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Application of Geo Textiles in Erosion Control – A Review Paper

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Abstract— ***Geo textiles are a possible great alternative before vegetation establishes itself, and provides immediate control on soil erosion on different types of slopes. In this study, different geo textiles have been used for better erosion control over different soils. Different structurally modified geomeshes are tested for runoff erosion control, culmination discharge over different types of soils at different slope angles and at different rainfall intensities. Though these geo textile products are in use since a long time, the selection of product is mostly based on the manufacturer's recommendations. Hence, there is a great necessity to understand the mechanics involved and to develop a comprehensive design methodology. In line with this, in the present study a review was done about the research takes place so far across the world.***

Index Terms— ***erosion control, geotextiles , culmination discharge, vegetation growth***

I. INTRODUCTION

Soil erosion is a process of loosening, detachment and transportation of soil particles from their initial position – can generally be attributed to natural processes such as rainfall, runoff, wind and landslides.

Soil erosion is the second major environmental problem throughout the world's terrestrial ecosystem after population growth. Around, 56% of the total erosion in the world is due to water. Sheet erosion, bank erosion, gully erosion, and runoff erosion are different types of water erosions. In runoff erosion, raindrops hit the exposed soil with great energy and break the bonds between soil particles and dislodge the soil particles from the surface. Generally, vegetation is the permanent way to control soil erosion. But the problem is that the soil should be stable till the growth of the plants, for which a temporary reinforcement is needed. Hence, a combination of plants along with the temporary reinforcement material is a better way for erosion control.

In this technique, geomeshes are laid over the slope which provides the reinforcement and held the soil till the permanent vegetation is established. Natural geotextiles are preferred over synthetic [2] geotextiles because they get degraded into the soil.(Ogbobe, O., K. S. Essien, and A. Adebayo. 1998.). While, synthetic geotextiles are not biodegradable which causes soil pollution. Natural fibers have the capacity to absorb water and degradation are the main properties which give edge over synthetic fibers. Among different types of natural geomeshes, coir geomeshes are preferred because they have capacity to absorb solar radiation (Bhattacharyya et al. 2011; Sarsby 2007; Verma, Midha, and Choudhary 2020).[3]

Effective erosion control is achieved by controlling the water flow velocity but it is highly influenced by the soil type. Soil type plays a vital role in determining the erosivity of the soil. It basically defines the fraction of sand, silt, and clay present in a soil sample. The soils which have higher percentage of sand are considered more prone to erosion (Schoonover and Crim 2015). [1] Therefore, to control soil erosion, a detailed analysis of soil texture is required because it determines the rate of erosion. Therefore, this phenomenon also helps in designing the geomeshes for different soil types.

II. FIELD STUDIES ON EROSION CONTROL PERFORMANCE

Geotextiles are used for stabilization of hill slopes is studied by analyzing various parameters such as soil moisture retention, organic carbon ,vegetative growth ,etc. The runoff from control plots are collected and analyzed for estimating the quantity of eroded [4] sediments. Soil samples were collected periodically from the control plots and analyzed for water cotent ,soil moisture retention and organic carbon.The biodegradation of the geotextile fiber is assessed by periodic sampling of the coir from the control plot and tested for ultimate tensile strength.

2.1 Soil erosion

A total hill slope area of 1600 m^2 (0.16 ha) in Kerala having an average slope of 26° was selected for erosion monitoring(K.R. Lekha,2003). [5] There are three sets of twin plots (with each twin plot having one protected and one non-protected slope) covering a total area of 240 m^2 for erosion monitoring. Each individual plot is of dimension 22 × 1.8 m^2 and had an average slope of 26°. Erosion is monitored from the control plots using specially fabricated collection drums provided at the bottom of each control plot. For each plot, the instrumentation setup consists mainly of three drums arranged in sequential order so that the outflow from the first enters the second and that from the second enters the third drum. There are fixed number [6] of holes of specified diameter on the walls of the first and second drums to enable quantification of sediments. The outflow from a single outlet is diverted to the next drum. Field installation of coir geotextile and sowing of grass seeds were completed by the end of September 1997. Soil erosion was monitored for one full hydrologic year from February 1998 to January 1999 (starting with the pre-monsoon period).

