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Influence of Non-Woven Geotextile Over Chemically Stabilized Soil in Controlling Erosion

R. Varsha[1], S. P. Jeyapriya[2].
[1]PG Scholar, Geotechnical Engineering, Government College of Technology, Coimbatore
[2] Professor, Department of Civil Engineering, Government College of Technology, Coimbatore

Abstract: Soil erosion is the most significant hazard in sloping terrain. It affects the hilly regions by the loss of top layer of the soil. Soil erosion is mainly induced by rainfall. As the surface runoff flows with high velocity, the detachment of soil particles takes place and it moves down slope. It causes instability and leads to slope failure. The soil erosion depends on erodibility, rainfall erosivity and spatial variability. Non-woven geotextile has the interlocking fibers which retain the fine soil particles and allow water to pass through the fabric. In this study, non-woven geotextile is used over chemically stabilized soil to control the erosion. The stabilizers used are Guar gum powder and Magnesium Stearate powder. Erosion tests are conducted in the slope model for maximum hourly rainfall intensities of 60mm/hr and 70mm/hr on an inclined slope having inclination of 20°. The erosion rates for the slope wherein geotextile is used as reinforcement on soil treated with Guar gum powder in the slope model for rainfall intensities 60mm/hr and 70mm/hr are 2112g/m²/hr and 2798g/m²/hr respectively. Similarly, the same soil slope model in which the stabilizer used as Magnesium Stearate and reinforced with geotextile sheet and for the same rainfall of 60mm/hr and 70mm/hr intensities produced reduction in erosion rate of 1950g/m²/hr and 2312g/m²/hr respectively. The results show, that the erosion rate decreased with the use of geotextile on chemically stabilized soil with Magnesium Stearate when compared to the other method.
Keywords: Soil erosion, Non-woven geotextile, Guar gum powder, Magnesium Stearate.

I. INTRODUCTION

Long-term soil degradation is brought on by soil erosion, which is a progressive process of movement and transport of the topsoil by many forces, primarily water, wind, and mass movement. India is losing its topsoil faster than it can be replenished because of soil erosion[1].The amount of runoff and erosion depends mainly on two factors that are the characteristics of the rainfall and the management of land use. Rainfall is the primary cause of soil erosion, having a direct impact on soil particle separation, decomposition of soil aggregates and migration of eroded sediment. The amount of soil erosion caused by erosive rainfall accounts for the majority of total erosion [2] . Erosion occurs when soil particles are displaced due to the impact of raindrops, moving water or wind. Water induced erosion is due to natural rainfall or artificial irrigation. Among these factors, rainfall is an important determinant. The processes of erosion are detachment, transportation and deposition by rainfall or by runoff. During rainfall, water infiltrates the soil at a rate depending upon the bonding of the soil particles. If the water does not infiltrate, then it begins to pond on the surface. After reaching sufficient depth it starts flowing as runoff water. Sedimentation occurs when eroded particles, are deposited in another location where they can cause problems. Sediments and sedimentation cause the problems associated with erosion and erosion control can prevent the problems associated with it. [7] The erosion rate can be controlled by adopting proper surface reinforcement and treatment which reduces runoff, sediment control and soil loss[2]. The surface protection of the slopes dissipates the energy of raindrop impact, increases infiltration and reduces the velocity of overland flow. In the uncovered soil surface, raindrop loosens the soil particles, which cause an incremental movement towards the down slope. [2] In this study, it is aimed to use non-woven geotextile on already stabilized soil with guar gum powder and Magnesium Stearate separately. The erosion tests are conducted in a fabricated slope model of 20º inclination. The rate of erosion was studied for hourly rainfall intensities of 60mm/hr and 70mm/hr and reported.

II. MATERIALS AND METHODS

A. Soil

The soil sample collected for the slope studies was initially prepared and subjected to laboratory investigation. The soil samples are tested for its natural moisture content, organic content, specific gravity, Atterberg’s limit, grain size distribution and Standard proctor compaction test. The soil is classified as Intermediate Compressible Clay (CI). The results obtained from laboratory tests are presented in table 1.

TABLE 1: Properties of Soil

SI.No	PROPERTIES	RESULTS
1.	Specific gravity	2.70
2.	Sieve Analysis a) % Sand b) % Fines	 39.80 60.20
3.	Atterberg's limit a) Liquid limit (%) b) Plastic limit (%) c) Plasticity Index (%)	 41 23 18
4.	Classification	CI
5.	Optimum moisture content (%)	18
6.	Maximum dry density(g/cc)	1.70
7.	Unconfined compressive strength(kPa)	40.6
8.	Cohesion(kPa)	20.8

B. Non-Woven Geotextile

Non-woven geotextile are types of geotextiles which are manufactured in the form of sheets that possess high permeability and high elongation characteristics. In non-woven geotextile, separation, drainage and filtration ability is better than others[4] [5] [9] .Non-woven geotextile of 200GSM, 1.5mm thickness with 8kN/m tensile strength is used in this study.

