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Procedia Technology 24 (2016) 47 – 53

Procedia Technology

International Conference on Emerging Trends in Engineering, Science and Technology (ICETEST - 2015)

Analysis of groyne placement on minimising river bank erosion

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Abstract

Bank erosion is the wearing away of the banks of a stream or river. Impacts of river bank erosion are multifarious: social, economic, health, education and sometimes political. Groynes are structures constructed in rivers to protect the shore. Groynes are generally made of wood, concrete, or rock piles etc. In the present study coir geotextiles in the form of cocologs are used as the groynes to make the groyne more ecofriendly. Study mainly concentrates on analysing the effects of placing groynes at different angles from 45^0 to 135^0 and to find the most effective arrangement for minimising the erosion. Results indicate that cocolog-groynes are effective in minimizing the erosion and protecting the bank. Maximum protection is observed for groyne angle of 135^0.

Peer-review under responsibility of the organizing committee of ICETEST – 2015

Keywords:cocologs; groynes; optimum layout ; river bamk protection

1. Introduction

Rivers have been used as a source of water, for obtaining food, for transport, as a defensive measure, as a source of hydropower to drive machinery. Riverbank erosion is one of the main phenomena causing the instability of the bank. Predicting the cause of riverbank erosion and preventing it is the main aim of the river bank protection. Rainfall, soil structure, river morphology, topography of river and adjacent areas, and floods are the main factors affecting the erosion. In some areas, vegetation act as protection to the riverbanks. Sometimes these vegetation cover has been destroyed by human activities which eventually resulting in the bank erosion.

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Peer-review under responsibility of the organizing committee of ICETEST – 2015
doi:10.1016/j.protcy.2016.05.008

Rivers are often managed or controlled to make them more useful, or less disruptive, to human activity. Commonly used methods are by vegetation, sacks and blocks, gabions ripraps, guide banks, groynes etc. Groynes or spurs are structures constructed perpendicular to the rivers to protect the shore. Groynes may either be impermeable or permeable. Groynes deflect the flow from the shore and protect the shore. It has to be taken care that the groynes simply move the erosion zone to another location. By blocking the flow at a side the groynes tend to increase the water depth and velocities in the stream. In the nose of the groyne, there is also chance of turbulence which eventually cause scour in the nose.

A spur angled upstream repels the river flow away from it and is called a repelling spur. These are preferred where major channel changes are required. A spur angled downstream attracts the river flow towards it and is called an attracting spur. The angle of the groynes generally varied between 45 to 135 degrees.

Cocologs are made from coconut fibres. Coir fibres are densely packed into a circular outer covering of coir or poly ropes etc. Sometimes it is even reinforced with sisal twines for more strength. Commercially available cocologs are in diameters of 20cm, 30cm 40cm etc. Coco logs are an economical, durable, biodegradable material and easy to install. That's why cocologs are used for wide range of purposes. These provides good condition for plant growth and then it acts as a shelter and become part of the eco system. Once the routing of vegetation is complete the function of the Coir geotextiles is over and the same will biodegrade itself into soil, without causing environmental issues.

Mojtaba and Bahare [5] conducted experimental studies on effect of groin location on minimizing river bank erosion by placing groins at three locations i.e. before, at the beginning and after erodible material. They found that groins placed 30 cm before erodible material was suitable for reducing bank erosion. Anil et al. [3] conducted field experiments using cocologs placed as spurs in southern Kerala. They found that cocologs strengthened river bank and was cost effective compared to other conventional technologies.Yossef et al. [10] conducted experiments in a mobile bed and found that there is net import of sediment into the groyne fields.

2. Experimental setup

An undistorted model was created in a rectangular flume size 12.95 m x 1.2 m x 0.95 m in the Hydraulics Engineering Laboratory of College of Engineering, Trivandrum. Scale selected for the study is 1:25.Bed slope of the model is 1 in 6000 and side slope is 1:1.25. Cross section is shown in Figure 1 (a).

