between cells. The findings showed that hexagonal geocells with a wide width-to-height aspect ratio have the maximum bearing capacity and deformation resistance. Additionally, deeper geocells were shown to improve the confinement effect and the soil's ability to support more weight. These findings offer insightful information.

Bandita Paikaray and et.al, [2021][3] In order to increase a model footing's bearing capacity on a reinforced foundation, the study looked at the efficiency of crusher dust as a reinforcement material. A model reinforced foundation and footing were built in a lab environment and put under a variety of loading circumstances to simulate real-world situations. Strain gauges, displacement transducers, and load cells were used to keep an eye on how the model behaved. The study's findings showed how the use of crusher dust as a reinforcement material significantly increased the foundation's bearing capacity. It was noted that the bearing capacity continued to grow as the reinforced layer's thickness rose and the distance between layers of reinforcement shrank. These results offer insightful suggestions for improving the design. The study also found that the use of geotextiles as reinforcement material was more effective than the use of geogrids.

Murad Abu-Farsakh, et.al, [2013][10] Laboratory experiments on sand samples reinforced with geosynthetics were carried out in an experimental evaluation of footings on the sand. The goal was to look at how geosynthetics affected footing settlement and load-bearing capacity. The results of numerous studies in this area show that the use of geosynthetics as reinforcement can greatly increase the load-bearing capacity and decrease settling in footings on sand. Additionally, the reinforcement increases the soil's stiffness and strengthens its drainage capabilities, lowering the hazards of soil instability and liquefaction. The efficiency of the various geosynthetics used in these experiments, including geotextiles, geogrids, and geocells, vary depending on the soil type, footing size and shape, and reinforcing arrangement.

Ahmed and et.al [2019][6] investigated through numerous laboratory tests, the behavior of circular footings on laterally constrained granular reinforced soil has been extensively researched. This research aimed to investigate the effects of lateral confinement and geosynthetic reinforcement on the load-bearing capacity and settlement characteristics of the footings.
The results repeatedly show that lateral confinement and geosynthetic reinforcement significantly increase the load-bearing capacity and decrease settlement in circular footings on granular reinforced soil. While the reinforcement lessens soil deformation and increases shear strength, confinement increases the soil's stiffness, enhancing the soil's capacity to support weight. In these investigations, geosynthetics like geotextiles, geogrids, and geocells have been employed; their success depends on variables like soil type, confining material, and reinforcing arrangement.

S.N. Moghadds Tafreshi and et.al [2019][5] investigated Numerous geocell or planar geotextile reinforcing layers have been utilized in studies to examine the performance of circular footings on sand. The impact of reinforcing configuration, layer count, and depth of embedment on the load-bearing capacity and settlement characteristics of the footings was investigated through laboratory tests.
The outcomes repeatedly show that the addition of several geocell or planar geotextile reinforcing layers considerably increases the load-bearing capacity and decreases settlement of circular footings on sand. The reinforcement lessens settlement and improves the deformation properties of the footings while enhancing the soil's stiffness and bearing capacity.

2.2. SUMMARY OF LITERATURES

- According to the study, adding geogrid reinforcement significantly improves the soil bed's performance under various loading scenarios. By supplying tensile strength and lowering plastic deformation, the reinforcement improves the behavior of the soil. The geogrid's tensile failure and the soil's plastic deformation were predominantly blamed for the failure mechanism seen in the reinforced soil bed. These discoveries have significance for reinforced soil structure design in a variety of engineering applications. They provide useful information on how to employ geogrid reinforcement to improve the functionality and stability of soil beds.

- The study shows that adding geogrid reinforcement significantly enhances soil performance under various loading circumstances. These findings have significance for the design of reinforced soil structures in a variety of engineering applications, including retaining walls, bridge abutments, and embankments. The study's findings provide important information about using geogrid reinforcement to increase the stability and load-bearing capacity of soil structures, resulting in more effective and dependable engineering designs.

- The study shows that adding geogrid reinforcement can greatly improve soil performance under various loading circumstances. Interestingly, the research results show that the footing's shape—whether circular or square—has little consequence on the bearing capacity and settlement characteristics of the reinforced soil. These findings have significance for the design of reinforced soil structures in a range of engineering applications, such as retaining walls, bridge abutments, and embankments. The study's findings provide important information about how to use geogrid reinforcement to enhance the stability and load-bearing capability of soil structures.

- In a variety of engineering applications, geocell reinforced foundation beds have shown promise for enhancing the soils' ability to support load. They are still being used and developed, as evidenced by their previous success, present tendencies, and prospective future. In order to improve the performance and stability of foundation beds, geocell reinforcement has proven to be useful. As geocell technology develops and offers novel solutions to satisfy the rising demands of diverse engineering projects, this trend is anticipated to continue.

