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An Investigation On The Slope Failure Of Bank Revetment Work Along Jamuna River At Chouhali, Bangladesh

Nabila Sumaia Hussain *, Mohammad Mashrur Fateh **
**(Bangladesh Water Development Board, Dhaka, Bangladesh*
*** (Public Works Department, Dhaka, Bangladesh*
Corresponding author : Nabila Sumaia Hussain

ABSTRACT : Failure of bank revetment work is often observed in Bangladesh which is a major concern for the country as considerable amount of resources are employed for the construction of the protection work. Consequently an understanding of the possible reasons behind such failures as well as the determination of remedial measures are important issues to be explored. This study investigates the probable causes of the slope failure of bank revetment work constructed on the left bank of Jamuna River which was later repaired. Recommendations were made to avoid such failure in future. Through systematic detailed analysis and investigation, the probable reasons of the slope failure were identified. Design of the revetment was reviewed and found satisfactory. From the field investigation and slope stability analysis it was revealed that the slope failure might occur due to some deviation from standard construction procedure and unfavorable natural phenomenon. Systematic construction method must be followed to avoid such failure. Regular monitoring and provision for proper adaptive and maintenance work must also be incorporated for the safety and sustainability of bank revetment work..

Keywords - Bank revetment work, Chouhali, Jamuna River, Slope failure.

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I. INTRODUCTION

Bangladesh, located at the lower part of GBM (Ganges-Brahmaputra-Meghna) basin, faces serious problem due to continuous widespread bank erosion, channel shifting and sedimentation. Although there is a declining trend of erosion due to construction of large number of riverbank protective works by Bangladesh Water Development Board (BWDB) during the last few decades, failure of implemented bank protective works is also notable. A combination of causes usually produce bank and revetment failures, and the primary mechanism or cause is difficult to determine. Some of the common causes include abrasion, debris flows, water flow, eddy action, flow acceleration, unsteady flow, human actions on the bank, precipitation, waves, toe erosion and subsurface flows [1]. One of the common failures in bank revetment work in Bangladesh is slope failure which might occur due to faulty design, steep slope, excessive surcharge load, inadequate dumping material, lack of proper key at the toe of the slope etc. This study investigates the probable cause of the slope failure of bank revetment work constructed on the left bank of Jamuna River at Chouhali Upazila, Bangladesh and provided possible remedial measures to avoid such failure in future.

Figure 1.1: Study Area: Satellite map of Chouhali channel(GoogleEarth)

Figure 1.2: Location map of Chouhali revetment

The Jamuna River is the downstream reach of the Brahmaputra River which started its journey from Kunming, China. It is braided in nature and its channels are very dynamic. Chouhali is an anabranching channel along the left bank of the river. From satellite images (Fig. 1.3) it is observed that both the right and left anabranches at Chouhali migrated outward during 1995-2005. The westward movement of the right channel was more prominent than the eastward movement of Chouhali from 2005 and it continued till protection work was done along the right channel in 2010 which restricted the migration towards west while the eastward migration of Chouhali continued more vigorously. The Chouhali channel was more prominent than the right channel afterwards.

