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A Sustainable Approach of Ground Improvement Technique using Geogrid Encased Stone Column Filled with Coconut Shell Chips - An Experimental Study

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Abstract— ***Stone columns are frequently used as a method of reinforcing soft ground as they provide increased bearing capacity and reduce foundation settlements. This paper represents an overview of sustainability approaches followed by their performance in relation to bearing capacity is well documented, but there is also a need for enhanced understanding of their settlement characteristics, particularly in relation to small-group configurations. Improving the soil strength for more durability of the building is necessary. Nowadays this technique of stone filled column is very much in need and useful as the soil profile will be enhanced with introducing the granular pile. In this work we aim in increasing the bearing strength of clayey soil by introducing the geogrid encased stone column filled with stone, M-sand, and coconut shell. This study aims towards sustainable development. Also, in this paper the response of the stone filled column towards the settlement of soil is analyses by an experimental study. For a detailed comparative study, we have observed the performance of stone column in two different cases with the clay medium and the same is presented in the paper.***

Keywords— ***Geogrid, granular pile, coconut chips, sand, settlement and bearing strength of soil.***

I. INTRODUCTION

The ever-growing demands of urbanization and industrialization have necessitated the development of innovative and sustainable solutions for ground improvement in civil engineering. Ground improvement techniques play a pivotal role in enhancing the bearing capacity and settlement characteristics of weak or compressible soils, ensuring the stability and longevity of various structures. As the global community continues to embrace environmentally conscious practices, there is a pressing need to explore alternative materials and methodologies that not only address engineering challenges but also align with sustainable development goals.

This research endeavors to introduce a ground-breaking approach to ground improvement by synergistically combining geogrid-encased stone columns with an unconventional filling material—coconut shell chips. Traditional ground improvement methods often involve the use of non-biodegradable materials, contributing to environmental concerns and sustainability challenges. In response to these issues, our study seeks to explore the viability of coconut shell chips as an eco-friendly alternative within the context of geotechnical engineering.

The geogrid encased stone column technique has gained prominence for its effectiveness in reinforcing weak reducing settlement and increasing bearing capacity. This

method involves the installation of vertical columns filled with coarse granular materials, typically crushed stones, to

create a composite structure that improves soil mechanical properties. In our experimental study, we introduce a novel dimension by replacing conventional fill materials with coconut shell chips—an organic, renewable resource.

Coconut shell chips, derived from agricultural waste, offer several distinct advantages. First and foremost, their use promotes sustainability by recycling a by-product that would otherwise be discarded, thus reducing environmental impact. Furthermore, coconut shells possess inherent lightweight properties, contributing to the overall reduction of structural loadings. The irregular shape and interlocking nature of the chips also provide potential benefits in terms of increased shear strength and improved drainage characteristics, which are crucial considerations in ground improvement projects.

To evaluate the performance of this sustainable ground improvement technique, a comprehensive experimental study has been designed and executed. The investigation encompasses laboratory-scale tests, including geotechnical characterization of coconut shell chips, triaxial shear tests, and full-scale physical modelling of geogrid encased stone columns. Through this research, we aim to contribute not only to the advancement of geotechnical engineering but also to the broader discourse on sustainable infrastructure development.

As we delve into the experimental findings and analysis in subsequent sections, the outcomes of this study are anticipated to offer valuable insights into the feasibility and

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efficacy of geogrid encased stone columns filled with coconut shell chips as a sustainable ground improvement technique. This research represents a stride towards harmonizing engineering solutions with ecological considerations, fostering a holistic approach to infrastructure development in the pursuit of a greener and more sustainable future.

II. MATERIALS

A. Stone (Coarse Aggregate)

Coarse aggregates are irregular broken stone or naturally occurring rounded gravel used for making concrete. Materials which are large to be retained on 4.7 mm sieve size are called coarse aggregates, and its maximum size can be up to 63 mm. The size of the aggregate used in this work is 20mm and below.

Specific gravity	2.56
Bulk density	Loose state = 1.3kg/m^3 Compact state = 1.5kg/m^3
Crushing strength	28.9%
Impact value	13.16%

B. M-Sand (Fine Aggregate)

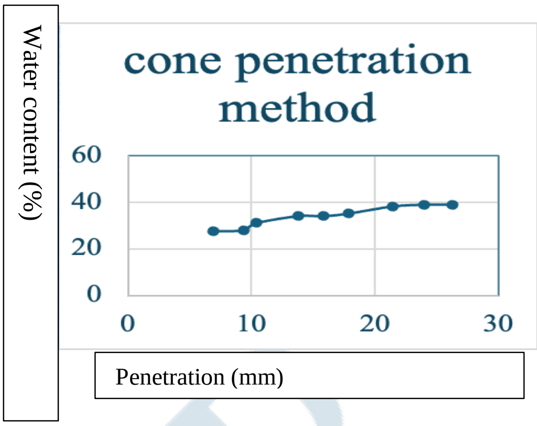
M Sand is nothing, but artificial sand made from crushing of rock or granite for construction purposes in cement or concrete. M sand differs from natural river sand in its physical and mineralogical properties. The main use of M sand in this project is to clear the voids and attain more strength.