C. Guar Gum Powder

Guar gum is a natural biopolymer extracted from the endosperm polysaccharide. It contains polymers D-galactose and D-mannose in the ratio of 1:2. Upon complete hydration, guar gum forms viscous, colloidal dispersions that are thixotropic in nature. The borate ions present in guar gum act as cross-linking agents, forming thick gels which are cohesive in nature[3]. In this study, 1 % of guar gum powder is added to 100kg of soil and is used for erosion studies.

D. Magnesium Stearate

Magnesium Stearate ($C_{36}H_{70}MgO_4$) is a simple salt made up of two substances, a saturated fat called stearic acid and the mineral magnesium. It has high plasticity and cohesiveness. It gives better results for absorption of water and acts as a binder between the particles [8]. In this experiment, 0.2% of Magnesium Stearate is added to the same amount of soil.

III. METHODOLOGY

Soil erosion rate is controlled by the use of different surface treatment. As the non-woven geotextile has better tensile strength and elongation, it is used as the reinforcement in the erosion control study.[7]The additives such as Guar gum powder and Magnesium stearate powder is used as stabilizers along with the non-woven geotextile as reinforcement to control the soil erosion rate. The rate of erosion is recorded for the slope model with and without use of non-woven geotextile and additives. The model is tested for 60mm/hr and 70mm/hr rainfall intensities of 20º inclination. The rainfall simulation is done using a constant head rainfall simulator.[1] [2]

A. Fabrication of Slope Model

To study the erosion rate on slopes, laboratory slope model was created using plywood boards. The length to breadth ratio is taken as 2:1. The boards are arranged and screwed in such a way that the sloping angle is 20º.The size of the model was 1m x 0.5m x 0.15m. It has been identified by different research that by increasing the slope angle the erosion rate increases, and therefore a gentle sloping angle was chosen for the present work. [1]

B. Fabrication of Water Tank

The rainfall simulation was performed with the help of a water tank with its base plate drilled with holes. The size of water tank was designed as same as plan area of slope model. The depth was calculated based upon maximum quantity of water. The size of tank was 1m x 0.5m x0.2m for a capacity of 0.1m³. The depth required for two different rainfall intensities is calculated and shown in table 2.

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TABLE 2: Head Requirement in the Water Tank for Different Rainfall Intensities

SI.No	Description	Rainfall intensity 60mm/hr	Rainfall intensity 70mm/hr
1.	Discharge(m^3/s)	8.33x10-6	9.722x10-6
2.	No of holes	180	180
3.	Discharge/hole(m^3/s)	4.627×10^{-8}	5.401×10^{-8}
4.	Velocity/hole	0.0147	0.0171
5.	Head required(m)	0.0598	0.0696

C. Fabrication of Rainfall Simulator

The erosion tests were conducted using a rainfall simulator which is a tank of size 1m x 0.5m x0.2m. The discharge required for different intensities are calculated. Based on the discharge, the size of the water tank was selected with 2mm diameter holes and 5cm spacing between the holes. The bottom of the tank is drilled with a total of 180 holes. Through these holes, water is allowed to pass through which is intended to obtain the desired rainfall intensities 60mm/hr and 70mm/hr. The rainfall intensity is simulated by maintaining the calculated head of water in the tank for an hour. The intensity is obtained by filling water tank up to a certain height. The rate of soil erosion was calculated for different intensities. The experimental setup is shown in figure 1.

Figure 1: Experimental Setup and Artificial Rainfall in Slope Model

D. Experimental Procedure

Initially the soil is stabilized with the additives such as Guar gum powder and Magnesium Stearate powder. For the density, soil with additives must be weighed and combined with water. While placing the soil in the slope model, it is compacted in three layers maintaining desired density. The geotextile is placed over the stabilized soil. Following that, the soil box is positioned at specified angle. Exactly over the soil box, the rainfall simulator arrangement is placed and the calculated quantity of water is allowed to fall as rainfall over the slope model for about an hour. The soil from the slope model starts eroding and is collected separately as soil debris and the experiment is continued till the completion of collection of soil debris. It is kept undisturbed for a long time and the supernatant liquid is removed. The remaining sediments are initially air dried followed by oven drying and the dried soil is weighed and this is taken as the eroded soil. The erosion rate is calculated as per the expression.[2]

$$\text{Erosion rate} = \frac{\text{Total weight of eroded soil}}{\text{Area of rainfall x Duration of rainfall}}$$

IV. RESULTS AND DISCUSSIONS

The soil is prepared and compacted in the model. Erosion rate is determined for 60mm/hr and 70mm/hr rainfall intensities without any treatment were obtained as 3148g/m²/hr and 3792g/m²/hr respectively is presented in Table 3.