- For geocell-reinforced sand foundations to perform better, choosing the appropriate geocell design is essential. The study's conclusions offer insightful information that may be used to enhance the creation and installation of geocell-reinforced foundation systems. For a variety of engineering applications, such as roads, trains, and embankments, this optimization produces affordable and effective solutions. Engineers can improve the stability, load-bearing capability, and long-term performance of geocell-reinforced sand foundations by using the study's findings to drive geocell design decisions.

- The study demonstrated how using crusher dust as a reinforcement material might increase the bearing capacity of foundations. These results show promise for the creation of long-lasting and affordable solutions to geotechnical engineering problems. Engineers may be able to increase the stability and load-bearing capacity of foundations in an efficient and environmentally responsible way by using crusher dust as a reinforcement material. The study's findings offer insightful information for improving geotechnical engineering procedures and developing more effective and sustainable solutions.

- According to the investigations, improving the performance of circular footings on sand may be accomplished by using multiple geocell or planar geotextile reinforcing layers. In places with difficult soil conditions or strong seismic activity, this strategy is especially advantageous. The load-bearing capacity and stability of circular footings on sand can be greatly increased by integrating several reinforcing layers. In order to ensure the long-term performance and dependability of circular footings in such places, this approach provides a sustainable alternative for addressing the issues caused by unfavorable soil conditions or seismic events.

Chapter 3
AIM AND SCOPE OF INVESTIGATION

3.1. AIM OF PRESENT INVESTIGATION

The purpose of the experimental inquiry is to determine how using a plastic geocell as a reinforcement material affects the bearing capacity and settlement characteristics of circular footings on sand. The purpose of the study is to comprehend how the installation of a plastic geocell affects the load-bearing capability and settling behavior of the footings. By carrying out the trials, the researchers hope to learn important lessons about the efficacy of employing a plastic geocell as a reinforcing material for enhancing the behavior and performance of circular footings on sand.

The HDPE-based plastic geocell acts as a honeycomb-like structure to increase the soil's ability to support loads. The geocell layer provides lateral confinement to the surrounding sand when it is positioned beneath a circular footing, increasing the footing's bearing capacity and reducing settlement. By effectively restricting the soil and more evenly dispersing the applied load, the use of a plastic geocell as a reinforcement material has the potential to enhance the overall performance and stability of circular footings.

The experimental research focuses on determining the ideal geocell depth and spacing to maximize gains in bearing capacity and settlement of circular footings. The experimental data gathered can be a useful tool for testing numerical models that can precisely forecast the behavior of circular footings on reinforced sand. For engineers and designers working on the foundation designs for structures built on soil, these discoveries are important. The findings offer useful information that may be used to improve the planning and building of foundations, thereby raising their effectiveness and maintaining the security and stability of the structures they support.

3.2. SCOPE OF THE PROJECT

When planning footings, the crucial factor is soil bearing capacity. There needs to be some kind of protection for the soil from the weight of any superstructures that are placed there. Some parts of India have inadequate bearing capacity and cannot support the weight of the superstructure. Thanks to advances in soil reinforcing techniques, civil engineers can now use in-situ soils as a viable building material for a variety of projects.

The market is stocked with a variety of reinforcing materials like geogrid, geocell, confinement, etc., that can be utilized to provide reinforcement for the area beneath the footing. This market-available substance is extremely expensive. To cut down on construction costs, different materials are available for reinforcing structures. Lot of experimental work done to determine the footing behavior resting on geosynthetic reinforced beds from various researchers found that local available waste material can be utilized in reinforcing the soil.

The increasing use of plastic goods has led to contemporary issues with waste management. These waste items can be used to enhance the geotechnical qualities of the soil and avoid disposal issues. Recycled plastic bottles are being used to enhance the soil's bearing capacity. A series of model tests is to be conducted on the ground, using empty bottles for support. With plastic bottles as reinforcement, experiments will be conducted using sand of varying densities, reinforcement, reinforcement layers number and lastly the distance between the bases of footing to first reinforcement layer.

The primary goal of this research is to examine the load bearing capability and settling of a circular foundation which is reinforced by plastic geocells in sand base. Sand is the primary medium used in the experimental study. Recycled plastic bottles are used in creating miniature geocells and are placed within sand to strengthen them.

