Experimental Investigation on the Effects of Geotextiles in Subsurface Erosion

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Abstract— Subsurface flow is known to contribute significantly to stream flow but its contribution to stream bank failure, a process which may contribute significantly to sediment loading in streams, is not well known. The effect of seepage or subsurface flow is usually considered to be limited to the production of surface runoff and the reduction of soil shear strength, there by underestimating the potential effects of seepage on erosion. From a geomorphologic perspective, subsurface hydraulic erosion is an important geomorphic process in the head watershed, because soil piping and water discharge via the pipes significantly affect hydrology, channel initiation, and slope evolution, as well as gully extension by tunnel scour erosion. In this study experiments were conducted in a reconstructed soil bank within a lysimeter. The feasibility of using non woven coir geotextiles as a control measure to seepage erosion was analysed. The introduction of non woven coir geotextiles found suitable to reduce stream bank erosion due to subsurface flow.

Keywords—Subsurface flow; seepage erosion; non woven coir geotextiles.

I. INTRODUCTION

A mechanism of stream bank erosion that has received relatively less attention historically, but its importance is being increasingly considered, is seepage erosion. Seepage erosion commonly results in stream bank failures on the recession limbs of stream flow hydrographs through the development of a head cut by liquefaction of soil particles at the stream bank face. Sapping is often used interchangeably with seepage; however, sapping is used here to include the material eroded by bank failure resulting from seepage erosion. High infiltration rates can cause the development of perched water tables above water-restricting horizons in riparian soils. As perched water tables rise on these less permeable layers, large hydraulic gradients can initiate towards stream channels, causing fairly rapid subsurface flow (interflow) towards streams. Subsurface flow within perched water tables can contribute in gully formation. Shallow subsurface flow plays a critical role in erosion in interacting with surface runoff mechanisms [5].

Bank erosion is one of the fundamental processes involved in channel migration and formation of flood plains. This is because the most important mechanisms in fluvial geomorphology are the hydraulic forces exerted by the flow. Flow in natural channels is a complex interaction between surface and subsurface flow. Water is continuously seeping into or out of the channel bed and channel banks. In most cases the magnitude of seepage flow is small in relation to the total flow. Seepage flow through boundaries of alluvial channels, rivers, and streams is a common occurrence because of porosity of the earthen material and the difference between water levels in the channel and the adjoining ground-water table.

Soil erosion is an inevitable environmental hazard anywhere in the world. One of the most effective and natural soil erosion prevention techniques is the use of coir geotextiles fabrics and are used extensively to prevent environmental degradation. Coir geotextiles have been used in various slope stabilization projects and soil erosion control. Coir fiber, derived from coconut, is a natural material available abundantly in a large part of south India and other coastal areas in India, Srilanka, Indonesia, Philippines, Brazil, and other equatorial regions, Due to its high lignin content (46%), it is stronger than other natural materials such as jute or cotton. Coir geotextiles are manufactured using various processes such as retting the coconut husk, separating it into fibers, making yarn, and then weaving it to obtain the desired type of geotextile. Coir fibers can also be used directly in applications such as erosion or seepage control. These are used widely for many other purposes such as stream and river bank protection, slope stabilization in embankments, Sediment control, reinforcement of rural unpaved roads, filtration in road drains, and erosion control in wetland environment [2].

Coir geotextiles protect the soil until the vegetation permanently covers its mesh. It gives the plants adequate room to grow and decomposes naturally into humus which will enrich and nourish the soil. Lasting between two to five years the coir fiber, compared to other natural fibers such as jute that is also used to control soil erosion, has several unique features. Known to be a good water absorbent the geotextiles has the ability to retain water three times more than its actual weight preventing the need to frequently water the plants. However at the same time with its adequate space within the mesh it drains the excess water easily preventing water from logging. With an easy installing method the coir geotextiles needs no chemical treatment as it lets in the right amount of air and light for a deeper rooted plant.

Coir geotextiles are reported to have applicability in conserving soil and moisture. Another reported advantage is its biodegradable nature, leaving no unwanted residues in ecosystem. Geotextiles cocolog has the ability to reduce water velocity by acting as semi- pervious media. This property of cocologs has prompted in using it for checking stream bank erosion as a temporary control material.

A study on sediment transport model for seepage erosion of stream bank sediment was conducted by Fox *et al.* In the absence of an established sediment transport model for seepage erosion, the objectives of this research were to investigate the mechanisms of erosion due to concentrated, lateral subsurface flow and develop an empirical sediment transport model for seepage erosion of non cohesive sediment on near-vertical stream banks [4].