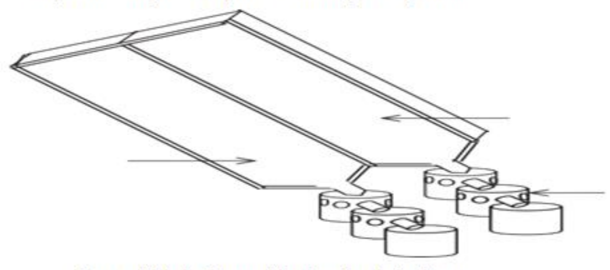

Fig. 1 Schematic of test plots with arrangements for collecting runoff and erosion debris.

It is observed that soil erosion in the protected plot is reduced by 99.6% during the pre-monsoon, 95.7% in the monsoon and 78.1% during the post-monsoon compared to that in the non-protected plot. This is a clear indication that the technology is extremely efficient in minimizing soil erosion in degraded hilly terrain.

A village pond in the kerala was selected for the study(S.vishniudas et al,2006) [7] tested the effectiveness of coir geotextiles for embankment protection.Coir matting selected for the study is MMV1 with the smallest mesh opening of 6×6 mm^2 and a density of 0.74 kg/m^2.The tensile strength of fresh coir matting is 13.8 kN/m. The selection of material was based on the steepness of the slopes.The experiment consists of three treatments (a) coir geotextile with planted grass (CGG), (b) Coir geotextile alone (CG) and (c) control plot (CP); replicated four times along the sides of the pond. Each side of the pond was divided in three equal parts for the three treatments. Erosion in the treated plots is significantly less compared to the control plot. Treatment with CGG stabilized first followed by CG. The control plot did not stabilize during the monitoring period.

A field test on erosion control was performed on a highway road cut slope in Mogpog, Marinduque at an elevation of 1H:1V slope with a total area of 16m x 5m. located in Philippines (Franz erickson Paz et al, 2018).[8] The three geotextiles Coconet, Geomat and Geocell were laid out on the slope and were subjected to weather exposure for three months as shown in Fig. The degradation of the geotextiles after weather exposure were determined by acquiring samples of the exposed materials and were submitted for laboratory testing together with the runoff and soil loss collected to the Department of Science and Technology - Philippine Textile Research Institute (DOST-PTRI) while observing standards set by the American Society for Testing and Materials (ASTM). The influence on vegetation performance was 00DEtermined through examination of the actual appearances of the slopes.

Fig. 2 Illustration of the Field Application of the Geotextiles on Project Site with Vegetation

To determine whether the type of geotextile affects the facilitation of vegetation, three kinds of live plants and seeds as recommended by the DPWH were sowed evenly on the entire soil with geotextiles, specifically: Vetiver grass, Kakawate and Ipil stakes.Runoff and soil loss from the plots were collected at the downslope end. Runoff and soil loss were intercepted by a gutter at the bottom of each slope and were collected through pails as shown below

Fig. 3 Runoff and Soil Loss Collection showing Gutter and Pail at Downslope End

The results show that the control plot had the highest soil loss rate, whereas coconet treated plot has the lowest soil loss. Next to coconet is geocell had lower amount of soil loss.

2.2. Soil moisture retention

Soil moisture retention refers to the amount of soil moisture that is retained in the soil at a particular pressure. Retention at 0.3 bar refers to the field capacity and at 15 bar refers to the wilting point. Amount of water between 0.3 and 15 bar is the water available for plant growth. Soil samples were collected from the field every month at different depths. i.e., 30 cm, 60 cm and 90 cm since the field installation was completed.

At both wilting point level and field capacity, soil moisture retention is higher in the protected plot with coir geotextile than in the unprotected plot (K.R. Lekha,2003) .[9] It is seen that in the pre- monsoon period (dry season), the soil moisture retention in the coir net protected slope was increased by 13% at 0.3 bar and 22% at 15 bar pressure. Thus water availability for plant growth is very much improved in the protected plots. This is because of the water absorption quality of coir fabric and the ultimate reduction in soil erosion achieved using coir nets.