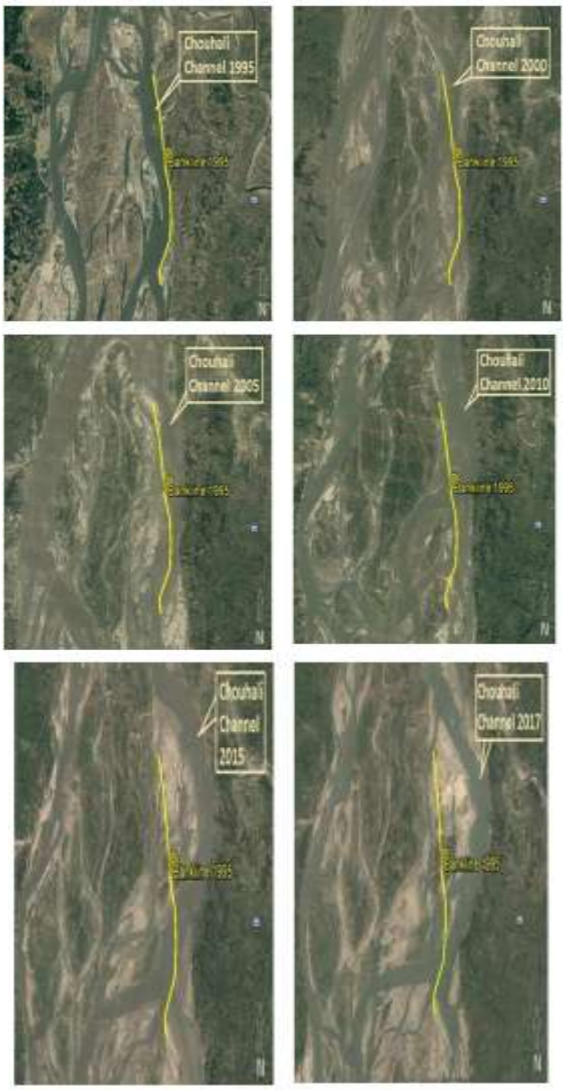

Figure 1.3: Planform development of Chouhali channel from 1995 to 2017 (Google earth)

To restrict the movement of the Chouhali channel further eastward, BWDB, under Flood and Riverbank Erosion and Risk Management Improvement Program (FRERMIP), constructed 7 km riverbank protection work along the left bank of the river.

During the construction of the revetment work, from the end of 2015 to mid-2017, particularly after the completion of the concrete layer above low water level in mid-2017, a number of slope failure occurred destroying mostly parts of the visible surface layer above low water level.

The first slope failures were observed in four locations with rising flood water levels in June 2016 and in another five locations thereafter during the recession from July until January 2017. All these slope failures occurred during first season when temporary wave protection covered the upper slope (Fig. 1.4). The majority of failures occurred during the flood 2017,at nine locations during the rising limb and at fifteen locations during recession. These failures occurred after the placement of the permanent wave protection layer (Fig. 1.5). A number of emergency repair work took place during the time 2016-2017 and the slope of the revetment work has been stable thereafter.

Figure 1.4: Slope failure after temporary wave protection, May,2016

Figure 1.5: Slope failure after permanent wave protection, March, 2017

II. METHODOLOGY:

For the identification of the probable causes of failure and to propose possible remedial measures, systematic detailed analysis and field investigation were carried out as stated below:

i. Check the design adequacy of the revetment work
ii. Carry-out field investigation and collect information from concerned field engineers
iii. Perform slope stability analysis

2.1 Verification of Design:

The approved design of protective works at Chouhali, as presented below, was collected from design division of BWDB.