Chapter 4

MATERIALS TESTING AND METHODOLOGY

The primary objective of this investigation is to analyze the load-carrying capacity and settlement of circular footings placed on a reinforced sand bed. The research utilizes sand as the fundamental material, with model plastic bottles employed for soil and sand reinforcement. A static loading machine, operated electrically, applies concentrated loads on the mild steel footing, which is then distributed onto the sand bed. The experimental study encompasses the materials used for the model foundation system, the testing procedure, and the details of the testing program.

4.1 MATERIALS

Following are the materials used for model plate load test,

4.1.1 M Sand

Manufactured sand (M-Sand) serves as a substitute for river sand in construction projects. It is produced by crushing hard granite stone, resulting in cubical-shaped sand particles with smooth edges. The sand is washed and graded to meet construction material standards, with a particle size less than 4.75mm.

Following are the preliminary tests conducted on the sand:

4.1.1.1 Sieve Analysis Test

To establish the sand sample's particle size distribution for this investigation, a sieve analysis was done. Several spun brass sieves with varying-sized circular apertures that were measured in millimeters or microns were used for the analysis. The chosen sieves, with sizes ranging from 4.75 mm to 75 microns, were set up in descending order, with the sieve with the greatest aperture at the top. The top sieve was covered with a lid, and the tiniest sieve was set in a pan to catch the tiny particles.

The sand utilized in this investigation had a poorly graded particle size distribution, as shown by the sieve analysis results shown in Table 1, it was concluded. The test was conducted in accordance with the instructions in IS: 2720 (Part 4) – 1983.

Fig 4.1: Sieve Analysis

Table 4.1: Results of Sieve Analysis

Test Conducted	Characteristics	Values obtained
Sieve Analysis	D10	0.09mm
	D30	0.23mm
	D60	1.2mm
	Coefficient of uniformity (Cc)	0.49
	Coefficient of Curvature (Cu)	13.33
	IS Classification	Poorly graded sand

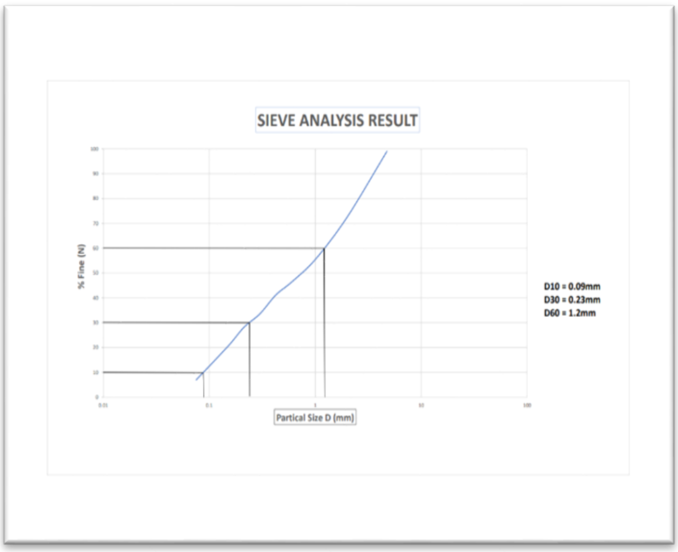

Fig 4.2: Gradation curve for Sieve Analysis

4.1.1.2 Specific gravity test

Procedure: [Specific gravity of sand - IS: 2386-Part 3 (1963)]

1. Take an empty pycnometer and weigh it (w1) in grams.
2. Collect a sample of fine aggregate for specific gravity determination and transfer it to the pycnometer. Weigh the pycnometer with the sample (w2) in grams.
3. Add distilled water to the pycnometer.
4. Remove any trapped air by rotating the pycnometer.
5. Wipe the outer surface of the pycnometer and weigh it (w3) in grams.
6. Empty the pycnometer into a tray, ensuring that all the aggregate is transferred.
7. Refill the pycnometer with distilled water up to the mark, ensuring it is completely dry on the outside. Weigh the pycnometer (w4) in grams.

Fig. 4.3: Apparatus used to find specific gravity of fine aggregate (Pycnometer).

RESULT:

The Specific Gravity of a given M Sand is = 2.52

4.1.1.3 Relative Density

A cohesionless soil, particularly sandy deposits, can be measured by its relative density to determine how compact or dense it is. It is calculated by dividing the ratio of the soil's void ratios between its loosest condition and its natural state and between its loosest and densest states. An arbitrary property called relative density suggests that sandy soil may become denser than it already is. It quantifies the actual reduction in void volume in comparison to the maximum feasible reduction, expressing the extent to which the sand can experience more compaction.

4.1.2 Reinforcement

The type of reinforcement used in our project is waste plastic bottles bought from recycling unit in Mysore. The capacity of the bottle is 1 litre, and it has a diameter of 75mm. These bottles were cut and joined using hot glue to form cellular structure as reinforcement which is shown in Fig: 4.4.