A lysimeter experiment and modeling on erosion of non cohesive sediment by ground water seepage was conducted by Fox *et al.*. Laboratory experiments were performed using a two-dimensional soil lysimeter. The experiments were conducted on two sandy soils: field soil (loamy sand) and sieved sand with greater sand content and less cohesion. The research then determined whether integrated finite element and bank stability models were capable of capturing both small and large scale sapping failures [3].

Objective of this study is to examine the possibility of using non woven coir geotextiles for controlling seepage erosion with non woven coir geotextiles at different layers on a sloped soil bank.

II. EXPERIMENTAL SETUP

The experiments were conducted in a lysimeter made up of Plexiglas of 4mm thickness and of dimensions 50cmX50cmX30cm as shown in figure 1. The lysimeter had a water reservoir on one end to maintain a constant water head during the experiments. An inflow tube allowed water to flow into the reservoir from the bottom. A porous plate made of 4.0 mm Plexiglas was inserted between the reservoir and the main body of the lysimeter. This porous plate had 0.3mm diameter holes. Overflow openings were located at 15 cm, 25 cm, and 35 cm from the bottom of the lysimeter on the inflow end. The outflow end of the lysimeter was flumed to allow sampling of flow and sediment.

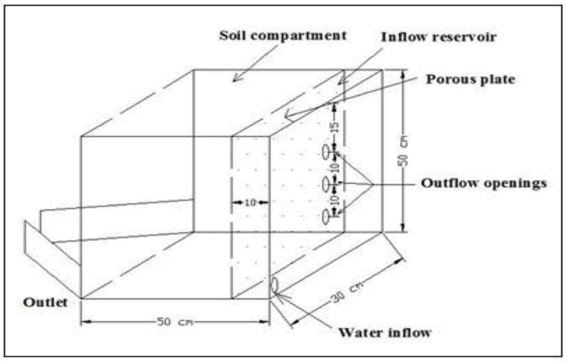

Figure1: Experimental lysimeter with inflow reservoir and Water outlet flume

The experiments were conducted with the material collected from the banks of Karamana River. The sample was analysed to get all the preliminary physical properties. The tests conducted are field density, sieve analysis, specific gravity, direct shear and standard proctor test [1]. Experiments were conducted on a soil block with slope 45^0 without geotextiles and with non woven coir geotextiles at three different positions for an inflow head of 15 cm. The non woven coir geotextiles used in the experiments have mass/unit area 940 g/ m^2, nominal thickness 10.3 mm, permeability $3.57x10^{-7}$ cm/sec, apparent opening size 2.36 mm are obtained through sample test on non woven coir geotextiles [6]. Figure 2 shows the positions of non woven coir geotextile placed at different layers.

- Position I- Placed vertically along the starting of sloping face of bank.
- Position II- Placed slanting at a height of 15 cm from the heel of soil block along the top flow line.
- Position III- placed slanting at a height of 25 cm from the heel of soil block above the top flow line.

The required soil was filled in the lysimeter at 90% of optimum moisture content by hand compaction. Water was added to the inflow reservoir to achieve the desired head. As the soil layer eroded and the undercutting occurred, flow and sediment samples were collected in sampling bottles at regular intervals.

Cumulative seepage erosion was measured as the seepage eroded soil upto bank failure. A series of 4 lysimeter experiments were conducted with soil block of height 25 cm and inflow head 15 cm and is as summarized in table I. Figure 2 shows the failure pattern of soil bank slope 45^0 without geotextiles and inflow head of 15 cm.

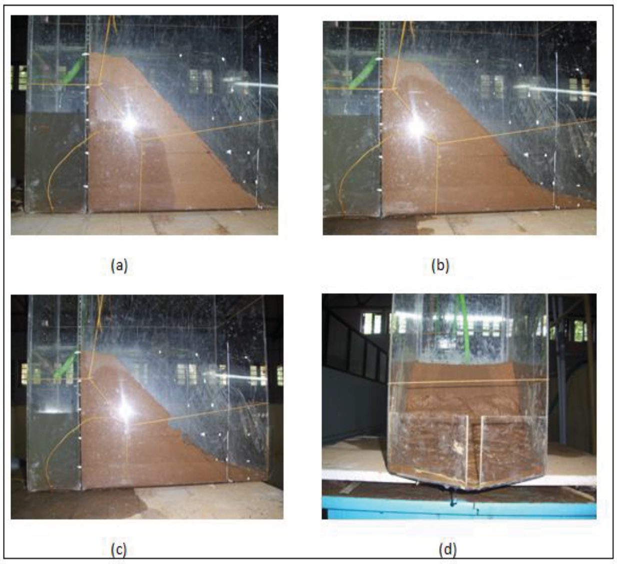

Figure 2.Failure pattern of bank slope 45^0 without geotextiles and inflow head of 15 cm , (a)Lysimeter with soil block 25X30X30 cm with inflow head 15 cm, (b)Lysimeter with soil block in sapping erosion, (c) Soil block with undercut, (d) Lysimeter with soil block after breaking

The erosion by seepage is a progressive process, starts from saaping erosion at the toe of the bank ,proceeds to soil block undercut formation followed finally by the bank collapse. The cumulative seepage erosion and discharge were measured and the time required to bank failure from the beginning of experiment was recorded . The same experiment was repeated by placing non woven coir geotextiles at the three various posions as shown in figure 3.

