Erosion Control of River Banks using Coir Geeotextiles

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ABSTRACT: River bank erosion occurs due to detachment of grains from the bank, followed by fluvial entrainment. Coir geotextiles are now being used as popular solution for erosion control and slope stabilization. In the present work, physical model studies were conducted on an undistorted river model to determine the efficacy of coir geotextiles as a river bank protection measure. Experiments were conducted with woven geotextile mat and cocolog along with woven coir geotextile mat, placed on the river banks. Cocologs are long knotted coir nettings filled with coir fibres. Erosion patterns were observed for different discharges and the cross section changes at different sections for different discharges and bed contours were plotted. Geotextile mat acted as check dams and arrested the migration of soil particles from river banks. Placement of cocologs reduced river bank erosion by absorbing water and reducing the velocity of flow by acting as a semi pervious media.

1 INTRODUCTION

Rivers, except when flowing through well-defined narrow sections confined by high and stiff banks, have caused problems of flooding, change of course, banks erosion etc. Bank erosion can lead to large amount of losses in terms of human life and other utilities. Hence bank protection measures which aim at maintaining the stability of the cross section of river against the action of water is necessary. Commonly used bank protection measures are groins, revetment, riprap etc. Even though they have proven to be effective, most of them are costly and causes environmental issues. Geotextiles have come to play an increasingly important role in civil engineering and are being used for river bank protection. Geotextiles consisting of woven mats, rolls or bags of natural fibres are placed on the bank surface or bank toe to prevent fluvial scour and the removal of fines from the bank face. Coir (coconut fiber) geotextiles are now being used as popular solution for erosion control, slope stabilization and bioengineering, due to the fabric's substantial mechanical strength and its applicability to conserve soil and moisture. Coir geotextiles are better preferred compared to other natural materials owing to their properties like durability, strength, hairy surface etc. Since Kerala state is an abundant source of coconut trees, coir geotextiles are available at low cost. Cocologs are long knotted coir nettings filled with coir fibre. They are 100 % natural material and biodegradable, has high tensile strength, high water absorbency, is easy to install and is eco- friendly.

Various experimental studies were conducted on effectiveness of groynes in river bank protection (Heever (2013)). Sudhakaran (1994), Subha et al. (2012) conducted various field studies were conducted to test the effectiveness of coir geotextiles for embankment protection. Anil et al. (2011) conducted field experiments using cocologs placed as spurs in southern Kerala and found that cocologs strengthened river bank and was cost effective. Shailaja and Jyothis (2002) conducted experimental studies on erosion control of river banks using three types of geotextile mats on cohesive and non-cohesive soils. Geotextiles effectively protected banks by reducing velocity of flow and restraining particles from moving away.

Hence in the present study physical models of river bank were prepared in a flume and the efficacy of coir geotextiles and cocologs were evaluated in protecting the river bank against erosion.

2 PHYSICAL MODEL STUDIES

Experiments were conducted on an undistorted river model in a rectangular flume of size 12.95 x 1.2 x 0.95 m. Based on the model production space available, a suitable scale of 1: 25 was selected. The cross section of river model in the flume is shown in Fig. 1. The bed slope and side slopes are 1 in 117 and 1:1.25 respectively.

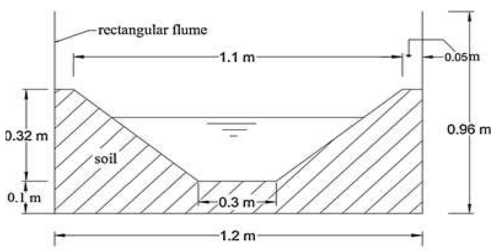

Fig. 1 River model cross section

Fig. 2 shows the model setup in the flume. 60^0 V -notch was fixed at the upstream of the flume for measuring discharge. Notch was fixed at a distance of 1.1 m from the river model so that the turbulence of water falling from the notch doesn't affect the bed and banks. Soil from Karamana river bank, Trivandrum district was used for conducting the model studies. Field density of the area was determined. The trapezoidal river model was set up in the flume with the same soil collected from the field for a length of 3.5 m. Thickness of bed provided in the model was 10 cm. To simulate field density in the model, volume of model was calculated and quantity of soil corresponding to the field density was used to setup the model. Same cross section was made in bricks for a length of 1.1 m upstream and 0.5 m downstream of the river model and was plastered for maintaining same velocity throughout the section. The V notch was calibrated and the calibration curve was developed. The calibration equation is $Q = 0.95\ H^{2.5}$.