Fig4.4: Model of Reinforcement

4.1.3 Test on waste plastic bottles using UTM

The waste plastic used in our project is Polyethylene terephthalate (PET) bottles brought from a recycling unit in Mysore. The bottles are cut into a specific shape and tested in Polymer science department JSSSTU Mysore using UTM (Universal Testing Machine).

Result: Tensile strength of PET bottles is 170N

Fig 4.5: Plastic Samples

Fig 4.6: Universal Testing Machine

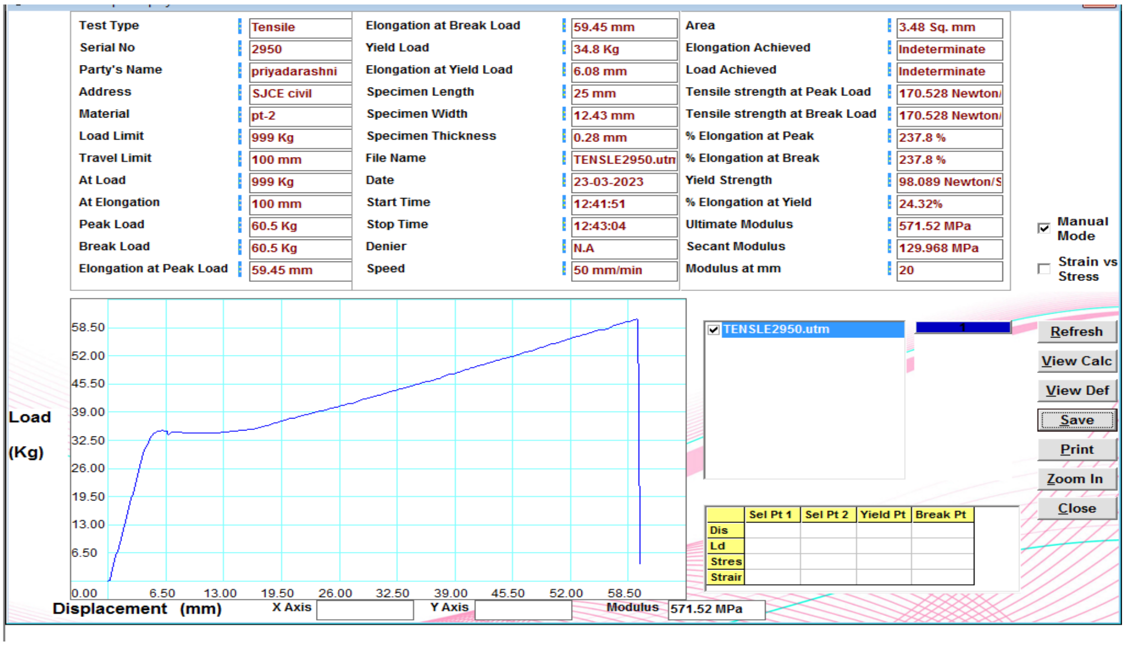

Fig4.7 Result of given PET Bottles

4.1.4 Test Tank

The size of tank is decided based on IS code and from the results of some literatures IS 1888-1982 says that minimum size of the tank should be 3 to 5 times the width of test plate to develop the full failure zone without any interference of side. Keeping the above criteria in mind, 600mm length, 600mm width and 600mm height size of test tank has been used for 150mm diameter footing model. The tank is made up of wooden box 10mm thick as shown in Fig 4.8.

Fig 4.8: Wooden Box

4.1.5 Funnel

This approach involves pouring sand into a tank while using a funnel to apply the raining technique to achieve consistent density. Through the use of a funnel, the sand is poured into the tank, preserving the tank's uniform density throughout its depth. The maximum and minimum densities of the sand can be calculated by pouring it from a variety of heights and comparing the resulting densities. In order to reach the desired density, this enables the pouring height to be adjusted. A PVC pipe that is fixed to the bottom of the funnel as shown in Fig 4.9 that allows for continuous pouring height. With this method, the sand density in the tank is distributed in a predictable and even manner. as shown in Fig 4.9.

Fig 4.9: Funnel

4.1.6 Footing Model

The model footing used in our project is circular of having diameter 15 cm and thickness 5mm which is made up of mild steel as shown in Fig 4.10.

Fig 4.10: Circular Footing Model

4.1.7 Screw Jack

In the experiment, a 5-ton capacity screw jack is used to apply vertical loading to the footing. In order to create exact and regulated loading conditions, the applied load on the footing is generated and controlled by the screw jack. With this set up, the footing will receive the desired vertical load during the experimental testing which is shown in Fig: 4.11.

