Application of Eco-Friendly Geotextiles for Landslide Mitigation in a Part of Ooty Hills, Tamil Nadu

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ABSTRACT

Landslide is one of the major natural hazards the world is facing. It happens as a result of both man-made as well as natural factors. It causes severe effects on the environment as well as for the mankind. The main triggering factors of landslide are rainfall/snowfall, tectonic activities and human activities. There are many methods adopted for controlling landslides. The study was carried out to know the application of geotextiles in slope stabilization. Ooty is one of the main areas in India which is prone to landslides. Many loose their life, property etc due to landslides every year. The present study attempted in Kattery watershed. Various thematic maps pertaining to landslide hazard studies were prepared from the toposheets and satellite imageries using GIS. Finally the landslide hazard zonation map of Kattery watershed was prepared by assigning proper weights and ranks for various themes. The north eastern and south western part of Kattery watershed is more vulnerable to landslides and the south eastern part is less vulnerable. About 200 kg of soil sample from the landslide site was collected and transported to the laboratory. Physical, chemical and engineering properties of the soil were tested in the laboratory. The laboratory results show that the soil is classified as inorganic soil of low plasticity. The optimum moisture content of the soil is 23.5% and the maximum dry density is 1.61g/cc. The result of direct shear test indicates that the angle of internal friction is 38°. The Liquid Limit of the soil is 45 % and the Plastic Limit is 31.40%. To understand the application of coir geotextile for soil erosion and slope stabilization, laboratory models were created, and the soil was tested by varying slope and moisture content. The model demonstrated that geotextiles performed better for protection of slope and soil erosion. As the coir geotextile is biodegradable and eco-friendly it will not affect the environment also.

Keywords: Eco-Friendly, Geotextiles, Landslide Mitigation, Ooty hills

1. INTRODUCTION

A landslide is a geological phenomenon which is simply defined as the mass movement of rock, debris or earth down a slope and has come to include a broad range of motions whereby falling, sliding and flowing under the influence of gravity dislodges earth material. Landslide is Defined as the movement of a mass of rock debris, or earth down the slopes (Cruden, 1991). The term 'Landslide' encompasses events such as ground movement, rock falls, and failures of slopes, topples, slides, spreads, and flows such as debris flows, mudflows or mudslides (Varnes, 1996). They often take place in conjunction with earthquakes, floods and volcanic eruption.

TYPES OF LANDSLIDES

The various types of landslides can be differentiated by the kinds of material involved and the mode of movement. Other classification systems incorporate additional variables, such as the rate of movement and the water, air, or ice content of the landslide material.

1.1 LANDSLIDE MITIGATION

Vulnerability to landslide hazards is a function of location, type of human activity, use, and frequency of landslide events. The effects of landslides on people and structures can be lessened by total avoidance of landslide hazard areas or by restricting, prohibiting, or imposing conditions on hazard-zone activity.

1.2 LANDSLIDES AND GEOTEXTILES

Landslides are the major land disturbing activities in the Nilgiri region causing mass erosion problems leading to heavy land degradation, decline in the quality and quantity of water resources and disruption in the communication lines. Re-vegetating of these areas is the final insurance against erosion but such highly degraded lands are difficult to vegetate due to their unstable nature and poor fertility status. Jute and coir geotextile materials have been most popularly used for erosion control and slope stabilization purposes in Europe/USA and most of the geotextile material produced in India is exported to these countries. In India, however, use of these materials for erosion control is not popular. Therefore, natural geotextiles (jute and coir) were experimented to study their efficiency for providing initial mechanical protection and help in establishment of vegetation on degraded steep slopes so that the ultimate protection against erosion would be provided by the lush vegetative cover established in due course of time.

2. SCOPE OF THE STUDY

This project work is carried out in order to study the applicability of Coir Geotextiles for slope stabilization. Landslides in the hilly region causes loss of life and property, damage to natural resources and damage to roads, bridges, telephone, electric lines etc. This leads to immobility of goods and services leading to huge loss of revenue. We can recommend the use of coir geotextiles for the stabilization of the slopes in that area.

3. STUDY AREA

The area of study is Kattery Watershed, which is located in Nilgiri District, Ooty, Tamil Nadu. The study area falls between latitudes 76°41'0"E and 76°45'0"E and longitudes 11°19'0"N and 11°24'0"N. It comes under the toposheet 58 A/11 published by the Survey Of India on 1: 50,000 scale.

