# River Bank Protective Work of Bangladesh: A Case Study on the River Padma

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***Abstract*—A well and exact documentation of the methodology and novel implementations of a river training work can pave the way for future economic, established and cost effective paradigm to work with. The paper describes contemporary practice for river training works, as well as site specifics, obstacles, costs involved and management exercises, along the Padma River, the main distributary of the river Ganges. A map of the riverbank erosion along the study area is provided in order to extract proper and useful information about the morphological nature of the river. Then the technical aspects for bathymetric survey along with the application procedure used for dumping and placing of geo-bag and CC block along the riverbank for its protection is described. After that, some of the concerns and challenges that were encountered by the team, which was working there, are discussed. It was found that the project would have benefited if the technical and instrumental risks in addition to the uncertainty of workers were taken into account beforehand. A cost analysis table is also provided to give information about the estimated expenditure for future projects.**

***Index Terms*— riverbank, erosion, geo-bag, CC block, anchorage, dumping, barge**

## I. Introduction

The morphologically active rivers of Bangladesh has very high rate of year round fluctuation of water flow as well as sediment transportation. Consequently, erosion-deposition, channel shifting and bar development are common phenomena in large rivers. The Padma River in central Bangladesh is approximately 100 km long and flows in a south-east direction from the confluence of the Jamuna (or Brahmaputra) and the Ganges to join the upper Meghna River, below which point it is known as the Lower Meghna [1]. In terms of average annual discharge, it is classified as the third largest river in the world, only surpassed by the Congo and Amazon [2]. Strenuous southwest monsoon precipitation (June to October) induces the fluid circulation of the Padma. Off that period, the drift is mainly associated with the base flow and snow melting in the Himalayas. Length averaged width of the river is about 10.5 km, while annual maximum erosion rate may transcend 1,000 m/year. It has been demonstrated by Klassen et al. [3], [4] that both river training and bank protection measures, which are strongly interrelated, have the objective to ensure a safe and efficient transport of water and sediments. Therefore, river training works are necessary to maintain Padma in a reasonably stable alignment to ensure expected flow at downstream and proper bank protection for the people living near the banks.

The study of labour management, cost analysis, extensive process and accidents at a specific project are seldom investigated in the river training works along the Padma. The complexities of the project, adversities faced during the process, intuitions considered and modifications attempted are all integral parts of a project. A foray into specifics of an ongoing project will lead to better understand the seminal measures needed for contemporary attempts at river training works and uncover possible challenges that are needed to be resolved. The paper describes the adaptive process, cost analysis, morphological background, challenges encountered for river training works at Mawa Old Ferry Ghat under Louhajang Upzilla of Munshiganj District, Aurangabad bazar to Braha Bazar ghat and West Narisha Bazar to Meghula Bazar under Dohar upzilla of Dhaka District along the left bank of the Padma.

## II. Study Area

### A. Observed Stations

Three sites are explored in this paper for different purposes. The first site is from West Narisha Bazar and Meghula Bazar at Dohar Upzilla, Dhaka. Bathymetric survey is carried out to get the depth from waterbed to water surface. The second site is the Aurangabad Bazar to Braha Bazar ghat, Dohar Upzilla Dhaka. The tender was properly scrutinized and the cost was analyzed to get the appropriate prices in Bangladesh. The third site is the Mawa Old Ferry Ghat. This site is especially important as the construction of Padma Bridge poses special conditions to be considered.

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### B. Erosion Scenario

The amount of erosion-deposition is an important information in processing and structuring of any river training works. The right amount of bank protection measures in the right site will result in the economic use of resources. With the intention of having an overall idea of the erosion and deposition characteristics of the sites mentioned earlier, ArcGIS 10.4 is used to calculate approximate area of erosion-deposition in the years between 2008 and 2018 [5], [6]. Landsat 4-5 TM C1 Level-1 and Landsat 8 OLI/TIRS C1 Level-1 images were used to draw the bank line along Padma River for years 2008 and 2018 respectively shown in Fig. 1 and 2. A map showing erosion and deposition along Padma River bank in Fig. 3 is formed based on these lines. The area of erosion at Aurangabad site is calculated to be approximately 6120933 $m^2$ and at Meghula site, it is 582269 $m^2$. Between Aurangabad and Meghula, the area of erosion during 2008-2018 is approximately 4519947 $m^2$. This measure enforced the setting to be as contemporary as possible.

