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Effect of Use of Geocell and Rice Straw in Slope Stability

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Abstract: *One of the most difficult challenges in geotechnical engineering is slope failure caused by soil erosion during rain. The geocell structures and rice straw reinforcement are used to create a composite soil treatment and slope protection approach. The geocell structures improve the planting soil's stability and provide a stable and fixed habitat for the vegetation, while the rice straw strengthens the soil while also increasing its fertility. The progression of slope failure during rainfall, soil erosion and slope displacement were all evaluated. The findings reveal that when rainfall persists, slope failure occurs, and soil deterioration increases with rainfall intensity. Although geocell treatment enhances slope stability, geocell with rice straw composite reinforcement provides the best erosion control and slope protection. The result shows that use of geocell improve slope stability , but geocell and rice straw composite shows best erosion control and slope stability.*

Keywords: Geocell, rice straw, slope Displacement, Slope erosion

I. INTRODUCTION

Kerala has undergone a lot of destruction and damage during the past few years due to severe downpour. Heavy rainfall and climatic conditions led to the massive floods and landslides in different parts of Kerala. Many studies have been conducted proving that, most of the land area in Kerala is susceptible to land slip or land failure in future. Due to variation in rainfall pattern and seasonal changes, landslides are becoming common from the year 2018 to till date. The major cause of slope failure is due to climate change, improper drainage facility and lack of study of the site.

Shallow slope failure refers to the elimination of plant cover and topsoil on a slope, which is a prevalent problem in locations with hilly or mountainous terrain, constructed roads, and embankments. Shallow slope failure is also known as shallow landslide and shallow soil erosion. Shallow landslides occur when the forces acting on the downslope surpass the mechanical resistance of the slope, whereas erosion occurs when rain water dislodges soil particles and carries them down a slope, generating rills and gullies that may eventually precipitate landslides. Shallow slope failure is a global geologic hazard that has significant consequences for both the natural environment ×and human properties.

A novel kind of slope protection and ecological restoration is the geocell structure combined with growing plants for soil fortification and erosion control. The cellular form geocell constructions may anchor the planting soil (local soil applied to the bare soil of the original slope for sowing) to the slope, providing a secure and adequate nurturing environment for plant development. This erosion management approach creates a protective layer for the slope, preventing the negative impact of rainfall from immediately reaching the slope surface, while the roots of fully developed plants on the protective layer go down below the protective layer and further stabilize the slope.

This project aims to present the results of an experimental study on selected site, Amboori Thiruvananthapuram, Kerala .The selected site has a history of landslide in the year of 2001 and claimed life of 39 people around the area. The rainfall data is obtained from the SODA Merri-2 software and the slope angle of the site is obtained and recorded as 32^{0}. Three types of slopes are analyzed in the study to evaluate the soil erosion and soil displacement. The geocell structures and rice straw were used in this work to suggest a composite soil treatment strategy for slope protection. The geocells are buried in the planting soil, and rice straw is mixed in with the soil to provide reinforcement at a short depth.

II. OBJECTIVE

1. To identify the properties of locally available soil collected from Amboori.
2. To stabilize the slope using geocell and rice straw.
3. To compare the slope erosion and slope displacement in natural slope, geocell supported slope, composite reinforced slope.
4. Comparative study of failure of natural slope, geocell supported slope, composite reinforced geocell and rice straw supported slope.

III. MATERIALS AND METHODOLOGY

3.1 Geocell

Geocell is a geosynthetic material that is commonly used in soil reinforcement and erosion control operations. EGS Geocell is a three-dimensional structure built of high-density polyethylene (HDPE) strips. It has the ability to expand on-site to produce a honeycomb-like structure that may be filled with sand, dirt, rock, gravel, or concrete. Geocell is collected from TECHFAB Industries Ltd.

Fig 1: Geocell

Table 1: Properties of Geocell (Source: TECHFAB Industries Ltd).

PROPERTIES VALUE	VALUE
Product	TCI356
Type	HDPE
Cell Depth	75mm
Wall Thickness	1.52mm
Surface	Textured and Perforated
Weld Spacing 356mm	356mm
Expanded Cell Dimension(W/L)	259 x 224mm
Expanded Cell Area	289 cm²
Perforations	10mm diameter
Seam Strength	1065 per 75mm
Price	120/m²

Table 1 shows the properties of geocell purchased from TECHFAB Industries Ltd.