Fig 4.11: Screw Jack

4.1.8 Bearing Ball

A ball is used in the experimental setup as a load transfer device between the loading frame and the foundation placed on the sand substrate. The footing can change its location during failure thanks to the ball's function as a hinge. Additionally, it aids in lining up the footing face with the sand surface at the point of failure. This system makes sure that the load is delivered smoothly and precisely from the loading frame to the footing, enabling precise measurement and observation of the footing's behavior and failure mechanism as shown in Fig 4.12.

Fig 4.12: Bearing Ball

4.1.9 Proving Ring

A proving ring with a 10kN load capacity is utilized in the experimental setup to measure the imposed load on the foundation. The proving ring's upper section is attached to the setup's metal frame, and its lower portion makes contact with a hard metal ball that is laid on the footing. This metal ball serves as a hinge, enabling the transfer of weight from the proving ring to the footing hinge. This configuration makes sure that the applied load is measured accurately and makes it easier to watch how the footing responds and behaves during the experimental testing.

Fig 4.13: Proving Ring

4.1.10 Dial Gauge

In the experimental setting, load is measured with a load cell, and settlements are measured with a dial gauge as shown in Fig 4.14. Dial Gauge is capable of measuring 0.02mm.

Fig 4.14: Dial Gauge

4.1.11 Loading Frame

Two vertical steel L-section channels with dimensions of 5 cm wide and 5 mm thick make up the loading frame in the experimental setup. These channels are 1.2 meters apart and rise 1.82 meters above the ground. The usage of a horizontal C-section steel channel with dimensions of 10 cm in width and 5 mm in thickness is also included. At the center of the horizontal channel, the manually controlled screw jack is fastened in an upside-down position. During the experiment, this design enables controlled vertical loading on the footing.

4.2 METHODOLOGY

4.2.1 Sand Raining Technique

In our project tests are carried out for different density of sand. This can be achieved using sand raining technique by varying height of fall of sand. Here the sand is poured using funnel for a certain height as shown in Fig 4.9. So that various density can get which is given in **Table 4.2**.

Fig 4.15: Density and the associated heights of falls

Table 4.2: Density and the associated heights of fall in the sand raining technique.

Height of fall (cm)	Density(kN/m^3)
25	16.84
35	16.95
45	17.05

4.2.2 Experimental Setup and procedure

Small-scale model experiments are conducted as part of the experimental program covered in this study. The report offers information on the experimental test program, including the materials used, the test technique, and an analysis of the test results gleaned from model studies. are presented below, Fig 4.16 shows the line diagram of experimental setup.

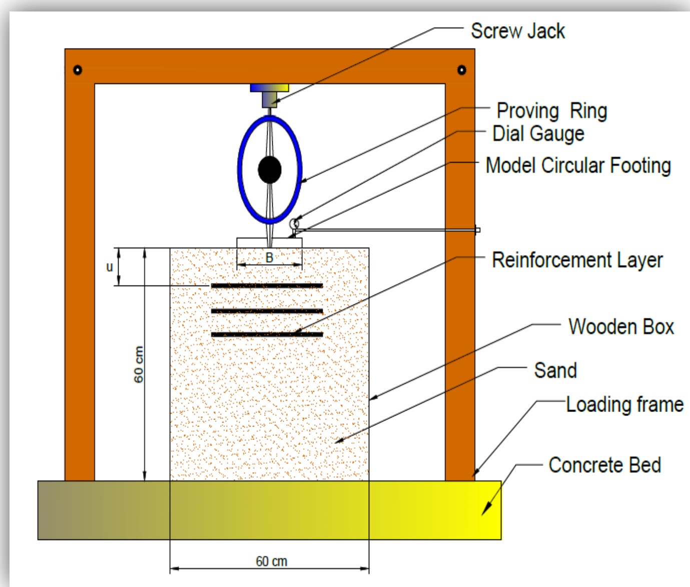

Fig 4.16: Line Diagram of Experimental Setup

4.2.2.1 Placement of sand

Experimental setup consists of wooden box which is placed over concrete bed. Sand is poured into the tank using the sand raining method.. Sand is poured into the box using funnel for certain height of fall to achieve required density. Here the height of fall is maintained constant by fixing PVC pipe to bottom of funnel.

4.2.2.2 Reinforcement placing

In our project plastic bottles are used as reinforcement. Cellular structure of reinforcement is placed horizontal in the wooden at certain level with different number of layers as shown in Fig: 4.4 placing of reinforcement is done by varying u/B ratio where u is the distance between the bottom surface of footing to the top surface of first reinforcement and B is the diameter of the circular footing. Here B is kept constant throughout and u is varied for 5cm, 8cm and 10cm. For different u/B ratio number of reinforcement layer will be changed. We have taken three numbers of layers.