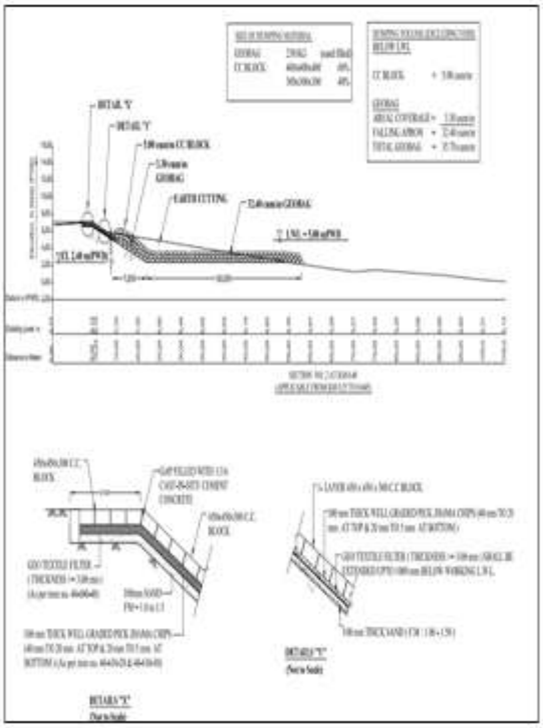

Figure 2.1: Approved design at Chouhali

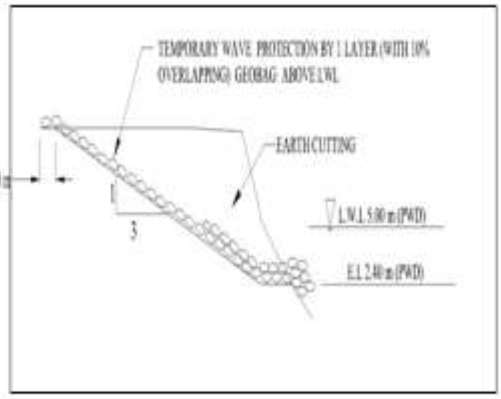

Figure 2.2: Design for temporary slope protection in the first phase

2.1.1. Hydraulic Analysis:

Available up-to-date data (from 1956 to 2013) of Bahadurabad station in Jamuna River was collected from surface hydrology section of BWDB. After determining yearly maximum discharge and highest water level for different years, flood frequency analysis was done for 100 years return period. This discharge was considered as design discharge multiplied with a factor of safety and braided index. High flood level of 100 years return period was considered as high water level. And for low water level, average monthly lowest of the recent years in various dry months was considered.

2.1.2. Structural Dimensions' Analysis:

On the basis of collected data and secondary information, necessary design parameters were analyzed. Sizes of concrete (CC) block and geobags were determined by applying commonly used formulas and those were compared with the sizes actually provided in the implemented revetments at Chouhali. The empirical regime formula of Lacey was used to determine the anticipated scour depth and was checked with the observed scour depth. Pilarczyk [3] and Hudson Equation [4] were used for the assessment of the design of cover layer of the revetment work. The size of geobag was determined using Pilarczyk formula. Provided thickness of the dumping material was checked with the required design thickness computed with JMBA equation [2]. The dumping volume was calculated considering Gales launching apron concept [5] and compared with the actual dumping volume provided.
The scour level calculated with lacey's formula is presented below:

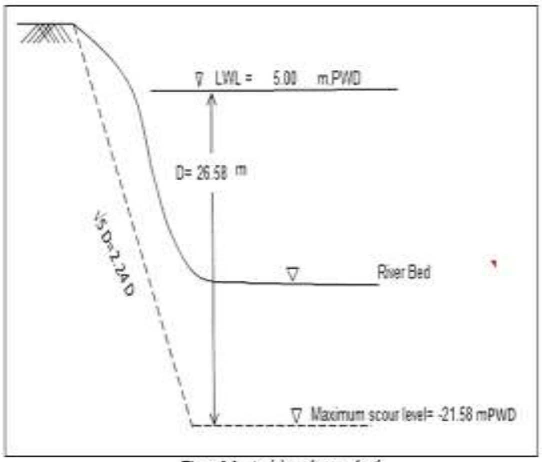

Figure2.3 : Anticipated scour depth

2.2. Field Investigation:

Several field visits were made during the implementation period and after the completion of the work to check the condition of the work and the construction procedure. All affected areas were visited and the in situ condition of the work was observed. Information was gathered from concerned BWDB engineers regarding the implementation phases , procedures , any difficulty during the construction ,post work circumstances and their views on the slope failure.

2.2.1. Implementation Process:

The protective work was implemented in two isolated phases. In the first phase, the erosion situation was controlled by providing under water coverage with sand filled geobags. The river bank was covered with geobags temporarily in the first phase to prevent bank-line shifting. Geobags were placed on a prepared bank slope of 1V:2H which was a deviation from the approved design of 1V:3H bank slope. The dumping of geobags was executed from floating dumping pontoon which was positioned exactly by power driver winches, thus obtained a uniform under water coverage of sand filled geobags. Every dumping of geobags was monitored by global positioning system. The dumping of geobag is shown in Fig. 2.4. The completed temporary wave protection is shown in Fig. 2.5. The first phase started from November 2015 and completed in December 2016.