Soil moisture was determined by gravimetric method from different treatment plots (S.vishniudas et al,2006) . Soil samples from the root zone were collected monthly and its initial weight was recorded (w1). Subsequently samples were dried in sunlight until a constant weight was obtained, which was considered as the oven dry weight (w2). Soil moisture was found to be declining subsequently during the observation period even with the increase in rain- fall events (40–120 mm/day) in the month of October; due to the peculiarity of the Southwest monsoon. Soil moisture in CGG is 21% higher than in the control plot during the dry period. In CG, soil moisture is less than in CGG.

2.3 Vegetation growth

Coir fibre installed in the soil helps to improve the organic content of the soil and hence can promote vegetation growth. Comparison of the vegetation growth in protected and non-protected plots show marked improvement in the protected plot. (K.R. Lekha,2003)

Improvement in the vegetal growth by installation of coir netting is noted from a comparison of the growth of grass in plots with and without coir net protection. It is seen that at the end of 16 months, the vegetative growth in the coir net protected slope is 21% higher than in the slope without coir net protection.

Growth of vegetation in CGG shows greater values than in CG (S.vishniudas et al,2006).[11] The control plot shows the lowest value. In CGG, vegetation established well before it started at CG and CP. In CG and CP, vegetation established with different varieties of weeds, whereas in CGG only Axonopus compressus was grown.

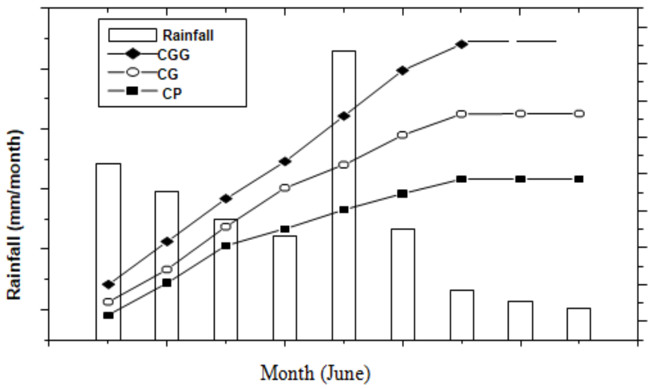

Fig. 4 Length of (grass measured.)

It is observed that vegetation was best developed in the slope covered with Geocell (Franz erickson Paz et al, 2018).This substantiates previous findings reported by Guo et al. (2015)[10] that because of Geocell's large opening sizes in forms of apertures and pockets, vegetation roots were able to penetrate thus were able to progress generously. The Geocell is followed by the vegetation on the control plot, whereas vegetation on the Coconet and Geomat were hardly distinguishable from each other. The bare soil in the project site was found to be fertile due to its clayey property which explains the proper development of vegetation on the control plot. Guo et al. (2015) also revealed that due to the small openings of some geotextiles, it is difficult for vegetation roots to penetrate them which gives justification for the poorly developed vegetation on Coconet and Geomat.

III. EXPERIMENTAL STUDIES ON EROSION CONTROL PERFORMANCE OF GEOTEXTILES

Runoff and soil loss from bare slopes resulting from road constructions, embankments etc., are becoming very serious problem.Geotextiles are a possible temporary alternative before vegetation establishes itself, and offer immediate soil protections on slopes. In order to examine the effects of geotextiles , the experiments were performed in the laboratory using different soils as a substrata under a rainfall simulator at different slope angles.

3.1 Runoff control

This experiment was carried out using a portable rainfall simulator made in key laboratory of soil and water conservation and desertification combating of Ministry of Education, Beijing Forestry University, China(Han Leo et al,2013). The structure is supported by four telescopic legs and the simulator was covered with a plastic curtain to protect the experiments against wind. The nozzle at the top of the structure is 4 m high and it is connected through a rubber pipe to a mobile pump. The water from the nozzle falls onto a squared area of 1800 × 800 mm^2. Rainfall intensity was measured by gauge, pump and pressure relief valve. In order to ensure the stability of the rainfall simulator, four support legs of the rainfall simulator were equipped with four tapered feet which could be inserted into the soil.