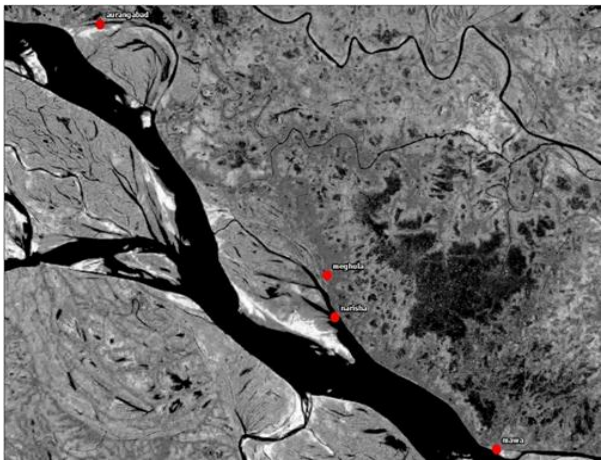


Figure 1. Landsat image of Padma River bank between Aurangabad and Meghula in 2008

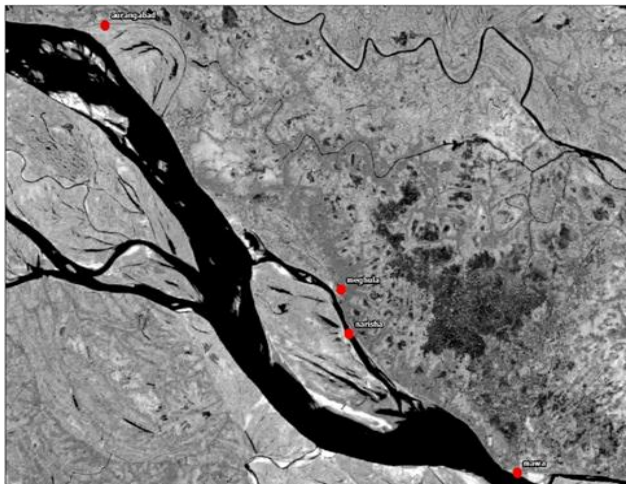


Figure 2. Landsat image of Padma River bank between Aurangabad and Meghula in 2018

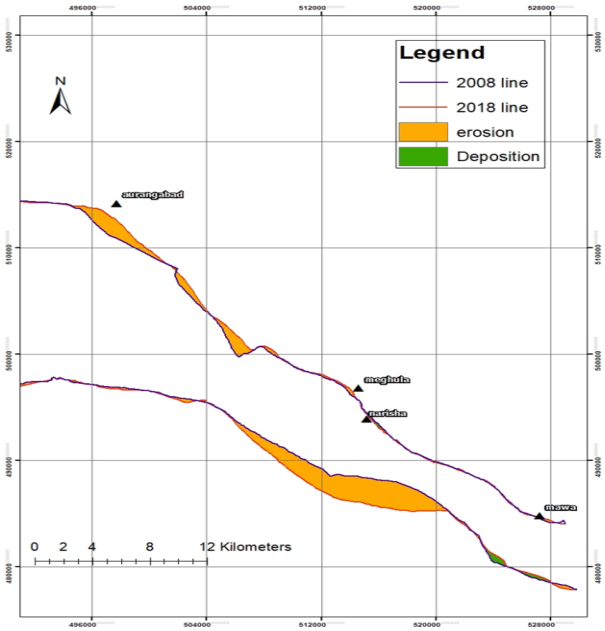


Figure 3. Map showing erosion and deposition along Padma River Bank bank between Aurangabad and Meghula during 2008-2018.

## III. Methodology

### A. Bathymetric Survey

Bathymetry is the measurement of water depth: height from waterbed to water surface. Bathymetric survey is carried out in the affected area before the design of bank protection work can be started. This survey is done by echo sounding that is a type of sonar used to determine the depth of water by transmitting sound pulses into water. The time interval between emission and return of a pulse is recorded. This process is carried out from a survey boat. Northing, easting and depth of riverbed data are recorded at various points along eroded bank and the scoured bed areas near the bank. Readings are taken at certain intervals depending upon the topography of the riverbed. If there are more undulations, close interval readings are taken. The software Surfer is used for mapping the topography of the affected area. For example, the following Fig. 4, Fig. 5 and Fig. 6 show the survey reports of the affected area along the left bank of Padma river at west Narisha Bazar and Meghula Bazar at Dohar Upzilla in Dhaka District.

