A CASE STUDY ON PERFORMANCE OF CONCRETE BLOCK MAT FOR RIVER BANK PROTECTION USING SCALE MODELING

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Abstract

This paper presents the findings of the research on Concrete Block Mat (CBM) - an innovative idea produced by Manob Hitoishi Sangstha (MHS) for river bank protection over the river Arial Khan at Ramarpole near Mollarhat bazar of Kalkini upazila under Madaripur district using scale modelling. The river reach of about 1.0 km with an average width about 133m of Arial Khan is reproduced in this research. The research is conducted on an open-air mobile bed of RRI having undistorted scale 1:30 and model is designed to satisfy both flow & sediment transport condition at the same time. In this research, different application test runs are conducted with different test scenarios using low, medium and high flows. The research shows that the proposed technology (CBM) is not so effective as compared to the conventional method though its cost estimate seems to be comparatively less. The construction of concrete blocks, filter placement under water, block placement through the wire etc. are found very complex in the model but in nature it might be more complex. CBM might be very difficult to implement in the field and its construction is time-consuming. It needs special working technology to construct in the field. This concept can be applied in any small river as a pilot project to investigate its effectiveness as well as to identify its complexity in the field.

Keywords: *Arial Khan river, concrete block mat (CBM), complexity, effectiveness, river bank protection, scale modeling and technology.*

Introduction

The Arial Khan river is a distributary of the Padma river. The river maintains a meander channel throughout its course and it is erosional in nature. Due to severe river bank erosion, a number of settlements have already been destroyed and the process is going on. Bangladesh Water Development Board (BWDB) has taken some measures to save these areas using conventional method. Concrete block mats and placed concrete blocks with filter are the developments of conventional loose concrete block placement and loose concrete block dumping. This idea and technique have been developed by Manob Hitoishi Sangstha (MHS). Before model testing, it is expected that the effectiveness of Concrete Block Mat (CBM) will be more than the conventional method of river bank protection and expenditure will be less.

From approximate technical and financial analyses, it is found that river bank erosion control using concrete block mats and placed concrete blocks with filter are the best effective substitute and much cheaper than the conventional loose concrete blocks placement and dumping for the control of river erosion. The technical and financial aspects of newly proposed protective measure has been tested through laboratory research using scale modelling on bank erosion control of Arial Khan river at Madaripur District.

Making contact with the concerned water resource specialists of different organizations, it is concluded that the proposed new river bank protective measure using concrete block mats and placed concrete blocks with filter can be applied to the bank of river after model test at RRI. The test can be done in the laboratory for a location along the bank of river in low, medium and high flow condition.

The overall objective of the study is to evaluate and determine the performance of concrete block mats and placed concrete blocks with filter in river bank erosion control compared to conventional methods.

Methodology

The research is done on a mobile bed. The hydraulic similarity is established in the model to an undistorted scale. The model is constructed to an undistorted scale. The scale ratio is selected as 1:30. The model has been designed to fulfil both flow and sediment transport criterion simultaneously. It means the model velocity is higher than the critical flow velocity for the initiation of sediment motion. This is because for any velocity higher than the critical, the scour dimensions are only function of flow direction and structure geometry. The model will, therefore, reproduce the scour holes correctly.

An open air model bed of RRI has been selected for model development. It provides all kinds of facilities related to model study. Then layout of

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model is given by grid system. After setting reference grid points in the model, channel planform is given using these grid points and the bed & bank levels are fixed up by levelling instrument as per bathymetry using Rise & Fall method. This requires some cutting and filling of sand from the model bed. In this scale model, various types of instrument and facilities are needed such as, a sharp-crested weir for measuring flow, point gauge for measuring water level, 3-D current meter for measuring velocity, high resolution camera for taking video and photographic view of model, stopwatch for taking instant time and plastic colored balls (floats) for tracing flow path of flowing water. The discharge in the model is measured using sharp-crested weir at the inflow section using Rebock's formula. Model velocity is quantified by current meter. Water slope can be found by analyzing the water level measurements of different point gauges installed in the model. Flow lines of the stream can be identified by dropping colored balls starting from calibration section and catching them at the end of the model. A stopwatch can be used to calculate surface velocity of the flow. In the scale model, model data requires to be analyzed for interpretation of test results.

