AN EXPERIMENTAL STUDY ON DUMPING OF BANK PROTECTION MATERIALS UNDER FLOWING WATER

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ABSTRACT
In Bangladesh, erosion-deposition, channel shifting and bar development are common phenomenon in large rivers. Bank materials of these rivers are mainly unconsolidated, fine non cohesive and uniformly graded that possesses little resistance against erosive forces generated by the flow of river. This study provides an insight into the behaviour and movement of bank protection materials (CC blocks and Geobags) under flowing water.A physical model was built and tested in the flume. The experiment was carried out for two sets of discharge of 760 m^3/h and 623 m^3/h. Materials were dumped from three different dumping conditions. For most of the materials the lateral displacement was found in the range of 0 to 2 m. Greater the velocity higher is the average lateral displacement of Geobags and more numbers of Geobags are lost. The percentage of loss is more in case of Geobags and is negligible in case of CC blocks.

Keywords: River erosion; dumping characteristics; bank protection; CC block; geobag

INTRODUCTION

Bangladesh is located at the lower part of the three mighty rivers, the Ganges, the Brahmaputra and the Meghna. The basin of these three rivers is called GBM basin. The total catchment of this basin is 1.72 million sq.km covering areas of China, India, Nepal, Bhutan and Bangladesh of which only about 8% lie within Bangladesh. The country is criss-crossed by more than 230 rivers, most of which are either tributary or distributary to the three major rivers. There are 57 trans-boundary rivers which originate outside the boundary of Bangladesh. The total length of the river course is approximately 24000 km and cover 9770 km^2 or 7% of the country. Studies by ISPAN (1995) indicate that the Brahmaputra-Jamuna River widened in the 1834-1992 period from 6.2 to 10.6 km representing a widening of some 27 m/year on average. In 19 years period from 1973-1992 the rate of erosion accelerated to some 140 m/year on average.Ahmed (1989) reached the same conclusion of secular widening of the river. They found the widening at a rate of 172 m/year between 1972 and 1986.Recent analysis of the satellite image by CEGIS (April, 2000) for the last few decades shows that the river is widening along both banks. During the last three decades (1973-2007) the net erosion along the 240 km reach of the Jamuna River were about 77840 ha. The rate of widening of Jamuna River declined from 150 m/year in 1970s and 1980s to 48 m/year in last 14 years.There is active bank erosion almost in all major rivers in the country causing damage to valuable lands, settlements and infrastructures from year to year. Because of high density of population along the river bank a great number of people are also displaced due to this continuous bank erosion process.

In Bangladesh, Standard practices of river bank protection are Groynes and Revetments.Groynes are stone, gravel, rock, earth or pile structures built at an angle to the river bank to deflect flowing water away from the bank. A typical groyne has mainly two parts: head, and shank. The part joining the head and the bank/embankment is the shank. Maximum flow convergence and divergence occur around the groyne head and deep scour holes are formed. So additional protection measures around the head of the groyne are required. The upstream and downstream sides of the shank also need protection but with less amount of erosion resisting materials than the groyne head.Revetment is artificial roughening of the bank slope with erosion-resistant materials. A revetment mainly consists of a cover layer, and a filter layer. Toe protection is provided as an integral part at the foot of the bank to prevent undercutting caused by scour. The protection can be divided as falling apron or launching apron, which can be constructed with different materials, e.g., CC blocks, rip-rap, and geobags.

Launching apron consists of interconnected elements that are placed horizontally on the floodplain and normally anchored at the toe of the embankment. The interconnected elements are not allowed to rearrange their positions freely during scouring but launch down the slope as a flexible unit. The falling apron, on the other hand, consists of loose elements (e.g., CC blocks, geobags, stones) placed at the outer end of the structure. When scour hole approaches the apron, the elements can adjust their position freely and fall down the scouring slope to protect it. The scouring and undermining process of the developed scour hole in front of the revetment initiates the deformation process at the toe of the revetment.Falling apron is a multi layer system of protection element placed on a sloping or horizontal surface as protection against scour. The individual units are rearranged freely with the morphodynamic forces of the river and stabilize the eroding bank. The single weight of each unit and the volume of protective material within a defined area are the decisive factors for designing an efficient falling apron. Apron is intended to launch when the underlying sand/sandy soil is scoured by the river current so as to form a continuous protection below the water level. A revetment may fail due to instability of the cover layer caused by external loads (current, waves etc.) or internal loads (e.g., due to pore water pressure), insufficient toe protection and instability or improper launching or falling behaviour of the apron materials, sliding of cover layer over intermediate layer, different micro and macro-instability arising from geotechnical characteristics of soil and changed boundary conditions e.g., due to rapid scour development or water level changes.In Bangladesh, different bank protection materials like flexible launching apron of C.C blocks or boulders, rocks, geobags, gabions of galvanized wire mesh filled with bricks or boulders are used. Proper size and amount of falling apron is required for safety of structure. As it is difficult and costly to investigate the launching characteristics of bank protection materials under water, laboratory experiment was done for better understanding of the characteristics. From the experiment, movement and position of materials can be determined.