Three types of geotextiles (shade net,non-woven fabrics and straw mats) widely used in China were selected and tested. Four road slopes(45^0) in the green construction were selected for experiments, three of which had been covered with straw mats, shade net and non-woven fabrics for three days, respectively. The last one, bare slope, where no geotextile was installed, was used as the control. Topographic and soil data of four slopes were collected one day before the rainfall simulation experiment. The rainfall simulator was calibrated, and the simulated rainfall lasted for 20 min at a rate of 70.6 mm h^{-1} which simulated the rainfall likely to occur in the study region. Ten rainfall simulations were carried out on each of the four selected slopes. We always used distilled water because the response of the soil could be influenced by the chemical composition of the water (Agassi et al., 1994). Runoff samples were collected continuously throughout the rain for every 2 min interval and the volume was noted. The samples were then oven dried at 105 °C and subsequently weighed to determine the sediment yield.

The three kinds of geotextiles significantly decreased runoff and sediment concentration compared to bare slope. Furhermore straw mats had the best effect as induced the lowest runoff coefficient(10.9%) and sediment yield(8.5g/m^2)

In another study (M.V.S.sreedhar and C.Prashanth kumar,2017) , [13] the popular fill material used for construction of embankments and other earth structures viz., silty sand with clay known as Morum is used and two coir products viz., needle punched with coir fibre with HDPE netting on one side (RECP1) and needle punched coir fibre with HDPE netting both sides(RECP2) were used. The efforts were made in the study to develop a rainfall simulator and to study the erosion mechanism through bench scale laboratory studies. The bench scale studies have been performed on model embankment slopes prepared in a test tank of 0.85 m x 0.60 m x 0.60 m. In this study, erosion on shoulders together with slope is modeled.

The tests were performed on slopes making 30^0, 45^0, 60^0 with horizontal under a rainfall intensity of 200 mm/h over a duration of 3 min.each successively with an interval of 5 min. in between each spell. In each of the slope angles, the soil with out protection, soil with RECP1 and soil with RECP2 are studied systematically. To study the effect of erosion on shoulder, similar tests are performed allowing rainfall on shoulder as well as slope portion at once.

The performance of RECPs was evaluated by calculating the Yield Factor(YF) and protection efficiency(PE) using the following equations

YF = soil loss with protection / soil loss with out protection

PE = (1- YF) x 100

A view of experimental setup

The erosion was controlled significantly when coir products were used as protective layers. The protection efficiency was in the range of 80.8% to 92.6%. This justifies the use of coir products in erosion control.Among the coir geoproducts used in the study RECP-2 with double HDPE netting has better protection efficiency and is proved to be 10.2% more effective than RECP-1 with netting on one face only. The erosion of shoulder portion per square meter is found to be relatively smaller (around 3.23%) than that of slope portion, owing to lack of inclination.

In another study(Muhammad Talha Zeshan et al,2021) Coir material was used as a geotextile mat for surface covering of the exposed slope. A rainfall simulation system was utilized to distribute rainfall at the measured intensity on the slopes. Sandy loam soil sample is taken for substrata.

A view of the experimental setup

Before the experiment, the soil to be utilized in the slopes was air-dried for 24 h and then filtered through a circular sieve with a diameter of 18 mm. The substrate for the composition of the bed of slope was the soil accessible on-site, which was compressed with a steel rod of 2.45 kg weight after each addition of 3 cm of soil. To ensure that a uniform bulk density of 1.1 g/cm^3 [14] was achieved for soil, the same soil volume was homogenously compacted for the container of geotextile covered slope . The rainfall was directed to the slope at a rate of 40 and 60 mm/h, and soil erosion was measured.

The effectiveness of coir geotextiles to minimize runoff was also found significant, approximately 4% at rain intensity of 40 mm/h and 7% at precipitation intensity of 60 mm/h. The study has effectively shown the ability of natural geotextiles for soil protection and runoff control.

Different structurally modified coir geomeshes are tested for runoff erosion control, culmination dis- charge over loamy sand, silt loam, and silty clay loam soil at different slope angles (Sushma Verma et al,2021).[20] For this study, Soils are collected from different places: Hoshiarpur (Punjab), Bilaspur, and Shimla (Himachal Pradesh). Hoshiarpur.

Runoff erosion control test is carried according to ASTM D 7101 standard with some modification in ramp size (Kumar and Midha 2017). According to the previous studies, a ramp size of 50 cm length and 25 cm width is used. V jet nozzles are used to simulate 100 mm/h of rainfall 3 min duration during each trial. Runoff erosion tests are carried out with soil (soil infiltration condition) and without soil (zero-infiltration condition) for better understanding of different soils and geomesh interaction.