3.2 Rice Straw

Rice straw is added as crumbles having size variation of 5mm to 10mm. About 1.5% of the rice straw crumbles are added to soil to improve the properties of the slope soil. When straw is mixed with soil, the weight of the straw steadily reduces as microorganisms multiply and break down the straw. The breakdown of wheat straw improves soil fertility by supplying nitrogen or other nutrients and encourages the growth of plants planted on the slope. The plant's root system reinforcing the geocell-reinforced soil, which enhances slope stability even further.

Fig 2: Rice straw

3.3 Soil

Soil is collected from selected site Amboori, Thiruvananthapuram, Kerala where several slope failures have occurred. Amboori is situated in the southern tip of western ghats, surrounded by hills and is near to kattakkada. Amboori has witnessed a large landaslide in 2001 which claimed the life of 39 people.

Fig 3: Soil collected from Amboori.

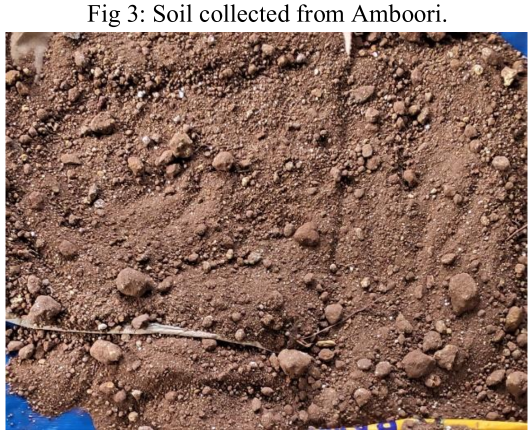

Fig 4: Soil sample collected.

The soil sample collected from an average depth of 4m from the ground surface. The soil is sundried for several days and tested for its geotechnical properties.

Table 2: Basic Properties of Amboori Soil

PROPERTIES	VALUES
Specific Gravity	2.24
Liquid Limit (LL)	54%

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Plastic Limit (PL)	30.55%
Natural Water content	13.67%
Percentage of gravel	5.09 %
Percentage of sand	81.26%
Percentage of silt and clay	3.74%
Maximum dry density (MDD)	1.77g/cc
Optimum moisture content (OMC)	16%

3.4 Steel Tank

The steel tank has a dimension of 1m×0.5m×0.7m. Polycarbonate material is used for front portion for viewing the failure mechanism. Bottom back and side portion of the tank is constructed using metal .One side of the tank remains vacant. An outlet is provided at the vacant side to collect the runoff provided during the simulated artificial rainfall.

Fig 5: Steel Tank

3.5 Artificial Irrigation System

Artificial rainfall system is implemented along with the steel tank to provide average intensity of rainfall from the site selected. The average intensity of rainfall from the site is calculated from SODA Merri-2 software and is recorded as 165mm/hr.

Fig 6: Artificial rainfall system

3.6 Soil Erosion Measurement

During the test, rainwater is collected using a measuring cylinder at the runoff port. For every 5 minutes, the volume (V runoff) of the runoff (including precipitation and dirt) was measured. An electronic scale was used to determine the mass (m runoff) of the runoff.

Mass of soil $m_{soil} = \rho_{soil} V_{soil}$

$= \rho_{soil} [(m_{runoff} - \rho_{water} V_{runoff}) / (\rho_{soil} - \rho_{water})]$

(Source : Xiaoruan Song, Miansong Huang et al 2021)

V runoff is the volume of the collected runoff from the port (including rain water and soil) at each collection, cm, m soil is the mass of the soil from the collected from the runoff in g; V soil is the volume of the soil from the collected runoff in cm. ρsoil is the density of the slope soil before rainfall selected as 1.77 g/cm3; ρ water is the density of water, 1 g/cm3.

3.7 Measuring System for Analysing Slope Displacement

The displacement of the slope is measured using the measuring ruler. Since the rods move together with the slope's displacement, a fixed position should be chosen as a point of comparison to calibrate the measurement. String and rods are aligned at a distance of 20 cm apart to analyze slope displacement. The slope displacement is measured for every 10minutes of rainfall.

IV. RESULTS AND DISCUSSIONS

4.1 Case 1: Natural Slope

Natural slope is created at an angle of 32^0 by compacting the soil in layers The heel and toe of the slope is created . The artificial rainfall simulator provide rainfall at the rate of 165mm/hr.