Model Setup

The river reach about 1.0 km length and average width about 133m is reproduced in the model. The model is run with different test scenarios using low, medium and high flows. The CBM protective work is from C/S53 to C/S57 covering a reach of about 168m along the R/B of the river. Model bed and bank are composed of fine sand having D_{50} about 0.16mm. Ebb discharge corresponding to LWL, 2.33-yr WL & 100-yr WL is taken into account to investigate the model. Two different discharge conditions used, one is Froudian discharge and the other is scour discharge. Froudian discharge provides flow pattern & velocity field as a whole and the scour discharge focuses on the scour simulation and sediment transport. Each test of the model continues until a dynamic equilibrium condition is reached and Froudian discharge is run for 12 hrs.

The model is setup in the outdoor model bed (60mX40m) of RRI. On the basis of topographic, bankline and bathymetric survey of March 2017, the model bed is constructed. After calibration of the model, application tests are conducted with the discharges corresponding to LWL, 2.33-year WL & 100-year WL. These data are used to measure flow velocity, scour depth and float tracking. The layout of the model is shown in **Fig. 1.**

Test Scenarios

In the model, 2 (two) calibration tests (T0-1 & T0-2) and 17 (seventeen) application test runs (T1-T17) were conducted. 6 (six) different designs have been tested in the model with various flow conditions changing velocity & water level as mentioned in **Table 1.** These designs have been applied in tests T1, T2, T5, T8, T11 & T12. Each test run is carried out using low, medium and high flow discharge.

Results and Discussion

Different designs of CBM are tested in this research. These are shown in test T1, T2, T5, T8, T11 & T12. Among the designs tested in the scale model, the design provided in test T12 performs relatively better than other tests. In this design, the lower bank is protected by using loosely placed concrete block mats on filter and upper bank is protected by using closely placed concrete block mats with some gaps on filter using low flow. Here the gaps in the upper bank protection on filter are kept for plantation. The model bed is prepared according to the bathymetric survey of March 2017. Scour discharge is run until equilibrium condition is reached and Froudian discharge is run for 12 hrs. Using the same design tested in test T12, test T13 and T14 have been conducted in the model using medium flow and high flow respectively. The details of the optimized design of proposed concrete block mats (CBM) are as follows:

a. River bank level: 3.0mPWD
b. Low water level: 0.24mPWD
c. Block type: Holed concrete block
d. Block size used in the model: 13.33mmX13.33mmX3.33mm (40cmX40cmX10cm in proto)
e. Length of river reach to be protected: 5.6m (168m in proto)
f. Length of upper bank protection: 0.22m (6.6m in proto)
g. Length of lower bank protection: 1.15m (34.5m in proto)
h. Length of RCC pipe: 12 inch (360 inch in proto)

i. Diameter of RCC pipe: 0.5 inch (15 inch in proto)
j. Width of filter: 12 inch (360 inch in proto)
k. Total nos. of CC blocks in each 12 inch (360 inch in proto) wide strip at top & bottom layer in lower bank: 58x5+58x5=580
l. Here each 12 inch (360 inch in proto) wide strip contains 5 column of CC blocks at the top layer & 5 column of CC blocks at the bottom layer. Each column containing 58 blocks. These strips are overlapped by 50 % over each other. The top 5 column of CC blocks have been placed over the spaces among CC block columns at the bottom layer. Here 2 layers of CC blocks & 2 layers of filter in each strip.
m. Length of u/s termination 0.75 m (22.5m in proto) & d/s termination 0.50 m (15m in proto)
n. The design of CBM tested in test T12, T13 & T14 is found to work better in spite of its other complexity. The optimised design is shown in Fig. 4, 5 & 6 (a&b).