4. OBJECTIVES

The study has been carried out with the following objectives

- To delineate landslide hazard zones using remote sensing and GIS
- To assess the engineering properties of soil
- To create a laboratory model for understanding slope stability
- To examine the application of coir geotextiles for the control of landslides
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5. STUDY AREA DESCRIPTION

Kattery Watershed is in the Nilgiri hills of Western Ghats mountains system. It is situated at 6 km from Ooty on the Ooty-Coimbatore Road. The watershed has a maximum elevation of 2400 m above MSL and is characterised with steep slope, lateritic soils and fairly good drainage network. The annual rainfall is about 1000 mm in two monsoons. The climate ranges from mild to very cold. It has an area of 2976 ha spread over 38 hamlets of two revenue villages with a population of 21,250. Besides forests, cultivation of potato and other vegetables on inwardly graded bench terraces was widely adopted earlier and thus problem of erosion and sedimentation down below were largely seen. However, about two decades before, with market fluctuations tea plantation has become popular. Most of the terraces were defaced to plant tea along the slope. Consequently, erosion got accelerated and silts flowing out silted up the Kattery Reservior that caters to the needs of defence's cordite factory at Aravankadu. In 1984-85, the reservoir was desilted at a huge cost and thus this high priority watershed was taken up for treating again to arrest soil erosion, reduce sediment inflow to Kattery Reservoir and improve the Livelihood of the watershed families.The base map of thestudy area is given in the figure 1.

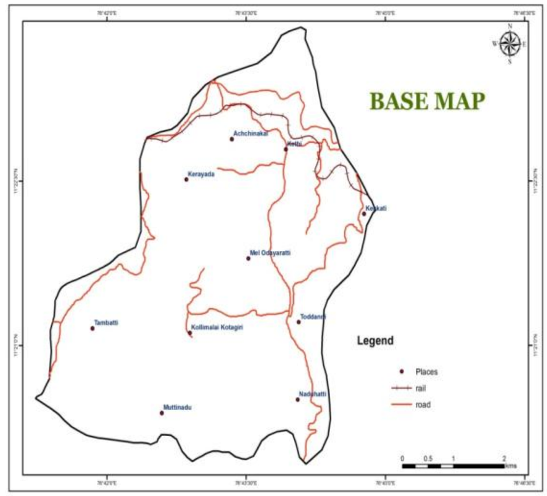

Figure.1 Base map of Kattery Watershed

6. CLIMATE AND RAINFALL

The district receives rainfall from both southwest and northeast monsoons. The southwest monsoon is more active contributing nearly 50 percent in the west and 40 percent in the east. The northeast monsoon is moderate, contributing nearly 40 percent. The precipitation of rainfall gradually decreases towards west to east. The rains during the winter and summer periods are significant. The climate of Nilgiri district is temperate and salubrious throughout the year. Mornings in general are more humid than the afternoons, with the humidity exceeding 90%.

7. GEOLOGY, GEOMORPHOLOGY, DRAINAGE & SOIL TYPE

Structurally the Kattery watershed comprise Archean metamorphic rocks made up of charnockite, biotite gneiss, quartzite & hornblende granite - along with some intrusive bodies like pegmatite dolerite and quartz veins. Apart from these small enclaves of schistose rocks like talc chlorite schist, chlorite schist are also found. The laterite found over the charnockites is hard.

The area falls in the Uthagamandalam – Kotagiri plantation surface which rises to a height of more than 2000 m above MSL. The Uthagamandalam region is more elevated containing Doddabetta peak and its eastern extension the Honnathalai RF. The elevation gradually drops from about 2500 to 1500 m which is the next plantation level referred to as Coonoor plantation surface. Much of the area forms plateau landform in this surface and the erosional action of the streams have resulted in the formation of valleys with steep to moderate slopes.

The plateau, nearly co-terminus with the Nilgiri district, is drained by hundreds of streams. The area forms part of the Moyar River drainage basin. The original consequent drainage has been superposed by a subsequent pattern as a later development, at places. The drainage is mainly dendritic in nature.

The soil of the area falls under two major types - (1) clayey soil, (2) loamy soil. The depth of the soil usually varies from one to three feet and that of the sub-soil from 10 to 14 feet. The sub- soil is invariably porous.