Fig 7: Natural slope before simulated rainfall

Fig 8: Natural slope after simulated rainfall

In natural slope the slope fails at faster rate compared to other two slopes.For the first 5 to 10 minutes the toe portion of the slope fails gradually . At the end of 30 minutes the slope get eroded gradually to the heel portion of the slope.The slope get displaced to a maximum value at the end 60 minutes.

Fig 9: Crack formed at the heel portion.

In the fig 9 cracks are formed at the end of 40 minutes at the heel portiondue to the displaceentbof slope.

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4.2 Case 2: Geocell Supported Slope

Geocell supported slope is constructed by placing the soil in the steel tank layer by layer and compacting to its maximum dry density. In the top 10cm of the slope, geocell is placed and voids between the geocell is filled with soil and compacted .The slope is cpmpacted and placed neatly**.**

Fig 10: Geocell supported slope before simulated rainfall

Fig 11: Geocell supported slope after simulated rainfall

4.3 Case: 3 Composite Reinforced Slope

Composite reinforced slope conssist of Geocell and rice straw placed in combination. The soil is placed in such away the bottom layers of the soil is placed and compacted and the geocell is placed in the formed slope .Soil mixed with rice straw is placed and compacted within the geocell for a depth of 10cm of the slope The rice straw give better stability and reinforcement to the soil.

Fig 12: Composite reinforced slope before simulated rainfall

Fig 13: Composite reinforced slope after simulated rainfall

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Fig 12 and 13 shows composite reinforced slope before and after simulated rainfall.The composite reinforced slope shows less erosion and soil displacement . It shows only 3mm of soil displacement at the end of 60minutes of artificial rainfall. The rice straw keeps the slope intact and more stablein nature . A small portion of the soil is only eroded at the end the simulated rainfall.

4.4 Amount of Soil Erosion

Table 3: Amount of slope erosion occurs for natural slope, geocell reinforced slope and composite reinforced slope

Time(minutes)	Amount of slope erosion (g)		
	Natural Slope	Geocell Reinforced Slope	Composite Reinforced Slope
0	0	0	0
5	765	316	252
10	2367	798	598
15	4125	2017	1532
20	6523	3459	2315
25	8231	5123	3102
30	9536	6649	3782

Table 1 shows the variation in soil erosion for natural Slope, geocell reinforced slope and Composite reinforced slope for a time period of 30 minutes.

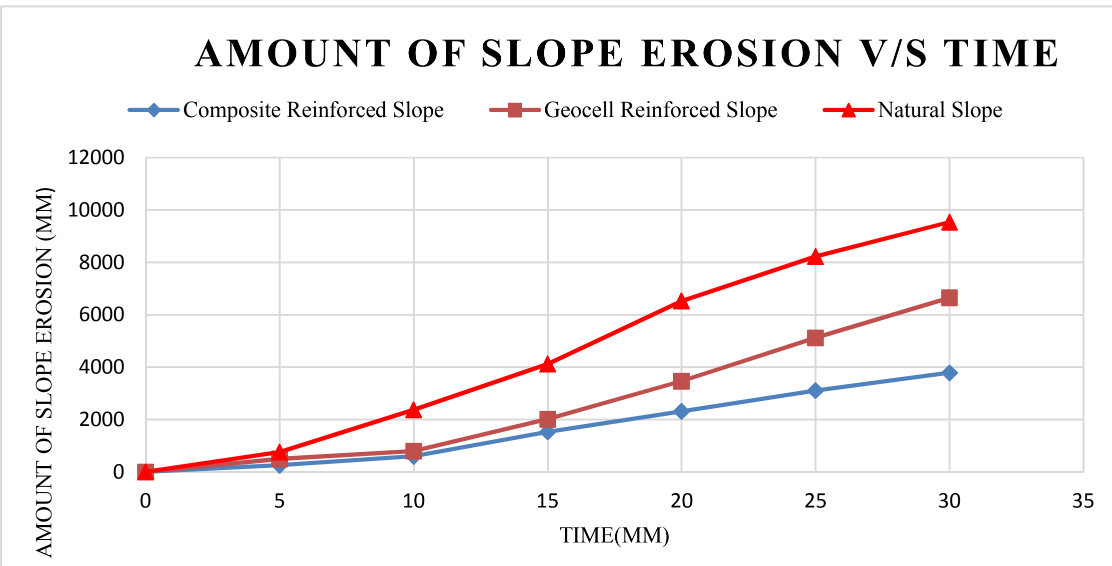

Fig 14: Amount of slope erosion V/S Time Graph

Fig 14 shows the amount of soil eroded for various slopes erosion for a time period of 30 minutes. The natural slope shows maximum erosion and the composite reinforced slope shoes less erosion. For the geocell supported slope the erosion is, only the top portion of the soil is eroded.