Figure 2.4 : Dumping of geobags

Figure 2.5: Temporary Wave Protection, April 2016

In the second phase, the geobags on the bank slope was removed and the river bank was flattened to a slope of 1V:3H. The permanent wave protection consisting of a 30cm thick layer of concrete slab over filter layer was then constructed supported by a key at low water level covered with 5 m3 concrete block. This phase started from January 2017 and completed within April 2017 (Fig. 2.6).

Figure 2.6: Permanent Wave Protection, February 2018

2.2.2. Field Observation:

During the field visits, some anomalies were found in the implementation process. It was observed that at some places dredged sand was dumped on the bank (Fig. 2.7) and slope damage was noticeable at those particular places.

Figure 2.7: Dredged earth heaped on the river bank

Excavated earth and temporary wave protection from slope was heaped at the toe of slope and CC block was dumped on this loose material (Fig. 2.8) which might have compromised the consistency of the cover layer.

Figure 2.8: CC blocks dumped on loose material

2.2.3. Exploration of Information Collected From Field Engineers:

The observed scour level was less than -18.00m (PWD) for most of the length. (-) 18.00 to (-) 22.00 mPWD scour level was observed for about a length of 1400m. It indicates that calculated scour level (-21.58 mPWD) almost matches with the observed scour level.

Where the river bed was launched, the length of the launched slope was 45m to 55m. So, average thickness of material after launching = 32.40/50 = 0.65m i,e average 3 layers of geobags which is sufficient for under water protection [6].

A severe storm and flood hit the project area on May, 2016. Due to this sudden flood, uncovered area of river bed and the slope adjacent to toe were seriously damaged. Moreover, due to the untimely flood, the water level was also rising and it was difficult to build the slope at toe. This made the intersection portion of toe and apron weaker at some places.

2.3. Slope Stability Analysis:

Slope stability of the river bank was performed for three different scenarios:

i. Designed river bank (slope 1V:3H) with protection
ii. Geobags placed on the river bank (slope 1V:2H) with no the heaped soil on the bank
iii. Geobags placed on the river bank (slope 1V:2H) with heaped soil on the bank

The soil parameters were determined from the boreholes near the bank collected from the feasibility report of the project [7]. Calculations were made considering the lowest water level as it is the most critical condition. An earthquake co-efficient 0.10 was considered and the critical factor of safety for each case were checked against the limiting value of 1.10 [8]. All calculations were performed with the software XSTABL version 4.1 [9]. Modified bishop method was used to calculate the factor of safety and for the type of failure, a circular failure was assumed. For each case, twenty five hundred failure surfaces were calculated to find the most critical one.

III. RESULT AND DISCUSSION:

The calculated design parameters and the corresponding values provided in the implemented bank revetment work is presented below:

Table 3.1: Verification of Design Parameters

Parameters	**Required/ Design Value**	**Provided/ Observed Value**	**Remarks**
1. Nominal Size of Revetment material	218mm (Pilarczyk) 373mm (Hudson)	393 mm	Satisfactory
2. Size of Geobag	141 Kg	250 Kg	Satisfactory
3. Thickness of Dumping Material	0.9 mm	0.9 mm	Satisfactory
4. Scour Depth	-21.58 mPWD	-22 mPWD	Slightly higher value observed
5. Dumping Volume	33.50 cum/m	40.70 cum/m	Satisfactory
6. Length of Launching Apron	40 m	43.8	Satisfactory

The calculated design parameters as shown in the above Table indicates that the design of the revetment work at Chouhali is accurate in terms of thickness of cover layer, size and thickness of dumping material, length of launching apron and total dumping volume. The observed scour level is slightly higher than the calculated scour depth which is negligible.