8. METHODOLOGY

To achieve the set objectives the methodology has been divided into five major parts which is illustrated in the figure.2.

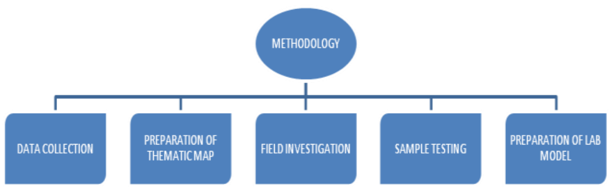

Figure.2. Flow chart of the methodology

9. DATA COLLECTION

- Various literatures related to coir geotextile and its application for slope stabilization were collected
- Toposheet of the study area and various satellite images were collected for preparation of various thematic maps pertaining to this study
- Rainfall details were collected form government departments
- The available maps such as soil and geology of the area were collected
- Coir geotextile materials were collected from a Geotextile manufacturing factory located in Alleppey

10. PREPARATION OF THEMATIC MAPS

Several thematic maps have been prepared to understand various parameters like drainage, slope, geology, geomorphology etc inorder to get an idea about the study area. All the thematic maps were integrated using GIS and finally the landslide hazard zonation map of the watershed has been prepared after giving proper weightage and rank.

11. FIELD INVESTIGATION

Field work was carried out in Ooty to verify the thematic maps and also to collect soil samples for preparation of laboratory model. Recent landslides and old landslide scars were investigated in the field. About 150 kg soil sample was collected from the Kattery landslide site and transported to the laboratory for assessing engineering properties. The area of recent landslide is Achanakal which occurred in the year 2009.

12. SAMPLE TESTING

The soil sample was tested in the laboratory to understand its various physical and engineering properties (Figure.3).

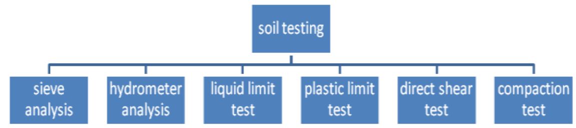

Figure.3. Soil testing

13. PREPARATION OF LAB MODEL

Since the complete study cannot be carried out in the field to understand the usage of gotextiles, a lab model was created with the samples collected from the study area. About 150 kg of soil sample was used for the construction of the model (Figure.4). A slope was decided for the model. The angle at which the slope failed (angle of repose) was measured for the two conditions namely (1) slope without geotextile (2) slope with geotextile. The experiment was also extended for the increased moisture content also.

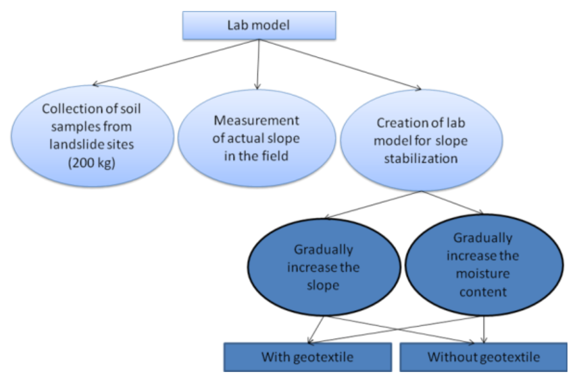

Figure.4. Flow chart of laboratory model

14. GEOTEXTILES & COIR GEOTEXTILE

Geotextiles are permeable fabrics which, when used in association with soil, have the ability to separate, filter, reinforce, protect, or drain. Typically made from polypropylene or polyester, geotextile fabrics come in three basic forms: woven (looks like mail bag sacking), needle punched (looks like felt), or heat bonded (looks like ironed felt).Coir geotextiles can be classified as woven and non-woven based on the method of manufacture. These can be further reclassified as Woven Coir Geotextiles and Non-Woven Coir Geotextiles.

15. LANDSLIDE VULNERABILITY ASSESSMENT

Several thematic maps (Figure.5.) pertaining to this study were prepared from toposheet and satellite imageries.