In soil-infiltration condition, the soils of different regions are filled in soil tray of dimensions 50 cm length, 25 cm width, and 25 cm depth. Based on the ASTM D 698 soils are compacted in the test tray at required moisture content by dropping the 5.50 lbf rammer from the height of 30 cm. Prepared soil trays are covered with geomeshes placed at different slope angles [15] on the instrument and subjected to rainfall. Simulated rainfall is allowed to fall on the soil trays for 3 min and runoff water with eroded soil is collected in a beaker by the sedimentation method. Initial three tests are not considered for the calculation to avoid the error that may occur due to the initial absorption of the water the soil and geomeshes. Similarly , testing is also performed for uncovered soil trays(with out geomeshes) to evaluate the control test performances (Kumar and Midha 2017; Verma, Midha and Choudhary, 2021). Erosion control percentage can be calculated by the equation given below

Erosion control (%) = (E-C) x 100 /E

Where,

E = Eroded soil without geomesh (g)

C = Eroded soil with geomesh (g)

It is observed that all the parameters (soil type, slope angle, and type of weave) have significant influence on the erosion-control performance of coir geomeshes. Soil type shows the highest contribution (42.99%) followed by slope angle (30.55%) and type of weave (19.99%). Lowest erosion control is observed over loamy sand due to higher amount of sand percentage. Twill weave of coir geomehses shows better performance on all soils (loamy sand, silt loam and silty clay loam) at 15° and 30° slope angle. At higher slope angle, plain weave performs better on loamy sand, silt loam while twill weave performs better on silt clay loam.

3.2 Vegetation growth

Germination test is performed according to ASTM D 7322. According to the standard, earthen pots are filled with different soil and sown with an equal number of wheat seeds (60 seeds/pot) . Each soil is covered with the different structures of geomeshes while one is left uncovered. These pots are kept at a uniform temperature, lighting conditions and 30–35% moisture is maintained for 21 days. Two trials of germination tests are conducted for the reliability of test results (Sushma Verma et al,2021).[16] At the end of 21 days, the percentage of vegetation is calculated as

Vegetation (%) = Number of plants germinated € the pot with geomesh X 100/

Number of plants germinated € the pot without geomesh

The number of roots, length of roots, and total rooting length are the important factors that determine the soil stability and germination of plants. After 21 days, 10 plants are randomly uprooted and the average primary root length and an average number of roots per plant are measured in each pot (Álvarez-mozos, J., E. Et al 2014). Total rooting length after 21 days is calculated as

Total rooting length = *N x n x L*

Where,

N = Total number of plants after 21 days

n = Average number of roots per plant

L = Average primary root length (cm)

It is observed that the percentage of germination is higher on loamy sand followed by the silt loam and silty clay loam soils. Similarly, higher germination percentage is observed in the satin woven structure.[19] But, root length and number of roots per plant are lower in case of satin woven structure. Twill weave shows the moderate root length and number of root length, while plain shows the lowest. So, highest rooting length is observed when twill woven geomeshes are applied.

IV. CONLUDING REMARKS

In this study, the performance of geotextiles especially coir in different forms on different soils for different rainfall intensities across the world is reviewed. The comparative study made for both field studies and experimental studies in the laboratories.

In the field studies , it is observed that using geotextiles for embankment slopes runoff erosion control , vegetation growth is improved a lot in comparison to the bare slopes i.e . slopes with out geotextiles. But the field studies are restricted to one type of soil, for a constant slope under constant rainfall intensity.

In experimental studies, it is observed that artificial embankment is constructed by following suitable compaction and a simulated rainfall which is spray nozzle type or shower type is created .The runoff erosion is calculated for different rainfall intensities but not tested for different types of soils. It is observed that vegetation growth is also improved by using geotextiles. But it better to use natural geotextiles like coir so that these are biodegradable.

REFERENCES

[1] K .R. Lekha , 2003.Fileld Instrumentation and monitoring of soil erosion in coir geotextile stabilized slopes – A case study. Geotextiles and geomembranes, 399-413.