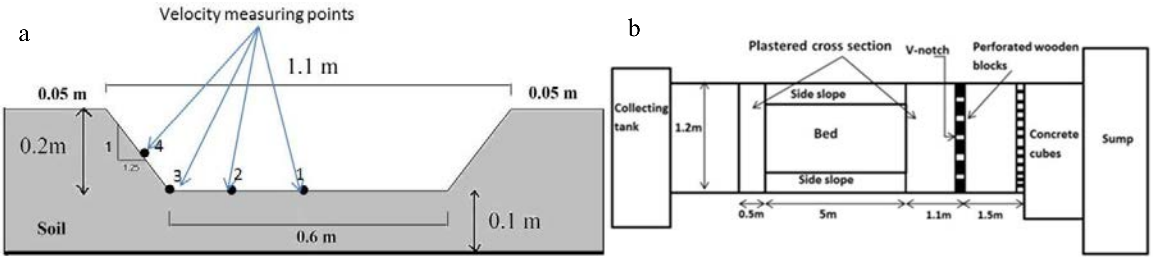

Fig. 1. (a) Cross section of the river model; (b)Schematic diagram of the model setup in the flume.

Concrete cubes and perforated wooden blocks were placed in the upstream to reduce turbulence of the flow. A 60^0 v-notch was placed 1.1 m upstream from the model in order to measure the discharge. The v-notch was calibrated and the calibration equation obtained was $Q=0.95\ H^{2.5}$. Soil collected from Neyyar river basin was used to fill the flume. Field density was found out using core cutter method. The same field density was maintained in the model. Rectangular flume was used for the study and symmetrical trapezoidal section was used for river model. Soil from the field was filled in the flume for a length of 5 m and total length of the model setup was 8.1m. Two pumps of 5hp are used for lifting the water from the sump into the flume.

2.1. Materials and methods

Commercially available cocologs are in diameters of 20cm, 30cm 40cm etc. Cocologs has made in small scale using polypropylene net of opening size of 1.27cm as the outer cover. Cocolog model was created by filling coir fibres in the outer covering of polypropylene net of diameter 2.5cm to get the density of actual cocolog as 144kg/m^3.

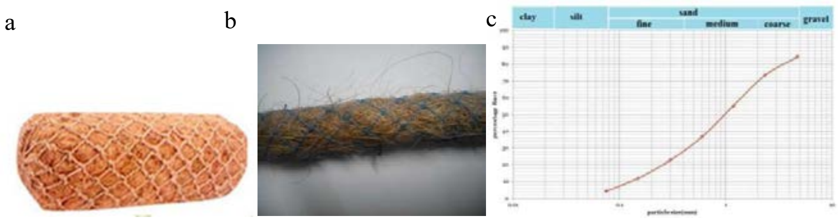

Fig. 2. (a)Actual cocolog; (b) Scaled model of cocolog;(c)Grain size distribution curve.

Sieve analysis of the soil was done and the grain size distribution curve is shown in Figure 2(c). From the grain size distribution curve it is observed that the soil selected is well graded.

Design of groynes was done as per IS 8408 (1994). The maximum length of the groyne as per IS recommendation is 1/5th of the flow. Maximum length of the groyne was obtained as 22 cm. A groyne length of 20cm was selected for the study. Length of the groyne is maintained same for all the experiment. As per IS specification spacing should be 2 to 2.5 times the length. Spacing was selected as 60 cm.

3. Experiments conducted

Experiments were conducted in the river model with and without the groynes. Velocity and flow depths were taken after the flow is stabilized. Experiments were conducted for a discharge of 0.033 m^3/s. Erosion/deposition patterns, velocity and flow depths were measured at 6 sections L_0,L_1,L_2,L_3,L_4,and L_5 1m apart along longitudinal directions from the upstream. Bed profiles were measured using point gauges and velocities were measured using pitot tubes. Velocities were taken at each section along the sloping side and bed at 1,2,3,4 as shown in Figure 1(a). Experiments were conducted without groyne to find out the actual erosion. Then the experiments were repeated for single groynes for different angles.

3.1. EXP1: without cocologs

Experiments were conducted without groyne to find out the actual erosion at a discharge of 0.033 m^3/s. Figure 3 (a), (b) shows the erosion pattern before after the experiment for no protection