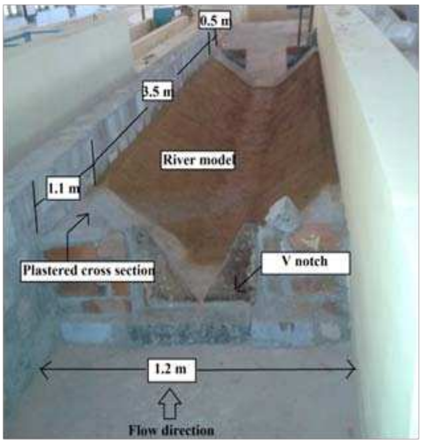

Fig. 2 Model setup in the flume

2.1 *Materials used*

Cocologs are usually available in diameters of 20 cm to 50 cm. A polypropylene geotextile of tensile strength 1.57 kN/m and opening size 1 cm was used as the outer covering of cocolog model. The model was prepared by filling coir fibres inside the outer covering, of diameter 2.5 cm, to achieve density of 144 kg/m^3. A 400gsm woven coir geotextile mat having an opening size of 2.25 cm x 2.25 cm was also used in the study. The geotechnical properties of the materials used are given in Table 1. Soil from Karamana river bank, Trivandrum district was used for conducting the model studies. The soil was poorly graded fine sand with effective size of 0.15 mm.

Table 1. Properties of materials used

Soil Properties	
Effective size , d_{10}(mm)	0.15
Field dry density, ρ_d (g/cm^3)	1.55
Minimum density, ρ_{min} (g/cm^3)	1.37
Maximum density, ρ_{max} (g/cm^3)	1.66
Minimum void ratio, e_{min}	0.59
Maximum void ratio, e_{max}	0.93
Natural void ratio, e	0.70
Relative density (%)	65
Geotextile Properties	
Mass/ Unit area (g/m^2)	400
Thickness (mm)	6.96
Tensile strength (kN/m)	2.98
Density of Cocolog (kg/m^3)	144

3 EXPERIMENTS CONDUCTED

Experiments were conducted in the river model without any bank protection measures to quantify erosion. Water was allowed to flow through the section at small discharge, to saturate the section. Discharge was increased further by controlling the valve. Observations were measured after the flow became steady. The experiments were conducted for 6 discharges i.e. 0.01 m^3/s, 0.013 m^3/s, 0.017 m^3/s, 0.022 m^3/s, 0.027 m^3/s and 0.033 m^3/s. Erosion patterns were measured at 8 sections i.e. L_0,$L_{0.5}$, L_1,$L_{1.5}$,L_2,$L_{2.5}$,$L_3$and $L_{3.5}$ along longitudinal direction at 0.5 m apart. Velocity measurements were conducted at 4 sections at 1 m apart in longitudinal direction using pitot tube.In transverse direction, measurements were taken at 3 sections along the top width (T) at bank toe, centre of cross section and half the distance between bank toe and centre which worked out to be 0.36 T, 0.50 T and 0.43 T respectively. At each section velocities were measured at surface, 0.2d, 0.6d and 0.8d where d is the depth of water from water surface.Water levels were measured using point gauge. Three sets of experiments were conducted with (a) no protection on side slopes (UB) (b) woven geotextile mat over side slopes(WCGM) (c) one cocolog at the bottom of side slopes over woven geotextile mat (WCGML1).