The main purposes of this study are to investigate the launching characteristics of C.C blocks and geobags with different launching configurations for different weight and width-length.

METHODOLOGY

Fall velocity is the velocity at which a sediment particle falls through a column of still water. In moderately deep streams the velocity is observed at two points; (i) at 0.2 times the depth of flow below the free surface ($V_{0.2}$) and (ii) at 0.8 times the depth of flow below the free surface ($V_{0.8}$). The average velocity in the vertical V is calculated using Eq. (1)

$$V = (V_{0.2} + V_{0.8}) / 2 \qquad (1)$$

$V_{0.2}$ and $V_{0.8}$ are usually measured by current meter. A current meter is so designed that its rotation speed varies linearly with the stream velocity V at the location of the instrument. A typical relationship is defined by Eq. (2)

$$V = aN_s + b \qquad (2)$$

Where,

V = stream velocity at the instrument location in m/s

N_s = revolutions per second of the meter

a, b = constants of the meter

Nominal diameter is the equivalent spherical diameter of a hypothetical sphere of the same volume as a given sediment particle.Neil established a formula for calculating the nominal diameter for stones Eq. (3).

$$D_n = 0.034V^2 \text{ [m]} \qquad (3)$$

Where,

V = mean flow velocity (average over a vertical) in m/s

D_n = nominal stone diameter in m

The angle of slope formed by particulate material under the critical equilibrium condition of incipient sliding or the maximum angle (as measured from the horizontal) at which gravel or sand or granular particles can stand.
Whilst dumping blocks under flowing water, they may be displaced downstream by the distance L as mentioned in Eq. (4).

$$L = 0.25hVD_n^{-0.5} \text{ [m]} \qquad (4)$$

Where,

h = water depth in m

V = mean flow velocity (average over a vertical) in m/s

D_n = nominal stone diameter in m

EXPERIMENTAL SETUP

The experimental model was constructed in a laboratory flume shown in [Fig. 1] following guidelines from literature (BRTC; RRI 2010). It is possible to change its configuration as and when needed for carrying out further studies, using the experimental facilities without any drastic constructive changes. The experimental set-up is shown in [Fig. 2].

Fig. 1: Laboratory Flume

Fig. 2: Experimental set-up (Top View)

A small current meter is used for measurement of flow velocity at low water level, e.g. in laboratories, river models, small canals etc. The meter with the extension rods is usually applied for measurements in shallow creeks or rivers with low current velocities. The highly precise, reinforced spindle bearing and a non-conduct signaling system give the possibilities for measuring flow velocities as of 0.025 m/s. Minimum depth of water required for this device is approximately 4 cm. The digital counter, fitted with a carrier belt, registers up to 10 pulses per seconds.A flow meter is used to measure the amount of water passing through the flow meter during a time period. The total discharge was taken as the sum of the two flow meter used during the experiment. The discharge data was checked frequently as the discharge rate fluctuates frequently. An angle measuring device is used to measure the angle of repose. A sloping platform was prepared to measure the angle of repose. The angle scale is adjusted with a large thumb screw on the handle. When the bubble vial reads level, the angle was set. The angle scale ranges from 0 to 130° in 2° increments. The rise scale ranges from 0 to 0.8 in 0.05 increments, and above 0.8 it reads in fixed increments up to 2.0.The lateral displacement was determined with the help of a linear scale. After dumping of CC blocks and geobags, lateral displacement of each cc block and geobag was measured. The materials were considered as lost when the lateral displacement was more than 3 m.Different stages of the experiments are shown from [Fig. 3] to [Fig. 8].