TABLE 3: Erosion Rate for Slope

SI.No	Slope angle (degree)	Rainfall intensity (mm/hr)	Surface treatment	Erosion rate (g/m²/hr)
1.	20	60	None	3148
2.	20	70		3792

With the addition of Guar gum powder stabilizer and with the placement of geotextile, the erosion rate is calculated and shown in table 4. The erosion rate when Guar gum powder and geotextiles are used are found to be 2112g/m²/hr and 2798g/m²/hr respectively for 60mm/hr and 70mm/hr rainfall intensities. The percentage reduction in the rate of erosion is observed to be 32.9% and 26.21%. It was observed that by the use of geotextile, there is reduction in the amount of eroded soil compared to that of untreated soil. This is due to the reason that the fabric holds soil particles to certain extent.

TABLE 4: Erosion Rate for the Slope with Geotextile on Chemically Stabilized Soil with Guar Gum Powder

S. No	Slope angle (degree)	Rainfall intensity(mm/hr)	Surface treatment	Erosion rate (g/m²/hr)
1.	20	60	Geotextile on chemically stabilized soil with guar gum powder	2112
2.	20	70		2798

On treating soil with Magnesium Stearate and with the use of geotextile, the erosion rate was 1950g/m²/hr and 2312g/m²/hr for 60mm/hr and 70mm/hr rainfall intensities which is presented in table 5. The percentage reduction in erosion rate was 38.05% and 39.02% when compared to untreated soil. The large reduction in erosion rate is due to transformation of soil to high plasticity.

TABLE 5: Erosion Rate for the Slope with Geotextile on Chemically Stabilized Soil with Magnesium Stearate Powder

S. No	Slope angle (degree)	Rainfall intensity(mm/hr)	Surface treatment	Erosion rate (g/m²/hr)
1.	20	60	Geotextile on chemically stabilized soil Magnesium Stearate powder	1950
2.	20	70		2312

A comparison chart is prepared showing percentage reduction of erosion rate of treated soil and presented in figure 2. From the chart, it is observed that the stabilizer Magnesium Stearate has performed well in controlling the erosion rate of soil to maximum of about 39% for the maximum rainfall intensity of 70mm/hr.

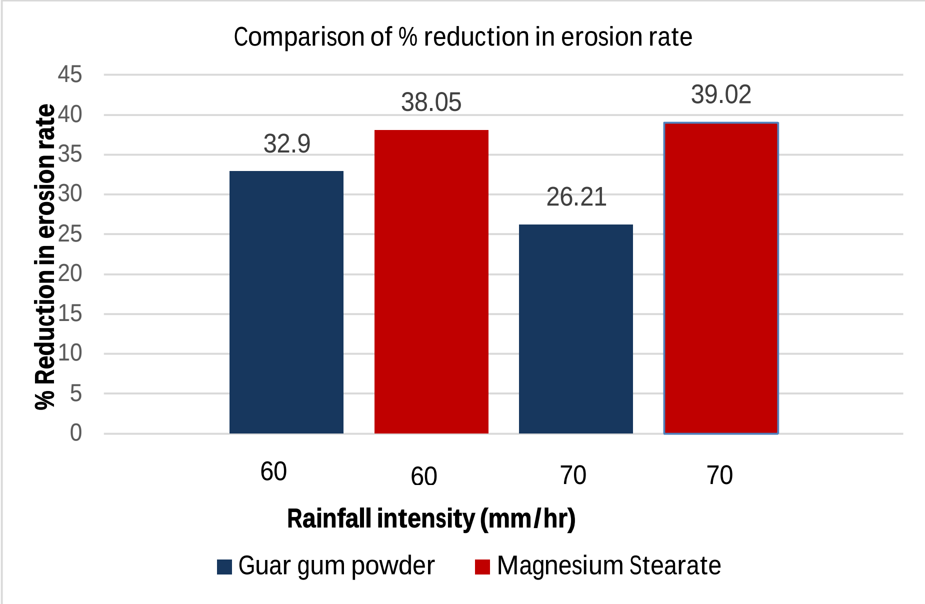

Figure 2: Percentage Reduction in Erosion Rate for Different Stabilizer and Geotextile

V. CONCLUSIONS

An experimental model study on erosion control of soil with geotextile material and additives were performed in the laboratory and the following conclusions were arrived.