Fig. 3 shows condition of river model before and after UB. Experiments were repeated with 400 gsm

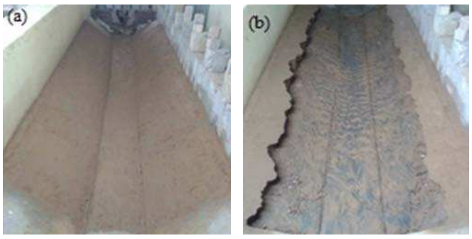

Fig. 3 River model without protection work
(a) before experiment (b) after experiment

woven geotextile mats fixed on the banks as measure, anchored using 3 mm metal wires bend in U shape. The anchors were inserted into the bank at 90^0 at a spacing of 35 cm. Rigid cross sections at either ends of the movable river models were also covered with geotextile mat so that the flow conditions remains same throughout the section. One cocolog was placed at the bottom of side slopes over woven geotextile mat and the experiments were repeated. The initial and final condition of model during the experiment is shown in Fig. 4.

Fig. 4 River model with geotextile mat and cocolog
(a) before experiment (b) after experiment

4 RESULTS AND DISCUSSION

4.1 *Velocity profiles*

Variation of velocity in the vertical direction along the cross section at $L_{1.5}$ for the three experimental setups were studied and observed that maximum velocity occurs at the centre of cross section (0.5 T) at 0.2 d from the water surface in all cases. Further it is noticed that velocity increases towards the centre of cross section and is maximum at the centre. Since the cross section was symmetrical about central longitudinal axis of river model, analysis was done only for half the width of cross section.

For erosion studies velocity near the bed and bank of the river is more important than the velocity at the centre of flow, as this velocity that is responsible for the erosion. Hence velocity at 0.8d (near bed) at 0.36 T (bank toe) was considered for further analysis. Fig. 5 depicts the comparison of velocity at 0.8 d with discharge for WCGML1. Maximum velocity was observed in case of UB. The placement of geotextile mat decreased the velocity of flow due to the increase in resistance to flow offered by geotextile mat. When cocologs were placed above the mat, velocity first increased more than that without any protection. This may be due to the fact that placement of cocolog reduces the waterway which in turn increases the velocity. As water flows, cocologs absorb water which in turn reduces velocity of flow. When discharge was increased, the velocity was more or less equal to the case of WCGM, up to a discharge of $0.027 m^3/s$. Further increase of discharge showed a decrease in velocity than the case of WCGM. Minimum velocity was observed in case of WCGML1.

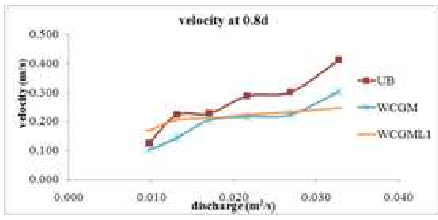

Fig. 5 Variation of velocity at 0.8d at $L_{1.5}$ at 0.36T with discharge for WCGM and WCGML1

4.2 *Water surface profiles*

Fig. 6 illustrates the comparison of water surface profiles for different discharges in the three experiments. Minimum water depth was observed in the case of UB. Placement of geotextiles increased water depth. Increase in water depth in cases of WCGM and WCGML1 were similar initially. As discharge increased, maximum water depth was observed in case of WCGML1. This may be due to contraction of waterway with the placement of cocologs.

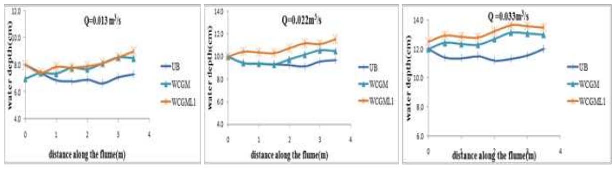

Fig. 6 Water surface profiles along the flow for different discharges

4.3 *Erosion patterns*

Cross sections of river model at different sections after experiment setups UB, WCGM and WCGML1 for maximum discharge of $0.033 m^3/s$ studied. When no protection was provided, sediments, detached from the bed and banks at low discharge itself even above the water level. As discharge increased erosion also increased and the eroded bank got deposited on the bed which resulted in increase in thickness of bed towards downstream direction. Increase in thickness of bed caused reduction in area of cross section and hence velocity increased further. When woven geotextile mat was placed, it acted as check dams and arrested the migration of soil particles by flowing water. It also increased the resistance to flow which in