Specific gravity	2.21
Moisture content	13.63%

C. Soil (Fine Aggregate)

Choosing the proper soil for your building projects is essential because it significantly affects how well your project turns out. Some types of soils are ideal for construction, while others aren't as good. To avoid having a construction with a weak foundation, you must be careful when planning your foundation. Generally stone columns are constructed in a place where there is black cotton soil available, but we have experimented in the normal soil which passes through IS sieve of 4.75mm and below.

Plastic limit	17.88%
Liquid limit	35%



Graph 1 : liquid limit by cone penetration method

D. Geogrid

Geogrids can be categorized as geosynthetic materials that are used in the construction industry in the form of a reinforcing material. The high demand and application of Geogrids in construction are since it is good in tension and has a higher ability to distribute load across a large area. The polymeric materials like polyester, high-density polyethylene and polypropylene are the main composition of geogrids. These grids are formed by material ribs that are intersected by their manufacture in two directions.

The geogrid we have used is **Biaxial BX geogrids.**

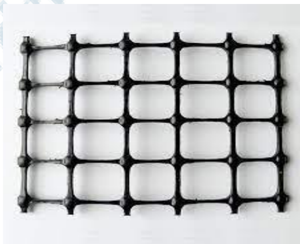


Fig 1 : geogrid

E. Coconut Shell

The main aim of using coconut shell in this project is to avoid the friction between the stone and sand as both are cohesive in nature. The coconut shell is environmentally friendly and mainly these can be reused and are natural resource. The chemical composition of the coconut shell is like wood. It contains33.61% cellulose, 36.51% lignin, 29.27% and ash at 0.61%. This will receive the dual advantage of reduction in the monetary value of construction material and as a means of disposal of wastes. Coconut shell particles are used as reinforcing material for investigation. Shell particles of size between 20 mm . coconut shells were collected locally. Coconut shells give more compressive strength and excellent bond strength with concrete. Since it is economical, durable, eco-friendly, thermal resistivity, flexibility, cost effective it can be a very good option as a filler material.

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III. METHODOLOGY

If As a part of model making, all the materials are collected as per the mix design. The height of the stone column is 23cm and the diameter is 10 cm. The tank dimensions are height is 28cm and diameter is 30cm and is made up of MS steel. The ratio considered is 1:2:3 , where 1 part of coconut shell, 2 part of m sand and 3 parts of stone are weighed and taken.

Total volume of column :

V = πr^2h=π * 5^2 * 23

= 1806.42 cm^3

1 part of coconut shell = 1806.42 * 1/6 = 301.07 g

2 part of m sand = 1806.42 * 2/6 = 602.14 g

3 parts of stone = 1806.42* 3/6 = 903.21 g

Fig 2: mix proportion

The MS steel tank is filled with ground soil by considering the below mix design Volume of tank = · * r^2 * h = · * 15^2 * 28

= 19792.03 cm^3

Volume of soil to filled = volume of tank – volume of column

= 19792.03 - 1806.42 = 17985.61 cm^3

Density of soil = 1.8g/cc

Weight of soil = density * volume

= 1.8 * 17985.61 = 32374.098

Approximately 32kg of ground soil was taken to fill the tank.

The soil sieved through IS sieve size of 4.75 mm size were used in the model making. The soil was mixed with 8% of water that is (obtained by omc and mdd graph) about

2.5 liter of water. The soil was mixed with thoroughly by breaking all the lumps.

CASE 1 :

The geogrid is filled with stone and m-sand in the ratio of 1:3 and compacted thoroughly. Then the entire setup is kept in UTM (Universal Testing Machine). Constant load application takes place until the failure in the model takes place.

Fig 3 : A depth of 23cm is dug.

Fig 4: The setup is placed in UTM.

CASE 2 :

The geogrid is filled with coconut shell, m-sand, and stone in the ratio of 1:2:3 respectively and compacted, then the entire setup is again placed under UTM machine and constant load is applied on it.

Fig 5: column filled with stone+ m-sand +coconut shell.

IV. OBSERVATION AND RESULTS

Both the trials satisfy the main aim of this project that is to increase the bearing strength and improve the ground soil economically. The trial 1 clearly says that the maximum deflection that a model of stone column can withstand is 1.82 and in trial 2 it can take up to a deflection of 3.59.