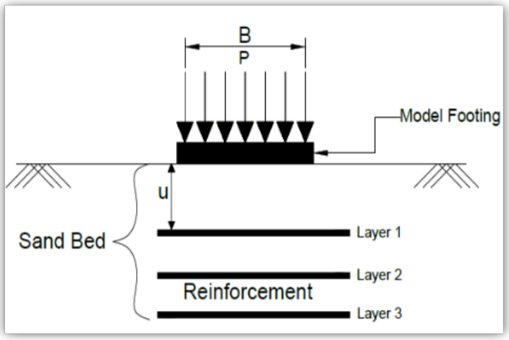

Fig 4.17: Layout and arrangement of reinforcement layers.

4.2.2.3 Equipment Setup

The sand bed, whether reinforced or not, is ready in the experimental setting. The circular footing is then positioned in the middle of the sand bed. The screw jack, which is installed at the top of the frame, is connected to a proving ring with the necessary capacity. To make sure that the loading is applied vertically, the proving ring is brought into contact with the footing. A dial gauge is positioned at a corner of the circular footing to measure the displacement or settlement of the footing. The Dial Gauge can measure up to 0.02mm.

4.2.2.4 Model test procedure

Initially sand is filled to wooden box for required density and reinforcement is provided for certain u/D ratio. Load is applied uniformly using screw jack and intensity of load is noted from proving ring and simultaneously settlement is noted down from Dial Gauge. This will be continued till the ultimate load which can withstand by sand bed. Finally, Graph is plotted as load (kN) vs settlement (mm) and results are compared between reinforced and unreinforced sand.

Fig 4.18: Experimental Setup

Fig 4.19: During Conduction of Experiment

Chapter 5
RESULTS AND DISCUSSIONS

5.1 RESULTS

The experimental work comprised comparing unreinforced and reinforced soil conditions with various layers of geogrid in order to ascertain the maximum bearing capacity of circular footings on sand. The outcomes include load-settlement curves derived from experimental testing performed on centrically loaded circular footings under both reinforced and unreinforced circumstances. These curves shed light on the footings' settlement characteristics and load-bearing behavior in the various tested soil conditions are shown in Fig 5.1, 5.2 and 5.3.

Comparing the settlement curves of unreinforced and reinforced sand for circular footings reveals that soil reinforcing significantly lowers the settling of foundations. This indicates that, even with the same sand density, it is possible to obtain the same permissible bearing capacity by applying soil reinforcement while experiencing far less settling. Geogrid layers, which help to limit lateral deformations and inhibit the spreading of sand particles through the reinforcement mechanism, are responsible for the decrease in settlement. This research emphasizes the efficiency of soil reinforcement in reducing settlement concerns and guaranteeing the stability of structures, particularly in circumstances when settlement sensitivity is a concern.

Figures 5.1, 5.2, and 5.3 illustrate maximum bearing capability for circular footings in relation to the increasing number of layers of reinforcement. The results demonstrate an enhancement in both bearing capacity and a settlement reduction. The bearing capacity exhibits improvement across all levels of settlement.