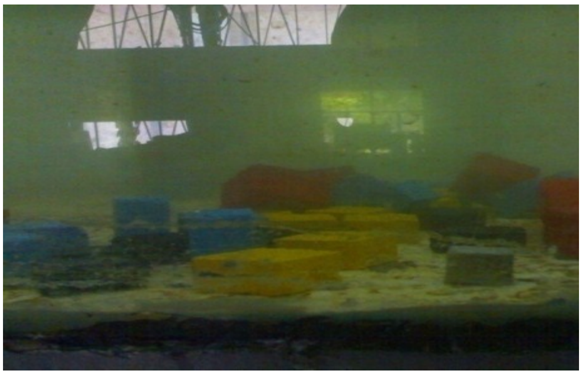

Fig. 3: Dumping of CC blocks

Fig. 4: Dumping of geobags

Fig. 5: Discharge measurement

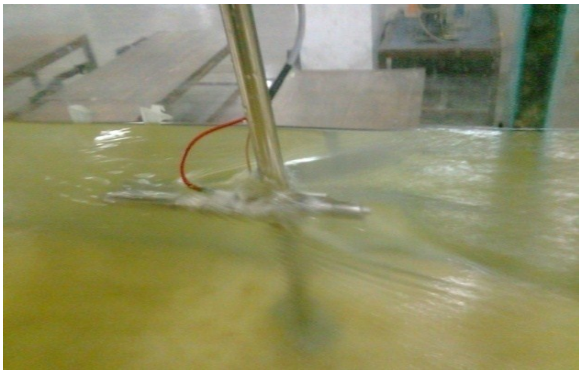

Fig. 6: Velocity measurement

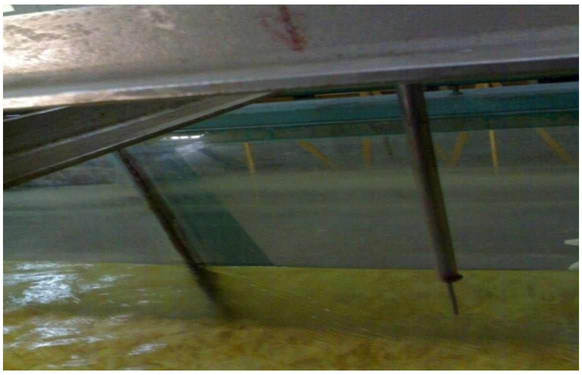

Fig. 7: Depth measurement

Fig. 8: Lateral displacement measurement

RESULTS AND DISCUSSIONS

The experiment was conducted with two set-ups of velocity 0.582m/s and 0.577 m/s. Average lateral displacement of CC blocks was found 0.61 m when dumped from the experimental horizontal platform at a water depth of 0.40 m for five different block configurations. Average lateral displacement of CC blocks was found 0.66 m when dumped from the sloping platform at a water depth of 0.40 m and at an angle of 38o for five different block configurations. Average lateral displacement of CC blocks was found 0.57 m when dumped from the water surface and at an angle of 0o for five different block configurations. Average lateral displacement is greater when CC blocks are dumped at the angle of repose of 38o. Average lateral displacement of CC blocks was found 0.58 m when dumped one at a time for different block and launching configurations. Average lateral displacement of CC blocks was found 0.65 m when dumped five at a time for different block and launching configurations. Average lateral displacement of CC blocks was found 0.61 m when dumped ten at a time for different block and launching configurations. Average lateral displacement is greater when CC blocks are dumped ten at a time. Average lateral displacement of CC blocks was found 0.66

m from the experiment and theoretically the displacement was 0.583 m. Average lateral displacement of Geobags was found 3.73 m when dumped from the experimental platform at a water depth 0.40 m, at the velocity 0.582 m/s and 70% bags were lost. Average lateral displacement of Geobags was found 3.65 m when dumped from the water surface at the velocity 0.582 m/s and 70% bags were lost. Average lateral displacement of Geobags was found 3.7 m when dumped from the experimental platform at a water depth 0.40 m, at the velocity 0.577 m/s and 55% bags were lost. Average lateral displacement of Geobags was found 4.38 m when dumped from the water surface at a water depth 0.40 m, at the velocity 0.577 m/s and 60% bags were lost. Greater the velocity higher is the average lateral displacement of Geobags and more numbers of Geobags are lost. The percentage of loss is more in case of Geobags and is negligible in case of CC blocks.

CONCLUSIONS

For smaller velocity or still water, percentage loss of materials is less than higher velocity. Average lateral displacement is greater when CC blocks are dumped at the angle of repose of 38^o. Average lateral displacement is greater when CC blocks are dumped ten at a time. The percentage of loss is more in case of Geobags and is negligible in case of CC blocks. Greater the velocity higher is the average lateral displacement of Geobags and more numbers of Geobags are lost.

The experiment was carried out for fixed bed condition and doesn’t represent any particular river problem, only deals with laboratory cases. The experiment was conducted with two set-ups of velocities with five different sizes of CC blocks. Further study can be carried out for other sizes and velocities. This study may be applied for a particular alluvial river to assess the applicability for field condition.

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