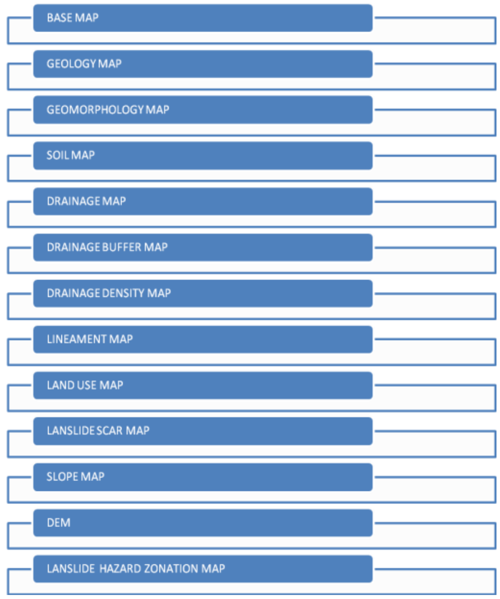

Figure.5.Several thematic maps

16. SOIL TESTING

For the implementation of geotextiles, it is necessary to determine the various physiochemical properties of the soil. Hence various tests were carried out in the laboratory.

1. Sieve Analysis 2. Hydrometer Analysis 3. Liquid Limit 4. Plastic Limit 5. Direct Shear Test 6. Compaction Test 7.Geochemical Analysis

17. GEOCHEMICAL ANALYSIS

17.1 XRF Studies

X-ray fluorescence (XRF) spectrometer is an x-ray instrument used for routine, relatively non-destructive chemical analyses of rocks, minerals, sediments and fluids. It works on wavelength-dispersive spectroscopic principles that are similar to an electron microprobe (EPMA). However, an XRF cannot generally make analyses at the small spot sizes typical of EPMA work (2-5 microns), so it is typically used for bulk analyses of larger fractions of geological materials. The relative ease and low cost of sample preparation, and the stability and ease of use of x-ray spectrometers make this one of the most widely used methods for analysis of major and trace elements in rocks, minerals, and sediment.

17. 2 XRD Studies

X-ray fluorescence (XRF) is the emission of characteristic "secondary" (or fluorescent) X-rays from a material that has been excited by bombarding with high-energy X-rays or gamma rays. The phenomenon is widely used for elemental analysis and chemical analysis, particularly in the investigation of metals, glass, ceramics and building materials, and for research in geochemistry, forensic science and archaeology.

18. PREPARATION OF LAB MODEL

First, a platform was constructed using plywood sheets covering three sides for building the landslide model ((Figure.6.)

About 150 kg of soil sample was filled in this platform inorder to create a model of a hill with a slope of 36°.

The model was divided into two halfs. One side was kept free without geotextile and the other side was fixed with geotextile.

Step 1:

- Slowly the slope was increased by lifting the entire model.
- The angle at which the slope failed for both the parts were noted separately.

Step 2:

- Water was added into both the parts simultaneously.
- The angles at which both the parts failed were noted separately.

Figure. 6. Landslide model constructed in the laboratory

19. RESULTS AND DISCUSSION

SIEVE AND HYDROMETER ANALYSIS:

The graph (Figure.7.) shows that the sand percentage of the soil sample of Kattery landslide is 37%; silt percentage is 50% and clay percentage is 13%. Since there are no values below D_{10} the soil can not be classified using the result of sieve hydrometer analysis.

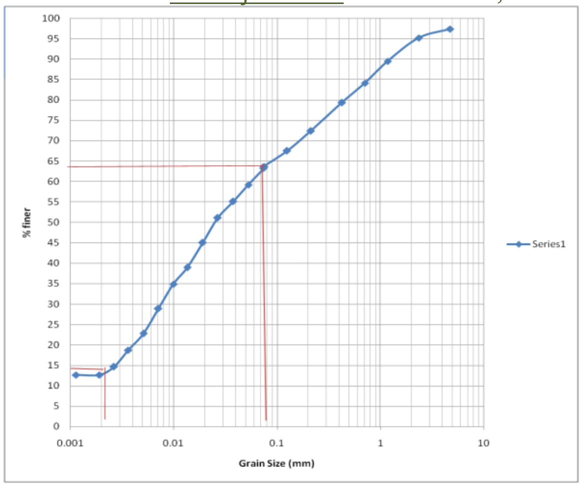

Figure.7. Graph for sieve analysis and hydrometer analysis

20. LIQUID LIMIT

Experiment result of liquid limit is presented in the graph (Figure.8) shows that the liquid limit of the sample is 45 %.