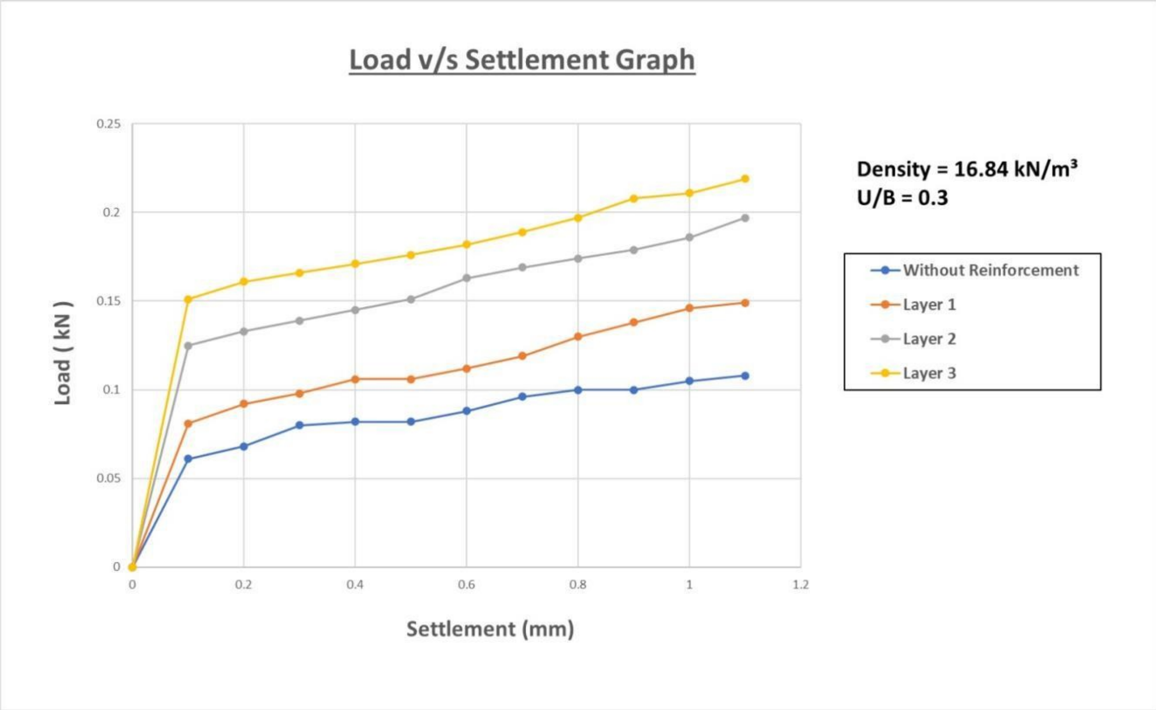

Fig 5.1 Load vs. settlement analysis for reinforced and unreinforced sand for circular footing at a height of 25 cm

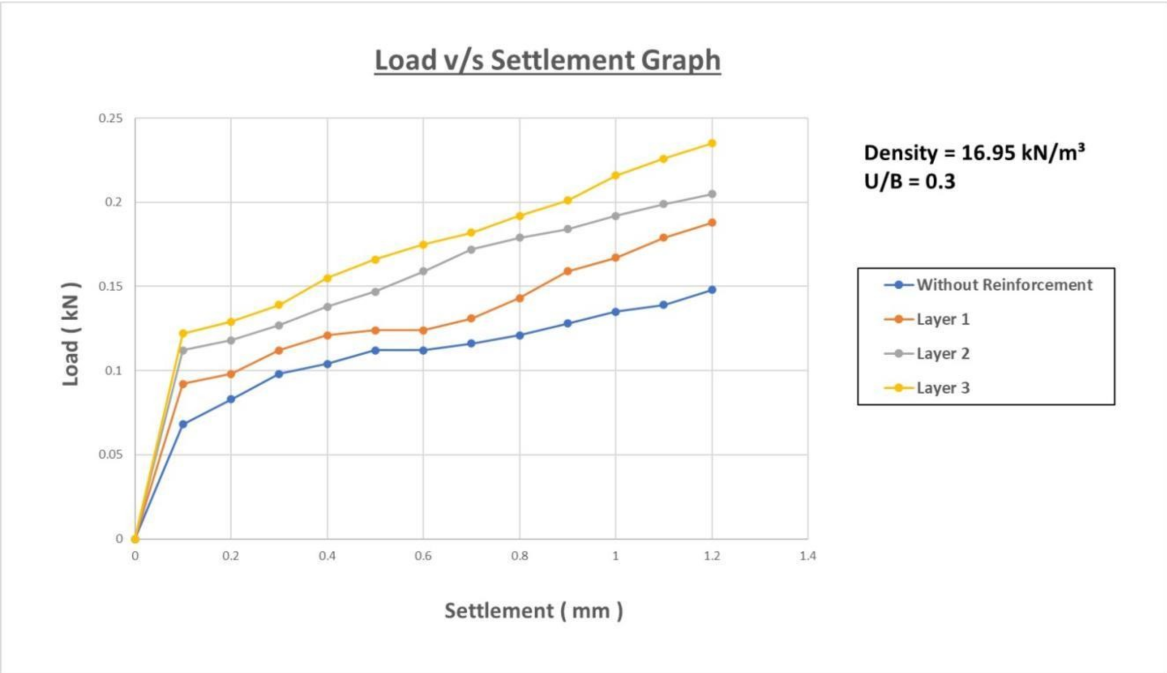

Fig 5.2 Load vs. settlement analysis for reinforced and unreinforced sand for circular footing at a height of 35cm