[2] S. Vishnudas, H. H. G. Savenije, P. Van der Zaag, K. R. Anil, and K. Balan , 2006. The protective and attractive covering of a vegetated embankment using coir geotextiles. Hydrology and earth system Sciences, 565-574.

[3] R.J.Rickson, 2006. Controlling sediment at source: an evaluation of erosion control geotextiles. Earth Surf. Process. Landforms 31, 550–560.

[4] Han Luo , Tingning Zhao , Mei Dong, Jun Gao , Xianfeng Peng , Yu Guo, Zhiming Wang , Chao Liang , 2013. Field studies on the effects of three geotextiles on runoff and erosion of road slope in Beijing, China. Catena 109 , 150-156.

[5] Jesús Álvarez-Mozos , Eguzki Abad , Rafael Giménez, Miguel A. Campo , Mikel Goñi, Maider Arive ,Javier Casalí , Javier Díez , Ignacio Diego ,2014. Evaluation of erosion control geotextiles on steep slopes. Part 1: Effects on runoff and soil loss. Catena 118, 168-178.

[6] Balan Krishnan and Praseeja Ayyappan Vasantha, 2014. Numerical Modeling for the Selection of Coir Geotextile for Erosion Control Application Based on the Universal Soil-Loss Equation. American society of Civil Engineers.
[7] S. Suresh Kumar & Vinay Kumar Midha , 2017. Influence of slope angle and rainfall intensity on the runoff erosion control performance of woven geomesh. Journal of natural fibers.
[8] M.V.S.Sreedhar , C.Prashanth Kumar and Parimi Thrimuti Raju , 2017. Laboratory Evaluation of Erosion Control Using Coir Geoproducts. Indian Geotechnical Conference 2017 GeoNEst.
[9] Franz Erickson Paz, Paola Flor-Paz , Nuna Almanzor and Maria Cecilia M. Marcos , 2018.
[10] Performance evaluation of soil erosion control geotextile materials on road cut slope.
[11] Advances in Civil, Environmental, & Materials Research (ACEM18) Songdo Convensia, Incheon, Korea, August 27 - 31, 2018.
[12] Muhammad Talha Zeshan , Muhammad Raza Ul Mustafa and Khamaruzaman Wan Yusof , 2021. Impact of Coir Geotextiles to Reduce Soil Erosion and Surface Runoff.Researchgate.
[13] Sushma Verma, Vinay Kumar Midha & Awadesh Kumar Choudhary , 2021. Runoff erosion control performance of structurally modified coir geomeshes on different soil type and slope angle. Journal of Natural fibers
[14] Akila R.,and T.E. Abraham, 2007. Coir fiber –process and opportunities : Part 1: Journal of natural fibers 3 : 29-41.
[15] Bhattacharyya, R., M. A. Fullen, C. A. Booth, T. Smets, J. Poesen, and A. Black. 2011. Use of palm-mat geotextiles for soil conservation: I. effects on soil properties. Catena 84 (3):99–107.
[16] Brischke, C., and L. W. Friedrich. 2019. Impact of water holding capacity and moisture content of soil substrates on the moisture content of wood in terrestrial microcosms. Forests 10 (485):1–16.
[17] Giroud, J. P., N. D. Williams, T. Pelte, and J. F. Beech. 1995. Stability of geosynthetic- soil layered systems on slopes.Geosynthetic International 2 (6):1115–48.
[18] Kumar, S. S., and V. K. Midha. 2017. Influence of slope angle and rainfall intensity on the runoff erosion control performance of woven geomesh. Journal of Natural Fibers 16 (2):153–62.
[19] ASTM D7101, “Standard Index Test Method for Determination of Unvegetated Rolled Erosion Control Product (RECP). Ability to Protect Soil from Rain Splash and Associated Runoff Under Bench-Scale Conditions”, ASTM International, West Conshohocken, PA, USA.
[20] Boker, J., Zanzinger.H, Bastian, M., Nemeth, E. and Eppel, J. (2012), “Surface erosion control investigations for a test field on a steep embankment of German Autobahn A3”, EuroGeo 5, Proceedings of 5th European Geosynthetics congress, vol 5, Erosion control and coastal works, Valencia, Spain, pp 77-83.