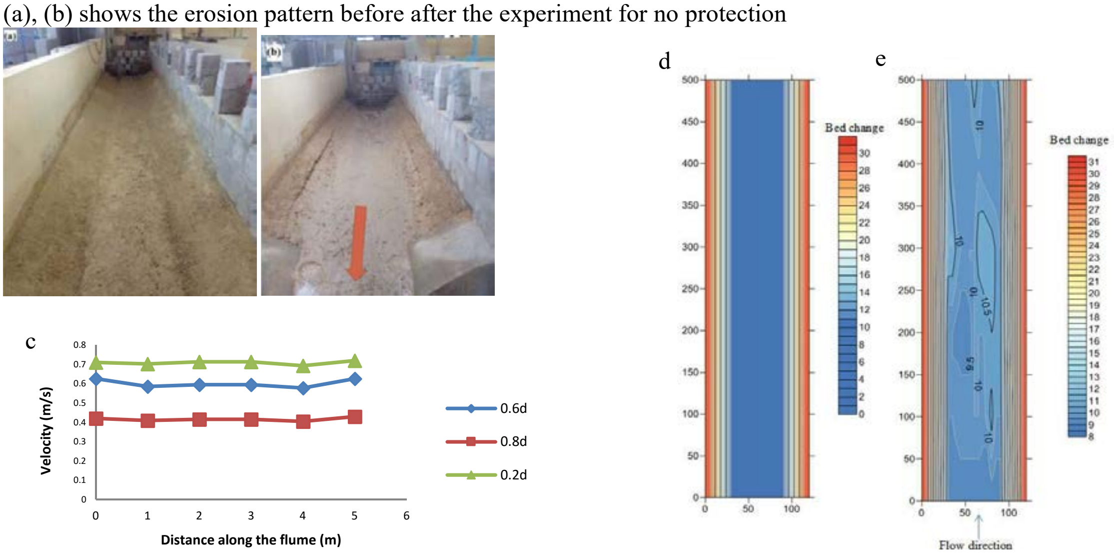

Fig.3. (a) EXP1: Before the experiment; (b) EXP1: After the experiment;(c) Variation of velocity along the length of flume; (d) Bed contour before the experiment; (e) Bed countour after the experiment.

Observing the water surface profile it can be seen that in the upstream sections the depth of flow is slightly low comparing with the downstream side. This may be due to the change in cross section due to erosion and deposition in the upstream. The water surface profile seems to be constant at the end of the flume.Figure 3(c) shows the variation of centre line velocity profile along the longitudinal direction of the channel. Velocity of flow was fluctuating throughout the length. But the velocity seems to be increasing towards the downstream end of the channel.

Figure 3 (d),(e)shows the bed contours of before and after the experiment. More erosion was observed in the sections L_0, L_1, L_2, L_4 and deposition was observed in L_3, L_5.. It is observed that sediments were detached from the bed and banks detached get deposited on the bed of the channel in the downstream end.Maximum erosion is found at the upstream end of the flume. Therefore it is decided to place the single groyne on the upstream end, 2m from the inlet. The groyne length is maintained as 20cm throughout the experiment.

3.2. EXP 2: single groyne at an angle

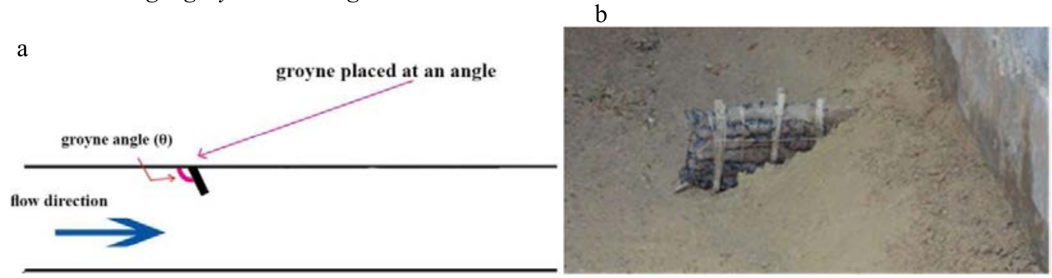

Fig.4. (a) Schematic representation of groyne placement in the flume; (b)Perpendicular groyne placed in the flume.