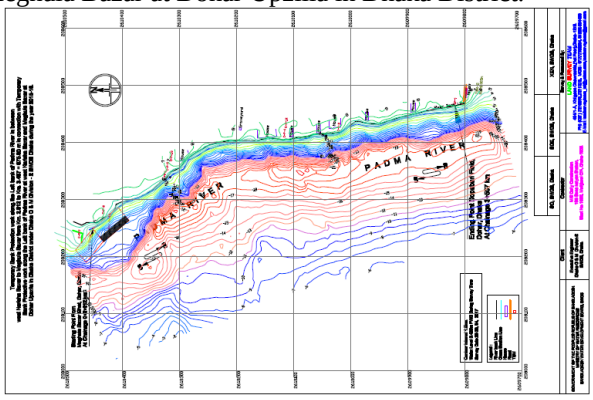


Figure 4. Erosion scenario between Narisha Bazar and Meghula Bazar

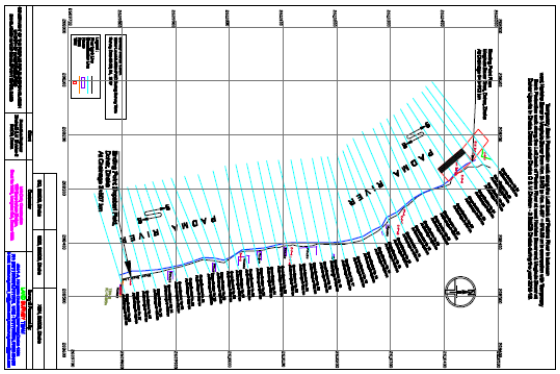


Figure 5. Map showing the x-sections taken for bathymetric survey between Narisha Bazar and Meghula Bazar

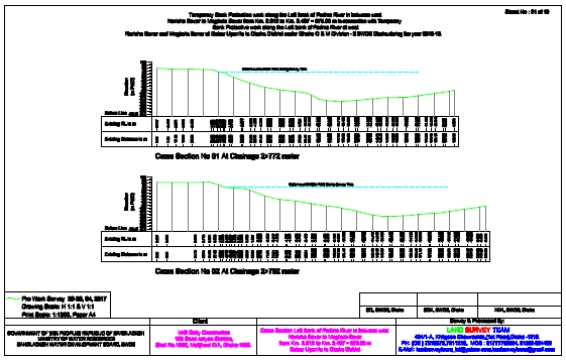

Figure 6. A typical x-section of the river under the study area

### B. Application of Geo-bag and CC block

Since geo-bags and CC Blocks have a higher resistance against scouring or bank erosion process, they are being used all over the erosion prone area in the country for immediate and permanent protection. Bangladesh Water Development Board (BWDB) has been using cement concrete (CC) blocks and sand filled geo-bags for the construction of revetments since 2001 as they were identified as a low cost effective solution in a pre-feasibility study in 2000 [7]. Sometimes volumetric structures like groin or spur are formed with a higher surface resistance using CC blocks and geo-bags to divert the flow direction in order to save the valuable area of the downstream area.

Korkut et al. [8] tested the performance of geo-bags as scour countermeasure for bridge abutments and concluded that geo-bags cannot protect the local scouring but they are very flexible to adapt in placing as protection materials. Geo-bags structures may also fail due to overtopping, sliding, puncturing and pull-out/dislodgement [9]. However it has been found from recent practices of BWDB that synthetic geo-bags also perform well under water.

Wahed et al. [10] compared the environmental impact of CC blocks and sand filled geo-bags under water in the river erosion protections for the major rivers in Bangladesh and concluded that geo-bags are eco-friendly. In the event of emergency, geo-bags require less time for preparation, curing and subsequent dumping.

On the other hand, because of having heavier weight than geo-bags, CC blocks are less subjected to be washed out by heavy current and wave action. [11]

Different points of the study area are being protected by either geo-bag or CC block or both depending on the extent of erosion, flow velocity and cost.

### C. Dumping Schedule

After the design of the riverbank protective (RBP) work has been approved by the design office of BWDB, it is sent to the field office for execution. Both geo-bags and blocks are dumped to the specified points from dumping barges. The field office prepares a dumping schedule according to the design and barge size. The total RBP area is divided into strips both length wise and width wise. For example, if the total length of the RBP work is 1500 meters in length and 55 meters in width (including aerial coverage and falling zone) and two barges of length 70 meters and 60 meters are used, then a different dumping schedule is prepared for each barge. This 1500-meter length is divided into number of strips of either 60-meter or 70-meter length and the width of the RBP work is divided into strips according to the width of the geo-bags or blocks. In the schedule, northing of easting of both upstream and downstream sides of the strips are mentioned.