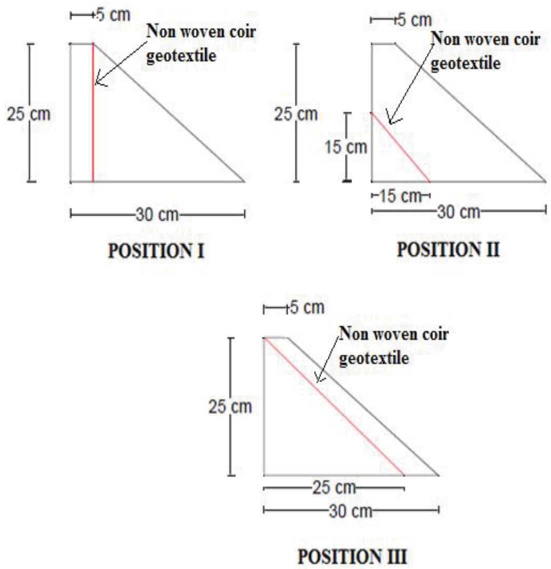

Figure 3. Positions of non woven coir geotextile placed in experiments

TABLE I SUMMARY OF LYSIMETER EXPERIMENTS

Experiment No.	*Bank slope*	*Inflow Head (cm)*	*Description*
1	45^0	15 cm	Without geotextiles
2	45^0	15 cm	With non woven coir geotextiles at position I
3	45^0	15 cm	With non woven coir geotextiles at position II
4	45^0	15 cm	With non woven coir geotextiles at position III

III. RESULTS AND DISCUSSIONS

Experiments were conducted with non woven geotextiles for a bank slope of 45^0 at three various positions. Measurements taken are time required to bank failure, cumulative seepage erosion, discharge and bank failure dimensions. The same experiment was conducted without non woven geotxtile for the bank slope of 45^0 . Experiments with geotextiles shown much better results in comparison with the same conducted without geotextiles. The soil block without geotextiles failed after 2127 seconds. For position I and position II experiments, bank failed after 2460 seconds and 2160 seconds respectively. For position III experiments bank does not failed within the experimental time frame. The measured discharge decreased from position I to position III. The seepage erosion and discharge were less in experiments with geotextiles than that with out geotextiles. On the other hand, the time required to bank failure increased in experiments with geotextiles. The results are summarized in table II.

TABLE II. SUMMARY OF EXPERIMENTAL RESULTS ON SOIL BANKS OF HEIGHT 25 CM AND INFLOW HEAD 15 CM

Sl No	*Bank angle (Degrees)*	*Water head (cm)*	*Time to failure (sec)*	*Cummulative seepage erosion (kg)*	*Q (ml/Sec)*
1	45	15	2127	1.228	8
1	45 – I	15	2624	1.14	2.1
2	45- II	15	2820	0.78	1.48
3	45- III	15	NF	NF	0.53

The bank failure dimensions were measured for soil block with slope 45^0 for all the experiments and are listed in table III. The failure dimension was measured as the vertical height from toe of the soil block and is as shown in figure 4.

TABLE III . BANK FAILURE DIMENSIONS

Sl. No	*Experiment Type*	*Bank slope (Degrees)*	*Failure height from toe of soil block (cm)*
1	Without Geotextiles	45	17
2	Position I Geotextiles	45	12
3	Position II Geotextiles	45	10

For experiment with out geotextiles, the bank failed at a height of 17 cm from the bottom. For experiments with geotextiles at position I and II, the failure was 12cm and 10 cm respectively for 15cm head. For position III experiment, the bank does not break. Experiments with geotextiles shown much better performance than the others. This is mainly due to the property of coir geotextiles to reduce seepage velocity and their by increasing the piping resistance of the soil. Inclusion of coir fibers in soil reduced the detachment of individual soil particles when water flows through the soil mass.