Figure4 (b) shows perpendicular groyne placed in the flume. Similarly different groyne angles of 45^0, 60^0, 90^0, 120^0 and 135^0 were tested

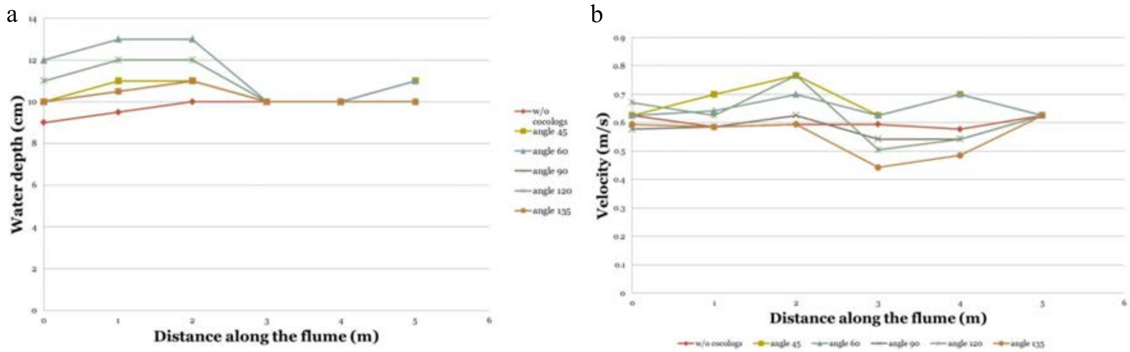

Fig.5. (a) Water surface profiles; (b)Centre line velocities of different angled groynes.

The water surface profiles indicate that the groynes increase the water level in the upstream. Maximum water level is observed near the groyne in section L_2 and downstream of the groyne the flow depth decreases. In section L_3 and L_4 water depths were same for all the angles. Slight variation in the water level is observed in the section L_5 which may be due to the deposition happened in the downstream end. Maximum water level was observed for angle 60^0 and minimum water level obtained for angles 90^0 and 135^0.

Figure 5 (b) shows the centre line velocities of different angled groynes at 0.6d. Slight variation in velocities were observed in the upstream section L_0 for all the angles. When moving downstream velocity increases and reaches the maximum at section L_2. Downstream of section L_2 velocities were slightly decreased. Some fluctuations were observed in the sections L_3 and L_4 that may be due to the change in area of cross section due to erosion and deposition. At the downstream section L_5 same velocity were observed for all angles.

In all the experiments there observed an erosion free zone nearer to the groyne. The length of this erosion free zone changes on the angle of the groyne. Table 1 shows the length of protected area for different angles .From table it is found that the maximum protected area is obtained for angle 135^0.

Table 1: Length of protected area fordifferent angles

Angle of groyne (degrees)	Volume (cm3)	Eroded volume (cm3)	Percentage of erosion (%)
Initial	965156	-	-
No protection	913835	51321	5.31
45	915577	49579	5.13
60	930133	35023	3.62
90	943219	21937	2.27
120	944329	20827	2.15
135	945494	19662	2.03

Table 2: Percentage of erosion for different angled groynes

Angle of groyne (degrees)	Length protected area in the downstream of groyne (cm)	Protected area in the upstream of groyne (cm)
45	65	25
60	45	15
90	55	10
120	60	10
135	67	45

3.3. EXP 3: multiple groynes

From the experiments with single groynes in the previous chapter it was found that groyne with angle 135^0 has minimum erosion. Mainly 2 types of arrangement are adopted for multiple groynes, Parallel and alternate arrangement. Parallel arrangement consists of placing parallel cocologs in one side only at a certain interval. In alternate arrangement, in between two groynes in one side another groyne is placed in the opposite bank.

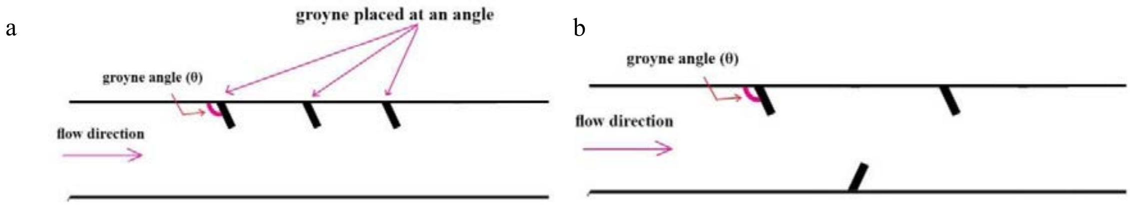

Fig.6.(a).Parallel arrangement; (b)Alternate arrangement.

As per the IS code the groyne spacing is between 2 to 2.5 times the length of the groyne. 3 times of the length was selected for the study. While observing the water surface profiles in it is observed that alternate arrangement shows high water depth than the parallel arrangement.in both the arrangements velocities increased till L_2 and decreased till the downstream end. In parallel arrangement there observed a sudden increase in water level in L_5. In section L_5 the water levels were almost similar to the initial experiment which shows that the effects of groynes were minimum in that section.