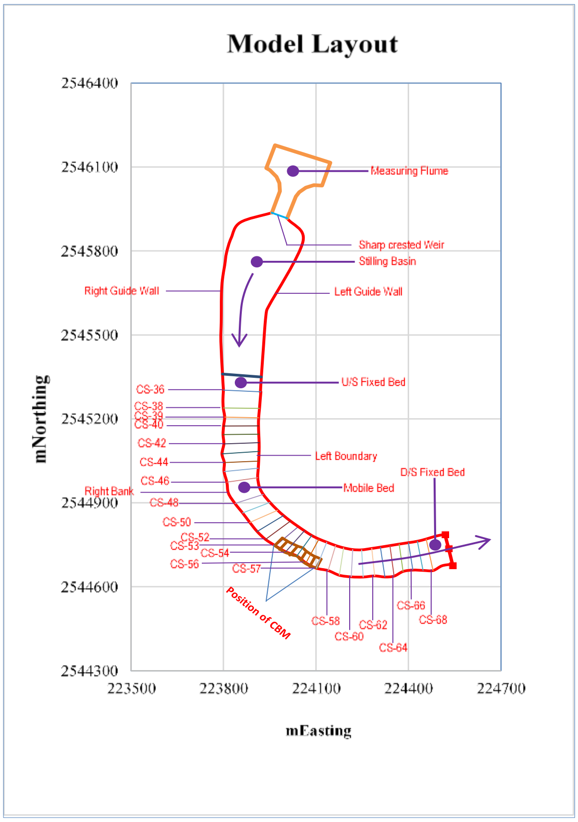

Fig.1. Layout of the Concrete Block Mats (CBM) Model

Table 1. Test Scenarios of the model

Test No.	Test Scenarios & WL/Q Conditions
Calibration Test (T0-1)	○ Test with existing conditions & 2.33-year RP water level ○ WL= 1.23 mPWD ○ $Q_{sectional}$ =1309 cumec (C/S39)
Calibration Test (T0-2)	○ Test with existing conditions & using field data ○ WL= 0.73 mPWD ○ $Q_{sectional}$ = 340 cumec (C/S36)
1st application test (T1)	○ Design supplied by MHS ○ Lower bank protection works applying strip type concrete block mats on filter ○ Upper bank protection works applying wide type concrete block mats on filter ○ Low flow WL= 0.24 mPWD ○ $Q_{sectional}$ =808 cumec
2nd application test(T2)	○ Modification of design based on test T1 ○ Low flow WL= 0.24 mPWD ○ $Q_{sectional}$ =808 cumec
3rd application test(T3)	○ Same design as in test T2 ○ Medium flow WL= 1.23 mPWD ○ $Q_{sectional}$ =1381 cumec (C/S36)
4th application test(T4)	○ Same design as in test T2 ○ High flow WL=2.93 mPWD ○ $Q_{sectional}$ = 1967 cumec
5th application test (T5)	○ New design supplied by MHS ○ Lower bank protection works applying loosely placed concrete block mats on filter ○ Upper bank protection works applying closely placed concrete block mats with some gaps on filter ○ Low flow WL= 0.24 mPWD ○ $Q_{sectional}$ =808 cumec
6th application test (T6)	○ Same design as in test T5 ○ Medium flow WL= 1.23 mPWD ○ $Q_{sectional}$ =1381 cumec
7th application test (T7)	○ Same design as in test T5 ○ High flow WL=2.93 mPWD ○ $Q_{sectional}$ = 1967 cumec
8th application test (T8)	○ Modification of new design based on test T5 ○ Low flow WL= 0.24 mPWD ○ $Q_{sectional}$ =808 cumec
9th application test (T9)	○ Same design as in test T8 ○ Medium flow WL= 1.23 mPWD ○ $Q_{sectional}$ =1381 cumec
10th application test (T10)	○ Same design as in test T8 ○ High flow WL=2.93 mPWD ○ $Q_{sectional}$ = 1967 cumec
11th application test (T11)	○ Different design supplied by MHS ○ Low flow WL= 0.24 mPWD ○ $Q_{sectional}$ =808 cumec
12th application test (T12)	○ Final design supplied by MHS ○ Low flow WL= 0.24 mPWD