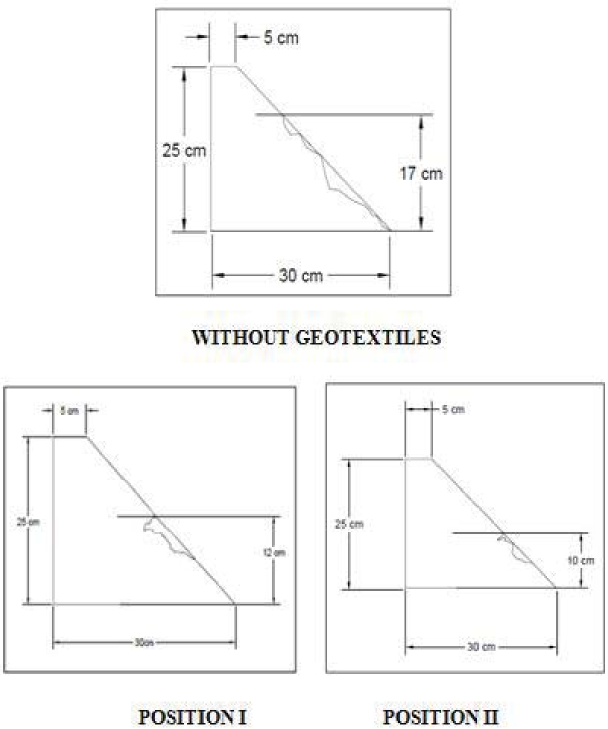

Figure 4. Failure pattern

The set experiments with geotextiles were compared with experiment without geotextiles inorder to calculate the percent reduction in cumulative seepage erosion and discharge and are summarized in table IV.

TABLE IV. PERCENTAGE REDUCTION OF EXPERIMENTS WITH GEOTEXTILRS FROM EXPERIMENT WITHOUT GEOTEXTILE

Sl No	*Position of geotextile*	*Discharge (%)*	*Cumulative seepage erosion (%)*
1	I	73.75	7.16
2	II	81.5	36
3	III	92.75	100

The experiments with geotextiles shown much better performance than that of experiment without geotextiles. It has greater bank failure time and reduced erosion rates and discharge than set I experiments (Soil block without geotextile and slope 45^0). The reduction in discharge for position I, II, III experiments are 73.75%, 81.5% and 92.75% respectevly from set I experiments. Cumulative seepage erosion decrease by 7.16%, 36% and 100% for positions I, II, III receptively from experiment without geotextiles.

The results has been shown that, as the position of geotextiles changed towards the outer bank face (i.e,position III), the bank protection rate increase, i.e, the erosion rate and seepage discharges get reduced than other positions (i.e, positions I and II) and bank seems to be more stable when the geotextiles are more close to the bank face. The three experiments performed with non woven geotextiles shown reduction in seepage erosion , discharge and bank collapse than experiments on soil block without geotextile and slope 45^0.

Among all the experiments, experiments with non woven coir geotextiles shown the best bank failure time and reduced discharge and cumulative seepage erosion. Among the experiments with geotextiles at position III found to be the most stable against bank failure and seepage erosion rates.

IV. CONCLUSION

This study analysed the feasibility of using non woven coir geotextiles as a control measure to seepage due to subsurface flow by conducting experiments on a reconstructed soil bank within a lysimeter. Experiments with geotextiles shown much better performance than the other conducted without geotextiles . The experiments with geotextiles shown 70-92% reduction in seepage discharge and 7-100% reduction in cumulative seepage erosion.

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This is mainly due to the property of coir geotextiles to reduce seepage velocity and their by increasing the piping resistance of the soil. Inclusion of coir fibers in soil reduced the detachment of individual soil particles when water flows through the soil mass. In the context of sustainable eco-friendly riverbank management, coir geotextiles can be used to strengthen the riverbank and protect them from erosion, which is cost effective and efficient compared to other conventional technologies. This technology not only prevent the riverbank erosion, but also helps in sedimentation of the soil particles carried with the flood water along the river bank.

References

[1] Arora K.R. (2009), "Soil Mechanics and Foundation Engineering (Geotechnical Engineering)", Standard Publications, New Delhi.

[2] Bipin J Agrawal (2011), "Geotextile: It's Application To Civil Engineeering – Overview", National Conference on Recent Trends in Engineering & Technology, B.V.M. Engineering College, V.V.Nagar,Gujarat, India.

[3] G.A. Fox, M.L. Chu-Agor and G.V.Wilson , "Erosion of Noncohesive Sediment by Groundwater Seepage: Lysimeter Experiments and Modeling",An American Society of Agricultural and Biological Engineers Meeting Presentation, Paper Number : 072235, 2007.

[4] G.A.Fox, G.V.Wilson, R.K. Periketi and R.F.Cullum, "Sediment Transport Model for Seepage erosion of stream bank Sediment", Journal of Hydrologic Engineering, vol.11, No.6, pp 603-611, 2006.

[5] Howard A.D. and McLane C.F., "Erosion of Cohesionless Sediment by Groundwater Seepage", Water Resource Research,24(10),1659-1674, 1988.

[6] Venkatappa Rao and Goutam K.Pothal, " Geosynthetics Testing-A Laboratory Manual", Technical Publication Division, Hyderabad, 2008.