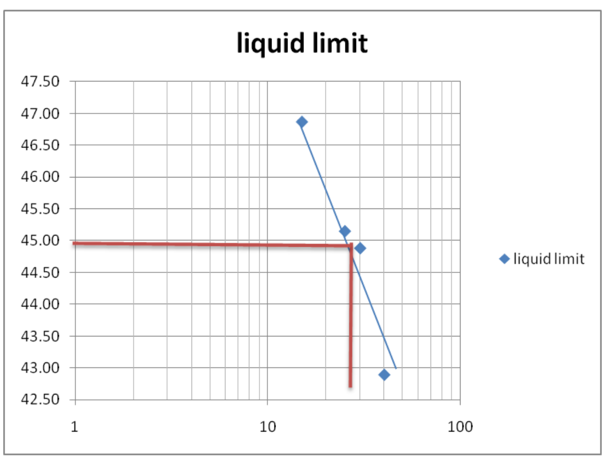

Figure.8. Plot of Liquid limit

21.PLASTIC LIMIT&PLASTICITY INDEX

Experiment result of plastic limit of the soil sample is 31.40%.`

PI = LL-PL where: LL = liquid limit, and PL = plastic limit.
PI = 45-32 = ***13 %***

The graph (Figure.9.) it is understood that the sample of the study area falls in the ML category, which indicate inorganic soils of low plasticity.

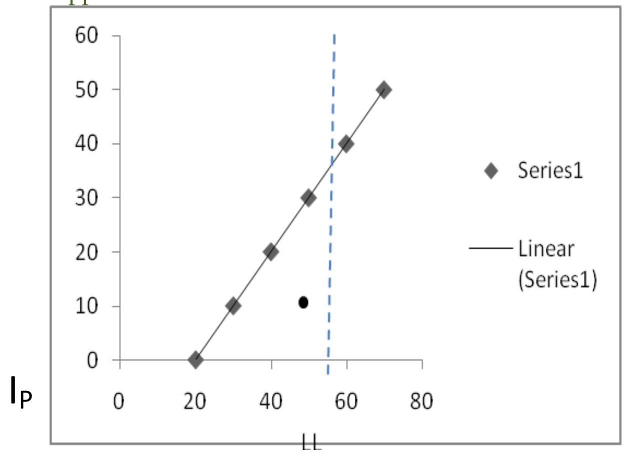

Figure.9. Plot of Plasticity Index Figure

22. DIRECT SHEAR TEST

The results of direct shear test are presented in the graph (Figure.10.), we can calculate the angle of internal friction. Beyond the angle of internal friction the failure can happen. From the graph the angle of internal friction is measured as 38⁰ for the sample of the study area

Slope = (1.4-1) / (1.5-1) =0.8 ***Tan***$^{-1}$***(0.8) = 38⁰***

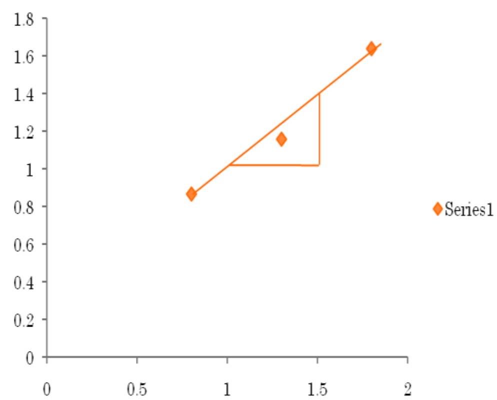

Figure.10. Plot of direct shear test

23. COMPACTION TEST

The results of compaction test are presented in the graph (Figure.11), the value for the optimum moisture content is obtained as 23.50 % and maximum dry density is obtained as 1.61 g/cc.