Test No.	Test Scenarios & WL/Q Conditions
	○ $Q_{sectional}$ =808 cumec
13th application test (T13)	○ Same design as in test T12 ○ Medium flow WL= 1.23 mPWD ○ $Q_{sectional}$ =1381 cumec
14th application test (T14)	○ Same design as in test T12 ○ High flow WL= 2.93 mPWD ○ $Q_{sectional}$ =1967 cumec
15th application test (T15)	○ Same design as in test T12 with introduction of oblique flow ○ Low flow WL=0.24 mPWD ○ $Q_{sectional}$ = 808 cumec
16th application test (T16)	○ Same design as in test T12 with introduction of oblique flow ○ Medium flow WL= 1.23 mPWD ○ $Q_{sectional}$ =1381 cumec
17th application test (T17)	○ Same design as in test T12 with introduction of oblique flow ○ High flow WL= 2.93 mPWD ○ $Q_{sectional}$ =1967 cumec

The optimized design of CBM is subjected to angle of flow attack. Here a char is artificially reproduced in the model which makes an angle of 140-degree oblique flow attack with the incoming flow as per recommendations of Chief Engineer (Design), BWDB. Under oblique flow attack, test T15, T16 & T17 have been conducted in the model using low, medium & high flow condition respectively following the same optimized design. Scour and velocity were measured in the vicinity of CBM and oblique char. Maximum local scour around CBM structure & oblique char is respectively 7.65m (-22.27mPWD) & 7.8m (-22.45mPWD) in test T17 under oblique flow condition. Maximum velocity measured around the top of CBM (along the right bank) is 2.36 m/s, 2.83m/s & 3.64m/s respectively in test T15, T16 & T17 with the introduction of oblique char.

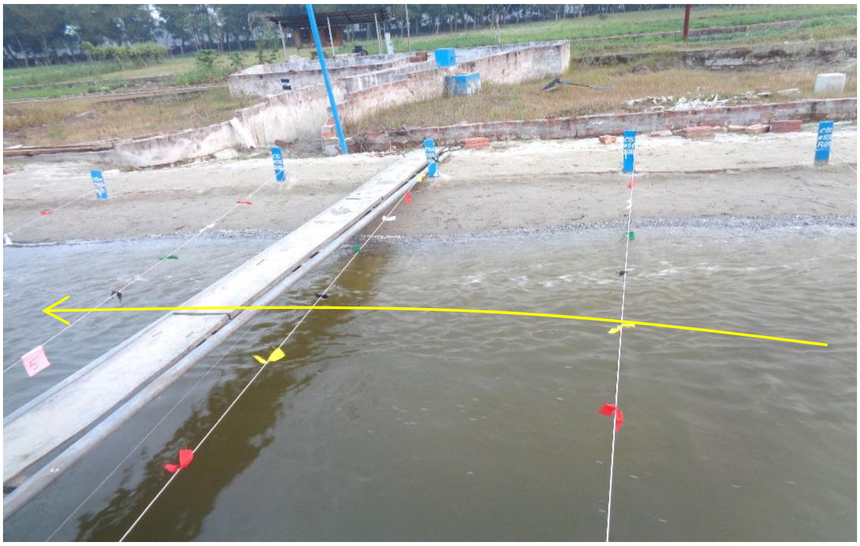

Fig.2. Model is under running condition with CBM (T14)