turn reduced the velocity. Hence erosion of slope was reduced considerably. Soil particles got trapped in between the grids of geotextile mat. In WCGML1, the erosion was found to be minimum. Geotextile mat and cocolog together acted as reinforcement to the soil and attained bank stability. At higher discharges banks eroded at water surface level and the eroded bank got deposited on the sides of both cocologs. Hence banks were stabilized and the soil particles were retained on the bank. As erosion was controlled, there was no deposition on the bed. Hence the bed erosion caused by the flowing water was maximum in this case.
Fig. 7 (a), (b)and (c) shows bed contours after experiment with discharge Q_6 = 0.033 m^3/s for UB,WCGM and WCGML1 respectively. These

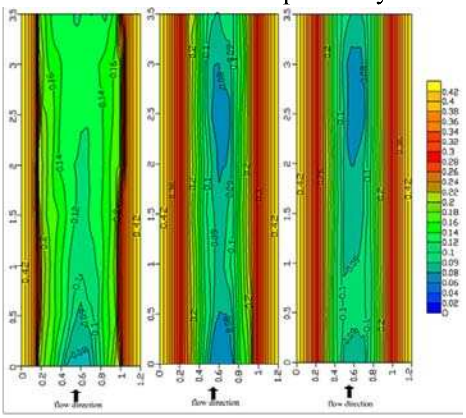

Fig. 7 Bed Contour after Experiment with Q_6= 0.033 m^3/s for (a)UB (b) WCGM (c) WCGML1

were generated from cross-sectional profiles at eight sections at 0.5 m apart in longitudinal direction, using contouring software Surfer v.8. In Fig. 7 (a), erosion observed on bed at upstream end may be due to sudden change in channel material from cement plastered surface to natural soil surface. Bed width was considerably increased throughout the section. Banks were eroded throughout section and deposited on the bed which resulted increase in thickness of bed. Bank was eroded above water surface level. In Fig. 7 (b), when geotextile mat was placed over t side slopes, it acted as check dams and arrested movement of sediment from banks. Hence sufficient bank protection was observed. Since banks were protected, the bed particles were carried more by the moving water and bed erosion increased. Upstream of the channel section which was subjected to more erosion in UB, was more protected as the coir mat was also extended over the plastered surface. The bed erosion increased downstream. In both cases, banks were eroded only upto water surface level whereas in UB, it extended above water surface.

The structural stability of the soil was improved by the tensile strength of the geotextile. Geotextile mat acted as check dams and arrested the migration of soil particles by the flowing water. Volume of cumulative erosion occurred in the river model after UB, WCGM and WCGML1 after 0.033 m^3/s were 0.076, 0.015 and 0.011 m^3 respectively. Percentages reduction in erosion with respect to UB was calculated. When geotextile mat was used, erosion reduced by more than 80 % in both WCGM and WCGML1, and maximum protection was obtained for WCGML1(86 %).

5 CONCLUSIONS

Physical model studies were conducted on an undistorted river model to study the efficacy of coir geotextiles as a river bank protection measure using woven coir geotextile mat and cocologs.

- The placement of geotextiles increased the depth of water and decreased the velocity of flow compared to the unprotected bank (UB).
- Cocolog acted as soft toe armour and protected the side slopes by retaining the sediments above it.
- Cocolog has the ability of reducing water velocity by absorbing water and acting as a semi pervious media.
- Geotextile mat acted as check dams and arrested the migration of soil particles by flowing water.
- The best erosion protection was produced when woven coir geotextile mat was placed over the side slopes with one cocolog at bank toe (WCGML1) as the volume of erosion was least in this case.

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