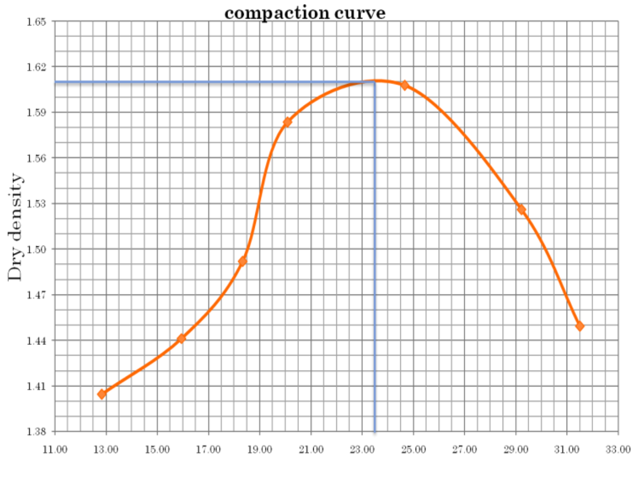

Figure.11. Compaction test curve

24. GEOCHEMISTRY

Chemical composition of the soil sample is determined using the handheld XRF instrument. The concentration of various elements in the soil is presented in XRD chart (Figure.12) of the soil sample shows that quartz, feldspar and pyroxenes are common

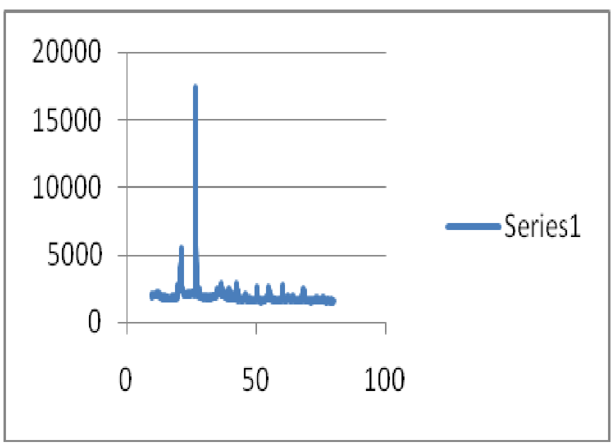

Figure.12. XRD chart of the soil sample

25. LANDSLIDE MODEL

7.7.1 Slope as variable

- ✓ The initial slope of the soil mass in the laboratory model was kept as 36° (Figure.13)
- ✓ The slope was gradually increased by lifting the entire setup
- ✓ The slope failure occurred at 56° where the geotextile is not fixed
- ✓ The slope was further increased up to 60°. However there was no failure in the soil mass where the geotextile is fixed.

Table 7.8 Slope failure of soil mass

Initial slope	Angle of repose	
	Without geotextiles	With geotextiles
36°	56°	-

25.1 Moisture content as variable

- In both the side of the model, the moisture content is gradually increased by spraying water. (Figure.14)
- Rate of erosion was high where the geotextile was not fixed. However the rate of erosion was very less where the geotextile was fixed.

26. CONCLUSIONS

- The soil test results show that the soil is classified as inorganic soil of low plasticity and its optimum moisture content is 23.50%

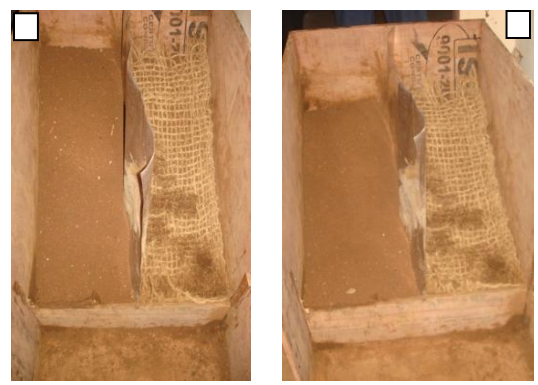

Figure.13 Slope failure of soil mass in the lab model

Soil without geotextile Soil with geotextile

Figure.14. Erosional behaviour of soil

- The soil of the study area contains 50% of silt and 13% of clay
- The maximum dry density of the soil is 1.61g/cc and the angle of internal friction is 38°
- The Liquid Limit of the soil sample is 45 % and the Plastic Limit is 31.40%
- The XRD results indicate that the soil contains quartz, feldspar, pyroxene and clay minerals.
- The landslide hazard zonation map shows that the north eastern and south western part of Kattery watershed is more vulnerable to landslides, whereas the south eastern part is less vulnerable.
- There are much possibilities of occurrence of landslide in the area where the landslide occurred during the year 2009 (near Achanekal)
- The laboratory model demonstrates that geotextiles can be used for slope stabilization and erosion control.
- As the coir geotextile is biodegradable and eco-friendly it will not affect the environment. Plantation can also be done over the geotextiles.

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