The factor of safety (FOS) calculated for different scenarios are presented below:

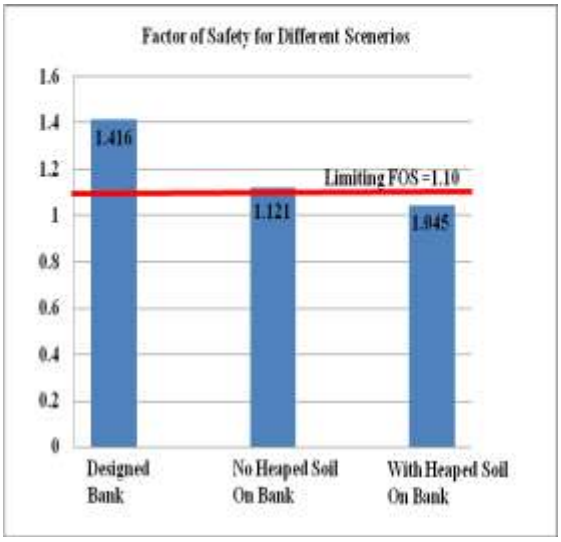

Figure: 3.1: Factor of safety for different scenarios

The most 10 critical surfaces for each case are shown below:

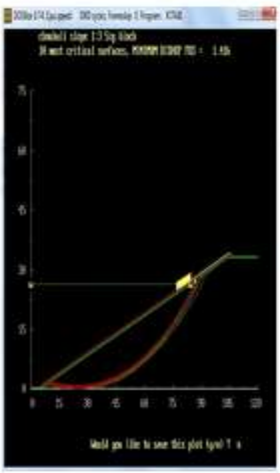

Figure 3.2: FOS for designed bank slope

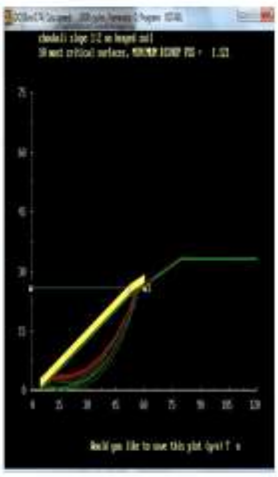

Figure 3.3: FOS for river bank with no heaped soil

The field investigation revealed some other deviations from standard construction method which might lead to the failure of the revetment slope after the permanent protection was placed. The CC block at the toe of the slope was dumped on loose materials. These loose materials were most likely to be washed away with flood water during monsoon initiating the sliding of dumped CC blocks as well as the pitching material leaving the river bank uncovered and finally leading to slope failure. The sudden flood during the implementation period damaged the slope and also caused difficulty in the construction of the key at the toe of the pitching material which might cause the slope failure during monsoon.

The condition of the revetment work was monitored regularly and necessary measures were taken accordingly which prevented further failure and ensured the safety of the work.

IV. CONCLUSION:

The slope failure in Chouhali revetment was initiated due to some deviation from standard construction procedure and unfavorable natural circumstances. The initial slope failure during the first implementation phase occurred due to the heaped soil on the river bank which caused surcharge load and seepage on slope. And the failure during monsoon after the permanent protection took place due to the placement of CC blocks on loose material. Regular monitoring and prompt maintenance work saved the revetment from further failure and retained the integrity of the work.

Following are the key lessons learned from this study:

1. There should be provision to manage the temporary wave protection and dredged soil. The excavated earth should not be heaped on the river bank or at the toe of the slope.
2. No concrete key shall be built on loose deposits.
3. The upper wave protection layer shall be anchored at the bottom with an anchor beam to avoid immediate sliding of the upper protection if the key is compromised.
4. There should be regular monitoring and provision for proper adaptive and maintenance work for the safety and sustainability of the work.

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