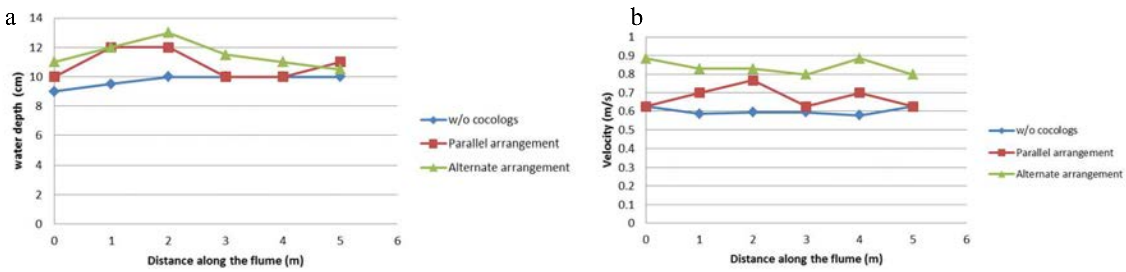

Fig .7. (a)Water surface profiles; (b)Centre line velocity of different sections.

Figure 7(b) shows the velocity profiles of both the arrangement. In both the cases velocities were fluctuating in nature. Sudden decrease of velocity is observed when moving from L_4 to L_5 in both the cases. Alternate arrangement showed more velocities than parallel arrangement.

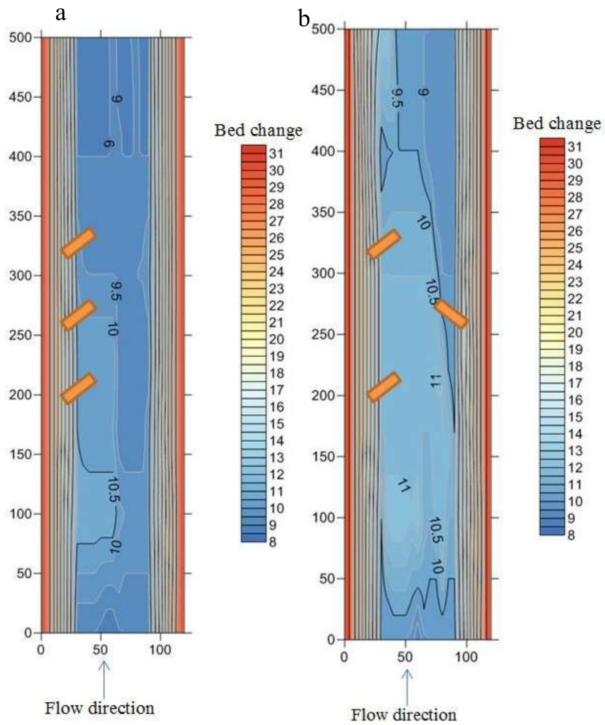

Fig.8: bed contours (a) parallel arrangement; (b) Alternate arrangement

Table 3: Percentage of erosion of different arrangements

Type of arrangement	Percentage of erosion
Parallel arrangement	
60 cm spacing	4.62
Alternate arrangement	
60 cm spacing	3.10

In parallel arrangement more erosion is observed on the opposite side of the groynes and in the downstream sections. Slight deposition is observed on the upstream side of the groynes.

In alternate arrangement the erosion was comparatively less. Erosion mainly happened on the upstream end and downstream end sections only. While comparing the percentage of erosion 60 cm spaced alternate arrangement showed less erosion than the parallel arrangement.

4. Conclusions

The velocity and water level profiles clearly indicate that cocolog groynes can be used for increasing centre line velocity and water levels in the upstream side for navigation purposes. Deposition is observed in the upstream vicinity of the cocolog may be due to the velocity reduction of the flow due to cocolog. More erosion was observed on the opposite bank of the groyne. An erosion free zone is observed near the groyne. The length of this erosion free zone changes upon the angle of the groyne. Maximum protection was obtained for an angle of 135^0.

In multiple groynes alternate arrangement showed more increase in the water levels and velocities in the upstream compared to parallel arrangement. But the erosion percentage was less than the alternate arrangements. In both the arrangements there was no erosion between the groyne fields.

The study proves that cocologs can be effectively used as groynes for river bank protection.

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