Fig.3. Scour pattern around CBM after run (T14) in the model

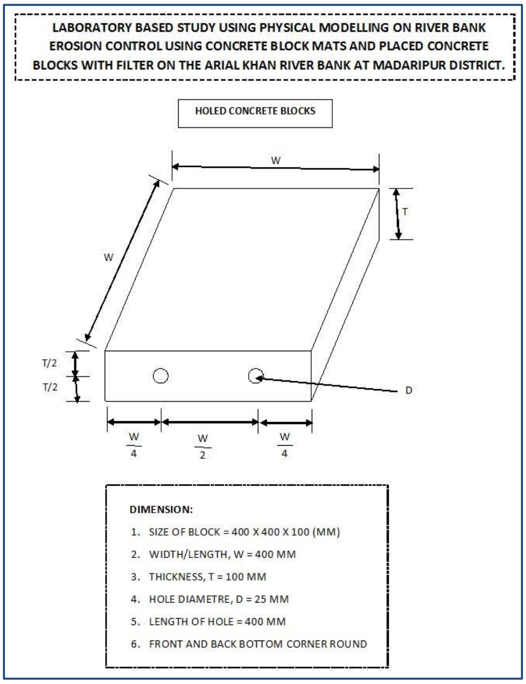

Fig.4. Typical holed block of CBM

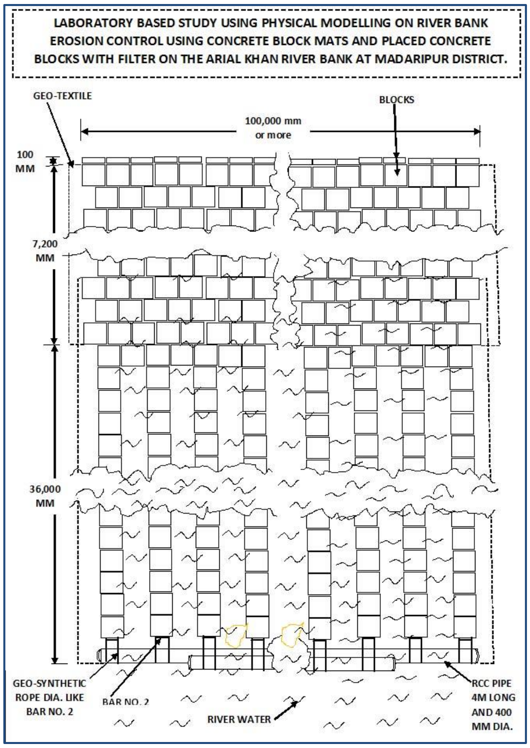

Fig.5. Typical plan of erosion control measure by CBM at Arial Khan River bank

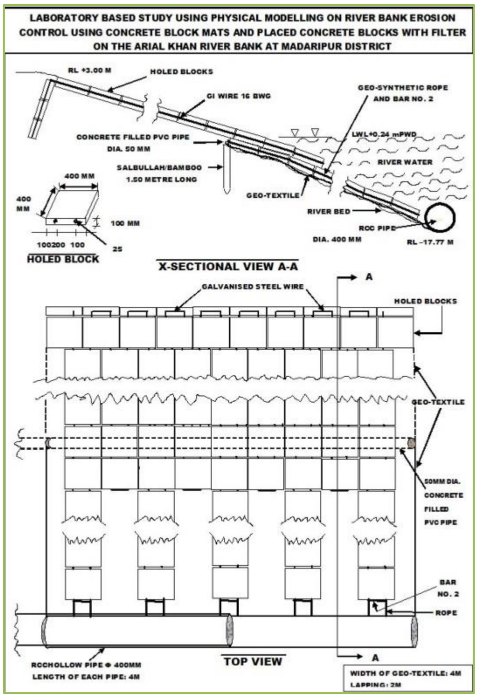

Fig.6 (a). Typical section (A-A) of erosion control measure by CBM at Arial Khan River bank