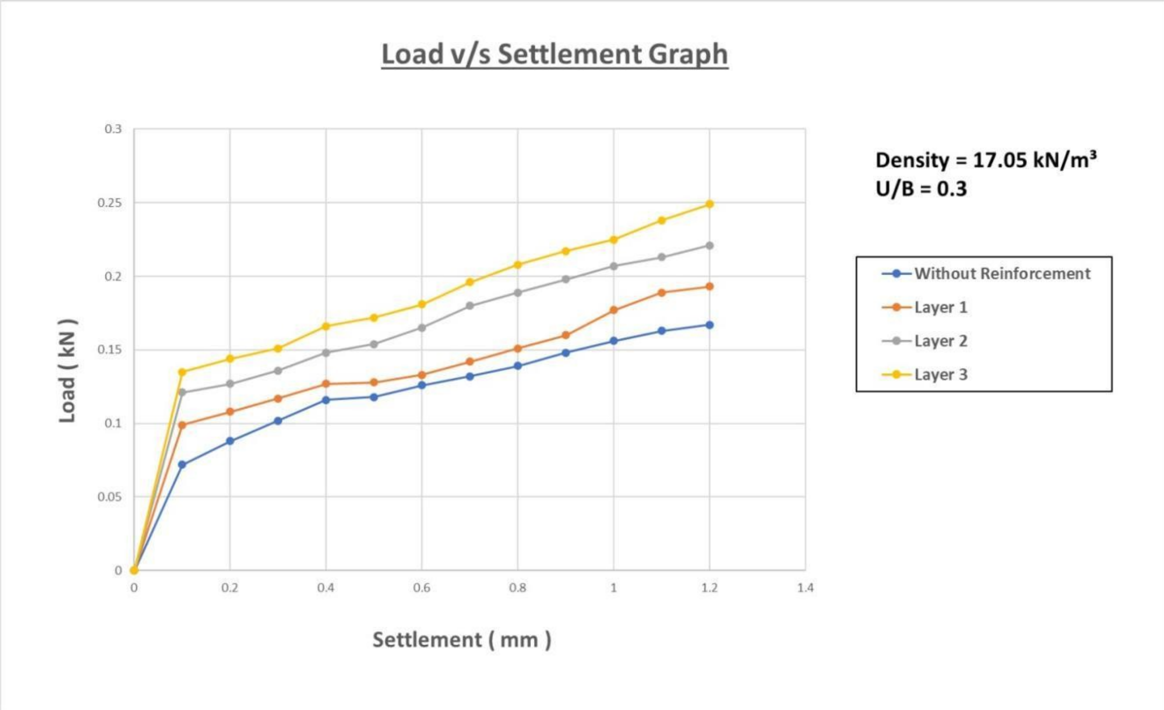

Fig 5.3 Load vs. settlement analysis for reinforced and unreinforced sand for circular footing at a height of 45cm

Table 5.1 Ultimate loads for different density

U/B Ratio	Density (kN/m³)	No. Of layers	Ultimate Load (kN)
0.3	16.84	Unreinforced	0.108
		1	0.149
		2	0.197
		3	0.219
	16.95	Unreinforced	0.137
		1	0.188
		2	0.205
		3	0.235
	17.05	Unreinforced	0.167
		1	0.193
		2	0.221
		3	0.249

5.2 CONCLUSION

The purpose of the study was to evaluate the advantages of employing geocell reinforcement to increase soil carrying capacity. It looked at a number of variables that could affect how well geocell reinforcement performed and included thorough explanations of how they affected performance. The deformation measurements that were taken while loads were being applied provided insight into the workings of the geocell reinforcement. In conclusion, the study gave important insights into the behavior and efficacy of geocell reinforcement in raising soil performance.

Following conclusions that can be drawn from the result of the model studies,

- The soil's bearing capacity is increased and settling is reduced when geocell is used as reinforcement.
- The diameter and height of the plastic geocell in relation to the footing diameter affect the load settling behavior.
- Moving the footing loads to a deeper level by raising the plastic geocell height also enhances soil behavior.
- In comparison to an unreinforced condition, the reinforced condition has a higher soil carrying capacity for circular footing.
- As more layers of reinforcement are added, the bearing capacity rises.

The experimental study showed that plastic geocells provide a durable and affordable alternative for soil reinforcement. Environmentally friendly, these geocells are light weight and simple to install. In place of more labor- and money-intensive conventional soil enhancement methods like deep soil mixing or stone columns, they offer an alternative. All things considered, using plastic geocells to strengthen soil is a practical and environmentally friendly method.

The experimental study of circular footings on sand reinforced with plastic geocells produced favorable results in terms of boosting load-bearing capacity, lowering settlement, increasing stability, and providing a long-term solution for soil reinforcement. This study expands on the body of knowledge in geotechnical engineering and provides a framework for further investigation and application of this soil stabilization technology in real-world settings.

Chapter 6
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