1) Addition of chemicals such as Guar gum powder and Magnesium Stearate have improved the binding effect of soil and hence the detachment of individual particles is less when compared to that of untreated soil.
2) Use of reinforcement over already stabilized soil has shown better performance in controlling the erosion rate of soil.
3) Among the stabilizers chosen, Magnesium Stearate has shown a reduction of erosion as much as 39% over untreated soil. Hence, addition of stabilizer and reinforcement have improved soil slope in controlling soil erosion.

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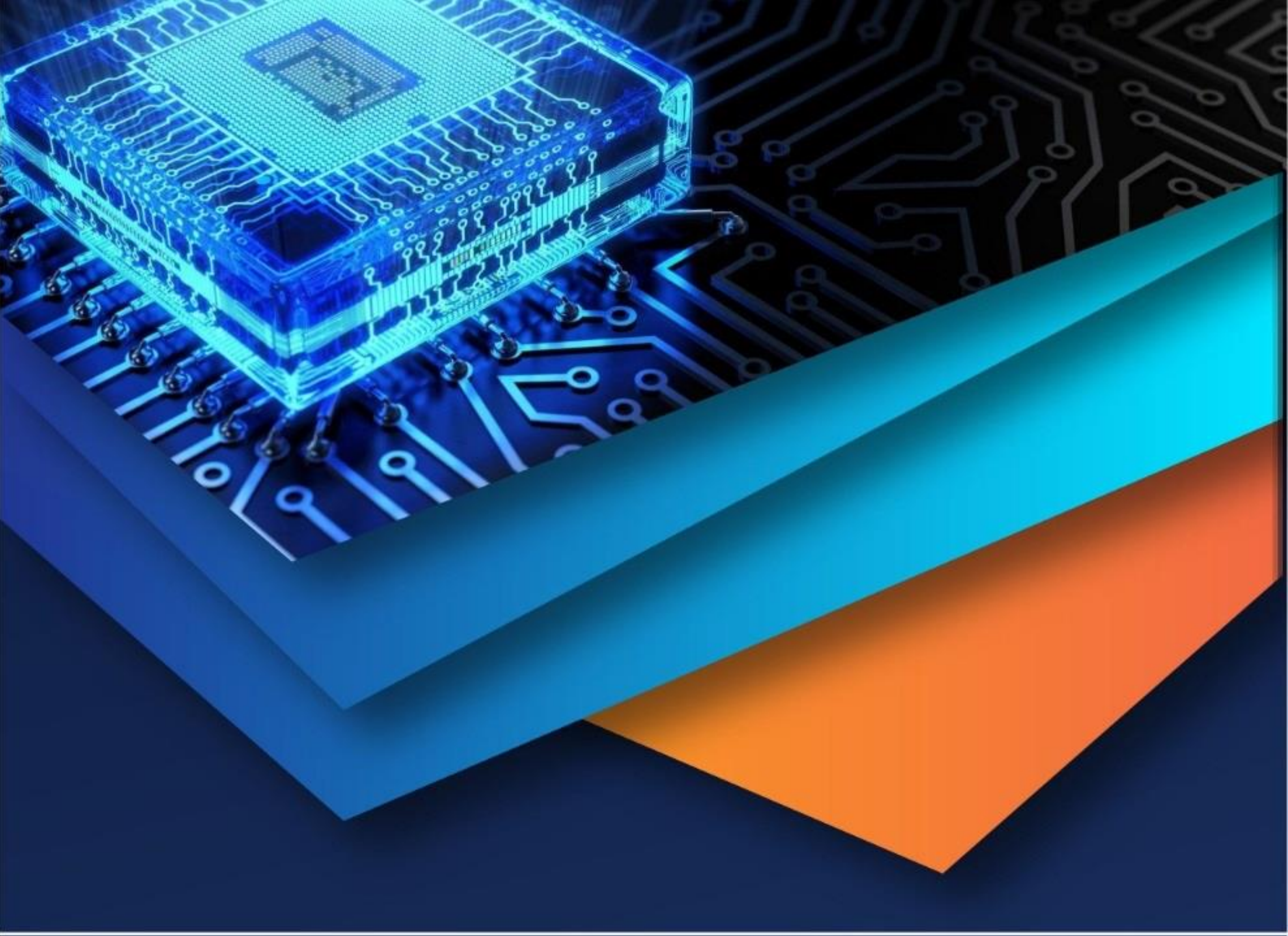

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