### D. Anchorage of Barge

Flat top barges are used for dumping. To set the barge at a particular strip lengthwise, the barge is anchored once for the whole width of RBP work. Its position is maintained with the help of a total station. The barge is anchored on both sides (riverside and bank side) and on both ends (upstream and downstream). The riverside of the anchor is done with the help of an anchor barge (Fig. 7) and on the bank side, anchoring is done manually. The barge is then fixed lengthwise but it can be moved laterally with the help of a drum mooring winch (Fig. 8) with ropes and anchor.

Figure 7. Riverside anchor

Figure 8. Drum mooring

### E. Geo-bag Dumping

Different sizes of geo-bags are used in protective works in Bangladesh. In the study area, the outer dimension of the geo-bags were 1250mm X 1000 mm and the required dry weight of sand filled geo-bag is 250 kg. For geo-bag dumping, sand carrying vessels (Fig. 9) are brought near the anchored barge. This sand should follow the design specifications that are checked on site. For Padma RBP work, according to design guidelines, filling material of geo-bag should be 100 % sand of FM more than 0.9 and percent retained on # 100 sieve is to be at least 90%. This is ensured and checked on the spot

(Fig. 10) by sieving the sand through #100 sieve. Sand should be free from clay and organic materials.

Figure 9. Sand carrying vessel

(a) wet weight (b) dry weight

Figure 10. On site checking of sand standard

Synthetic geo-bags are transported to the barge from the stack yard using an engine boat. Each stack consists of fifty geo-bags. Specifications of the geo-bags are mentioned in Table I. Actual weight of the geobags in gsm (gram per square meter) unit can be calculated by weighing one fifty bag stack (Fig. 11) and then dividing the weight by fifty and the surface area of each bag.

Figure 11. Stack of geo-bags

TABLE I. SPECIFICATION OF GEO-BAGS

| Properties | Test Standard | BWDB Value |
|---|---|---|
| Minimum Thickness | ENISO 9863 | 3.00 mm |
| Opening size, $D_{90}$ | ENISO 12956 | 0.08mm |
| Mass per unit area | BSEN 965 | 400 gm/m |
| TensileStrength (MD/CMD) | ENISO 10319 | 23 KN/m |
| Elongation –(MD/CMD) | ENISO 10319 | >=40% & <=100% |
| Grab Strength | | =>1500 N |
| Permeability | ENISO 11058 | $\geq 2X10^{-3}$ m/s |
| CBRpuncture resistance | ENISO 12236 | 3800 N |
| Abrasion | Following RPG of BAW Germany, $D_{90}$ according to ENISO 12956 and thickness according to BSEN 9641 | After test: tensile strength $\geq$ 75% of specified tensile strength, thickness $\geq$ 75% of original value, $D_{90} \leq$ 0.09mm |
| UV Resistance | ASTM D4355 | $\geq$ 70% original tensile strength before exposure |

The bags are then filled with specified sand at exactly the marked positions on the barge. This process is done with the help of manual labor (Fig. 12).

After they are filled properly, the bags are sewed with sewing machines . Sewing should be done with lock stitch and number of stitch should be six numbers per inch and thread for stitching should be 100% polypropylene or nylon. Minimum margin from edge of geotextile to stitch line should be 280 mm.

Figure 12. Geo-bags are being placed on the barge according to position

Figure 13. Counting and lengthwise placing of filled geo-bags

Figure 14. Manual dumping

After ensuring the required weights of the filled geo-bag, they are aligned lengthwise. These are counted using paints for marking and then dumped all at a time upon instruction ( Fig. 13 and Fig. 14).

### *F. Placing*

After completion of geo-bag dumping of a particular strip, berm is prepared and the required number of geo-bags as per design are placed on the berm. Then the river bank is cut in a particular slope for example 1:2 or 1:3. The slope is compacted as required and after that geo-bags are placed along the river direction on that slope (Fig. 15).

Figure 15. Placing of geo-bag

## IV. Concerns

The engineers and workers associated with the bank protection work have to face a great deal of challenges. Because of huge flow velocity and loose anchorage, failure of the anchorage can occur. There has been an incident reported in the mentioned site when one labor actually died when the anchorage failure occurred. He got hit by the anchorage that hit him with huge force. Again, there exists high risk of accident of laborers falling from barge or falling of blocks on the legs of labors.

Due to bad weather barge cannot be positioned at perfect latitude and longitudinal position mentioned in design data due to invisibility of prism of total station. Moreover, stitching of geo-bag is not possible during rain as the geo-bags become slippery.

Sand used as geo-bag fill generally comes from dredging of the riverbed done for preventing siltation. It is very important to maintain the quality of sand as mentioned in the design data. However, most of the time it becomes a great challenge to do so.

Sometimes local people pressurize the working engineers of the site to perform bank protective work at their preferred places.