This says that a stone column filled with even a little amount of coconut shell can give more strength to the column. The coconut shell reduces the friction between the stone and m sand as they are high in friction property. Since the coconut shell is a natural fiber, it adds more support and strength, and it exhibits the non-deterioration of the aggregates.

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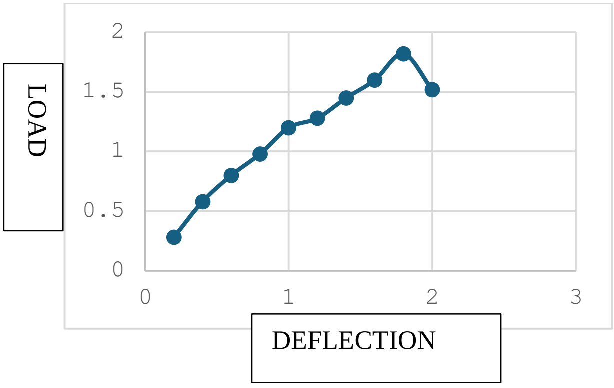
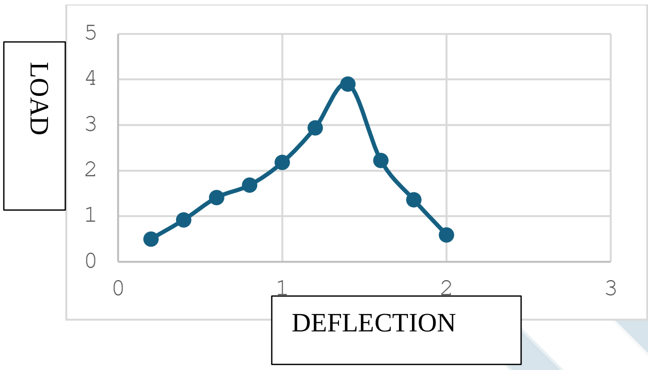


Graph 2: represents a compressive strength of stone column . The ultimate stress was found to be 1.82kN after that it starts to fail.



Graph 3 : The fig represents a compressive strength of stone column . The ultimate stress was found to be 3.9kN after that it starts to fail.

V. CONCLUSIONS

In the pursuit of sustainable ground improvement techniques, this experimental study has illuminated the promising prospects of a novel approach—geogrid encased stone columns filled with coconut shell chips. As we conclude this investigation, it becomes evident that the integration of eco-friendly materials and innovative methodologies not only addresses geotechnical challenges but also contributes significantly to the paradigm shift towards sustainable infrastructure development.

Our research began by acknowledging the global imperative for sustainable practices in civil engineering, prompted by the escalating demand for urbanization and the associated environmental concerns. Traditional ground improvement techniques, while effective, often rely on non-renewable resources and contribute to carbon footprints. The synthesis of geogrid encased stone columns with coconut shell chips represents a conscientious departure from this trend, offering a sustainable alternative that aligns with the principles of circular economy and environmental responsibility.

The comprehensive experimental study conducted in this research has provided valuable insights into the geotechnical properties and performance of the proposed sustainable ground improvement technique. Laboratory-scale tests, including geotechnical characterization of coconut shell chips and triaxial shear tests, have illuminated the inherent strengths and attributes of this bio-based material. The full-scale physical modelling of geogrid encased stone columns filled with coconut shell chips allowed us to evaluate the technique's efficacy in real-world conditions, considering factors such as settlement reduction, increased bearing capacity, and structural stability.

The findings of this study showcase the potential of coconut shell chips as a sustainable alternative fill material in ground improvement projects. The lightweight nature and irregular geometry of the chips contribute not only to the reduction of structural loadings but also to enhanced shear strength and improved drainage characteristics. These attributes hold immense promise for applications in diverse geotechnical scenarios, from foundation reinforcement to slope stabilization.

As we reflect on the outcomes of our research, it is essential to emphasize the broader implications and significance for the field of geotechnical engineering. The integration of sustainable practices into ground improvement not only safeguards the environment but also enhances the resilience and longevity of critical infrastructure. The circular use of agricultural waste in the form of coconut shell chips exemplifies a harmonious synergy between engineering innovation and ecological consciousness.

In conclusion, this study serves as a pioneering contribution to the evolving landscape of sustainable geotechnical solutions. The amalgamation of geogrid encased stone columns with coconut shell chips showcases a viable and environmentally responsible alternative for ground improvement. As we envision the integration of these findings into mainstream engineering practices, we set a precedent for a future where sustainable methodologies are not just an option but an imperative in shaping resilient and eco-conscious infrastructure worldwide.

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