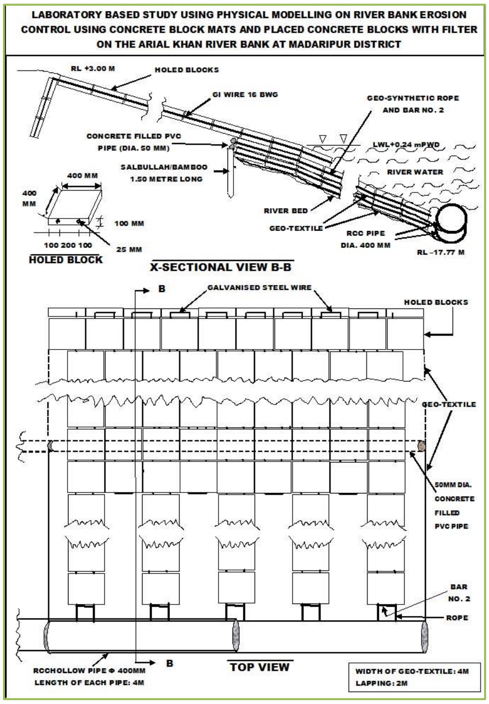

Fig. 6 (b). Typical section (B-B) of erosion control measure by CBM at Arial Khan River bank

Cost Comparison

The concerned field office of BWDB at Madaripur was requested to extend their cooperation to analyze the cost of protection measure applying loose concrete blocks and proposed concrete block mats for a same location. The location is selected at Ramarpole, Mollarhat under Kalkini upazila of Madaripur district along the bank of Arial Khan River. Scale modeling was done referring to this location. From the above comparison it is found that the protection measure applying new measure of concrete block mats is about 30% less than the cost of protection measure applying conventional measure of loose concrete blocks.

Comparative Statement between Conventional & Proposed Concrete Block Method

A comparative statement made by MHS between conventional method and proposed concrete block method with respect to Technical Performance, Workability and Sustainability for river bank protection is given below:

Table 2. Comparison of conventional & proposed new method

	Conventional Method	Proposed Concrete Block Method
Technical performance	a) In conventional method, loose concrete blocks are used at upper bank and lower bank for river bank erosion control. So, the placed position of individual blocks can change easily due to soil erosion. b) Block can move from one position to other due to free connection with other blocks when underlying soil erode. c) In lower bank, huge blocks are accumulated by dump which attract sedimentation, blocks can move to the river bed. So, river depth can decrease.	a) In proposed new method, concrete block mats can be used at upper bank and lower bank for river bank erosion control. So, the placed position of individual blocks can't change easily due to erosion. b) Block can't move from one position to other due to inter connection with other blocks when underlying soil erode. But, direction of block can change due to flexible inter connection. c) In lower bank, two layer concrete block mats can be used which don't attract sedimentation, blocks can't move to the river bed. So, river depth can increase.
Workability	a) Easy to construct in the field. It is practiced from British period. b) Workers are already acquainted with the construction procedure due to practice for a long time. c) For construction no diver, swimmer and barge required.	a) Not easy to construct in the field but possible. b) Workers are not acquainted with the construction procedure. So, training will be required. c) For construction diver, swimmer and barge may be required.
Sustainability	a) Sustainable if huge expenditure for maintenance is ensured. b) Less durable than new method.	a) Sustainable with negligible expenditure for maintenance. b) More durable than the conventional method.
Cost comparison	a) Cost for 314m length protection by Conventional Loose Concrete Blocks is Taka 5,05,19,318.00	a) Cost for 314m length protection by Proposed Concrete Block Mats is Taka 3,58,65,859.00

Conclusion

- The effectiveness of the proposed CBM is not so attractive compared to the traditional method as a whole, though the cost estimate supplied by the Senior Design Engineer appears to be relatively less.
- The construction of concrete blocks, filter placement under water, block placement through the wire etc. are found very complex in the model. But in nature it might be more and more complex.
- The construction of proposed bank protective structure (CBM) might be very difficult to implement in the field. The construction of proposed new method of bank protection (CBM) is time-consuming.
- CBM needs special working technology to construct in the field.
- The optimized design tested in test T12 is found to work better compared to other tests.
- Proper monitoring & supervision of CBM is necessary during and after construction phase if implemented in the field.

Recommendation

This concept can be applied in any shorter reach of a small river as a pilot project to verify its effectiveness as well as to identify its various complexity in the field condition.

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