4.5 **Amount of Slope Displacement**

Slope displacement is measured using line and pin method in which line and pin is placed at a distance of 20cm apart.

Table 4: Slope Displacement of different slopes

Time(minutes)	Slope Displacement(mm)		
	Natural Slope	Geocell Reinforced Slope	Composite Reinforced Slope
0	0	0	0
10	3	1	0
20	4	2	1

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30	5	4	2
40	6	5	2
50	9	6	3
60	12	7	3

Table 4: shows the variation in slope displaced for natural slope, geocell supported slope and Composite Reinforced Slope at the end of 60 minutes.

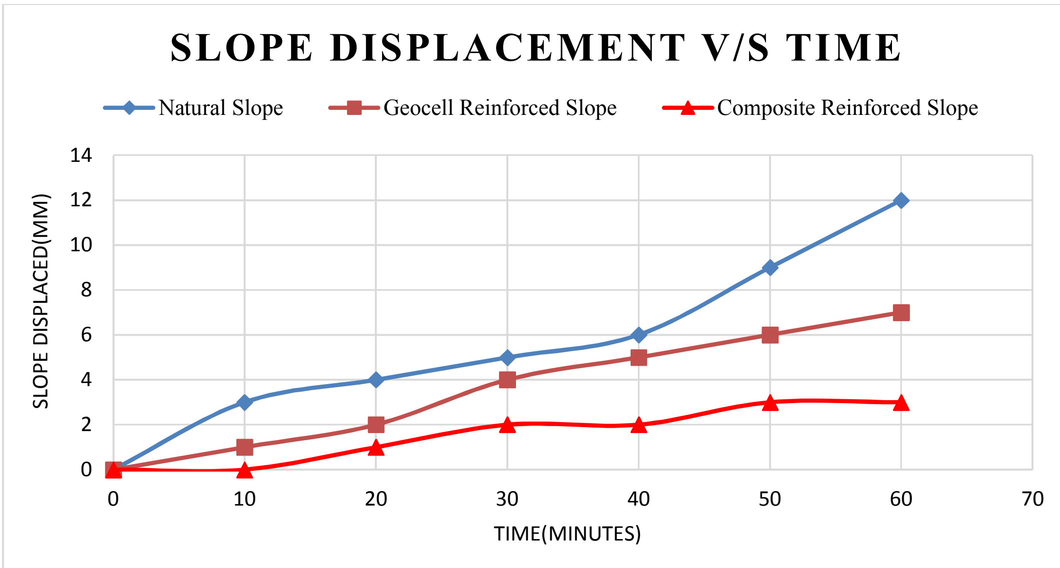

Fig 15: Slope displacement V/S Time graph

Fig 15 shows the variation in slope displacement with increase in time. For the natural slope it shows maximum slope displacement occurs during the simulated rainfall compared to the other two slopes. The natural slope has a displacement of about 12mm at the end of 60 minutes it shows cracks at the heel portion during the displacement. For the geocell reinforced slope the slope displacement is less compared to the natural slope and shows about 7mm.For the composite reinforced geocell and rice straw slope the slope displacement is very less showing a value of 3 mm ath the end of the test.

V. CONCLUSION

The studies shows that the values of slope erosion and slope displacement is very low for composite reinforced slope compared to natural slope and geocell supported slope.

- Preliminary soil sample test were done .The soil is identified as silty sand ,which has gravel of 5.09 %, sand of 81.26% and silt and clay of 3.74 %
- Soil erosion and soil displacement is very less for composite geocell and rice straw supported slope.
- The maximum displacement of the slope is about 12mm, 7mm and 3mm for natural slope geocell supported slope and composite reinforced slope respectively.
- Natural slope shows maximum deterioration due to simulated rainfall.
- Failure type observed is slip failure.

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