Labors are paid daily after work based on the number of geo-bags or blocks they dumped on that particular day. Especially in case of geo-bag, dumping, dredged sand has to arrive at the dumping site on time. If there is some delay in getting the sand available at the site, many labors leave the site for the day unnoticed in search of some other sites where they will get more money. Surprisingly this is a common scenario in Bangladesh riverbank protection sites. Also in case of block dumping, all the required sizes and numbers of blocks must be ready and properly cured at the site before the dumping can begin which is also a major challenge.

## V. Cost Analysis

The abstract cost for bank protection work along the left bank of Padma River at Aurangabad Bazar to Braha Bazar Ghat from km 3.500=3500 m (+U/S End Termination 418.67 m and D/S End Termination 78.5 m) in Dohar Upzilla, Dhaka under O & M Division-II, BWDB , Dhaka, during the year 2015-2016 is listed in Table II.

The total cost is estimated to be around **1.88 billion BDT.** Therefore, a huge amount is being spent for riverbank protection work along the large riverbanks of this country. Still this cost should be lower than other countries since labor cost is very cheap in Bangladesh.

## VI. Concerns River Training Work of Padma Bridge

Bangladesh Government is currently constructing a 6.15 km long multipurpose rail-road bridge over Padma River which will create a link between the South and West of the country. This construction project is considered one of the most challenging construction projects of the country. BWDB is responsible for carrying out 1300 m of river training work upstream of the bridge on the Mawa end. This huge task consists of both geo-bag and CC block dumping. Total number of 250 kg geo-bag is 337004 nos. 3 types of CC blocks are being used- 40 $cm^3$, 50 $cm^3$ and 60 $cm^3$ and the total number of block is 2659242. The total estimated cost of this 1300 m river training work is 4.2 billion BDT.

TABLE II. COST OF RIVER TRAINING WORK

| Items | Quantity | Unit | Rate | Amount |
|---|---|---|---|---|
| Earth work in excavation | 1656 | P/Cum | 158.85 | 26315337.2 |
| Earth work in cutting and filling | 160949 | P/Cum | 130.35 | 20979723 |
| CC Block size 45cmx45cmx45cm | 451496 | nos. | 903.23 | 407804732 |
| CC Block size 45cmx45cmx30cm | 334590 | nos. | 582.74 | 194978976 |
| CC Block size 35cmx35cmx35cm | 639731 | nos. | 413.63 | 264611933 |
| Supplying Geo-bag:size 1200mmx950mm | 1620110 | nos. | 269.13 | 436020204 |
| Filling Geo-bag:size 1200mmx950mm | 1620110 | nos. | 118.86 | 192566274 |
| Dumping Geo-bag:size 1200mmx950mm | 1620110 | nos. | 66.9 | 108385359 |
| Labour Charge for dumping(within 200m) | 2742 | P/Cum | 1213.46 | 33283285.6 |
| Labour Charge for dumping(beyond 200m) | 41142 | P/Cum | 1717.31 | 70654639.6 |
| Supplying and filling empty gunny bags(75kg) | 821938 | Each | 53.72 | 44154509.3 |
| Supplying and placing non-woven geo-fabric | 77673 | P/$m^2$ | 193.13 | 15001112.0 |
| Supplying and laying sand(FM 1-1.5) | 6909 | P/Cum | 914.83 | 6321369.18 |
| Supplying and laying dry 1st class or jhama chips (40mm-20mm) | 3454 | P/Cum | 3591.88 | 12409737 |
| Supplying and laying dry 1st class or jhama chips (20mm-5mm) | 3454 | P/Cum | 3912.19 | 13516389.5 |
| Labour charge for protective works(within 200m) | 8130 | P/Cum | 1051.99 | 8553243.61 |
| Labour charge for protective works(beyond 200m) | 12195 | P/Cum | 1857.62 | 22655173.1 |
| CC work(25mm down graded stone chips) | 181 | P/nos | 9126.47 | 1653104.89 |
| RCC boundary pillar,bench pillar, km post | 36 | P/day | 897.9 | 32324.4 |
| Country boat with majhee | 365 | P/day | 1200 | 438000 |
| Driver without safety device | 365 | P/day | 800 | 292000 |
| Bathemetric survey | 1010 | P/sections | 1800 | 1818000 |

## VII. CONCLUSION

River training work is a complex and intricate process. Proper river training and protective work help protect the land of thousands of people in a densely populated country like Bangladesh. Success of such works depend on a number of factors which should be carefully addressed. This documentation will help to draw a proper scenario of river training works carried out in Bangladesh.

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