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River bank stabilization with the application of bamboo bandalling structure: a case study

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ABSTRACT : Bandalling is a locally bamboo made structure used for the river course stabilization by river bank erosion protection. Due to the locally available low cost materials and labours, the construction of the bamboo bandalling is also cost effective for the protection of erosive floodplain land. As a case study, the bamboo bandalling structures are constructed at the river bank erosion prone area of the river Jamuna near the Shaheed Salahuddin Cantonment at the upstream of the Bangabandhu Bridge East Guide Bund, Bhuapur, Tangail, Bangladesh. Due to the effect of the constructed bamboo bandalling structures in the river bending reach, the secondary current is not able to attack the bending river reach which is responsible for accelerating the river bank sedimentation. It is also observed that water flow velocity is diverted towards the main channel and that f less magnitude near the river bank. Due to this low flow velocity near the river bank and the disturbed secondary current, there is huge sedimentation occurs near the erosive bending river reach between the constructed bamboo bandalling structures indicating that the bamboo bandalling structures can be used successfully as the river bank stabilization.

1 INTRODUCTION

The alluvial rivers of Bangladesh have its bank erosion especially in the river bend. Due to this river bank erosion, the socio-economic conditions of the country are being affected and so river bank stabilization is important for the agricultural land safety and food security for its economic development. By this time, Bangladesh Water Development Board (BWDB) has constructed lot of constructed structures such as the spur, groin, revetment etc along the major rivers such as the Brahmaputra-Jamuna, the Ganges-Padma river system to protect the rural people and agricultural lands from the damage in flooding. Due to this river bank erosion, the bank protections are often required also during the monsoon flood season and post-monsoon season.

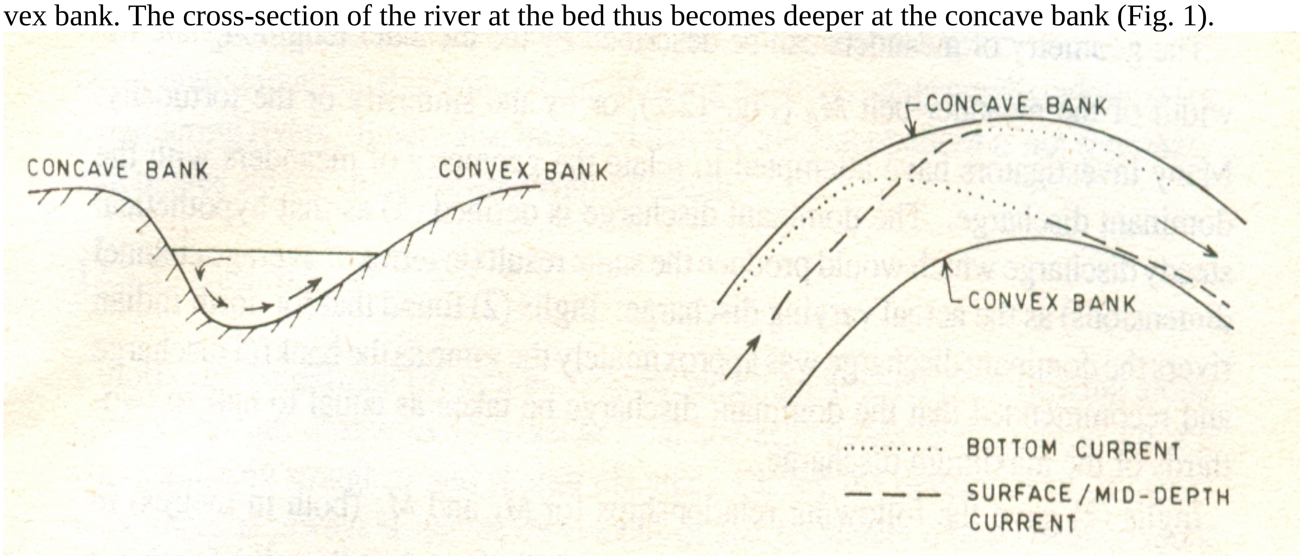
The structures spur/groins and revetments are used as a method of bank protection conventionally. The characteristics of the alluvial rivers are such that its river courses are shifting within the limited regime width by changing its depth of the flood plains rivers. Some cases the length and width of the river is more than the regime length and width of the river. It gives us an indication of the degree of instability of rivers in Bangladesh. If the bank protection structures such as groynes, revetments or spurs are applied in the alluvial rivers the utmost success may be achieved protecting river bank locally. But these structures will create problem somewhere else resulting far away bank erosion and additional instability to the sand bars where a number of rural people may be lived in the sand bars or chars. So, applying these conventional methods of countermeasure, the river bank erosion at the short term basis can be obtained, whereas, the long term stable channel or regime channel can never be developed. The possibility of using bandals for long-term channel stabilization is examined using field data and laboratory investigation (Rahman et al., 2003). It is obvious from the flood hazards so that the river bank erosion is one of the natural disasters in Bangladesh. The global climate is changing which has an effect in Bangladesh for the river bank erosion. It is mentioned here that every year the river bank is being eroded and the intensity of erosion is increasing day by day. So it is needed to protect river bank erosion for its channel stabilization. As because of the bamboo bandalling structures are constructed with the locally available bamboo as raw materials and local labor oriented workers and so this is the low cost method for the river bank erosion protection structures (Rahman, at el., 2009). From Bangladesh Water Development Board (BWDB) practiced different river bank erosion structures, we can get the comparative costing from literature as shown as in the table-1 for the river bank erosion protection or river bank stabilization.

Table 1. Comparison among implementation cost of different bank protection structures

Type of structure	Name of the Rivers	Implementing Agency	Cost in USD
Guide Bund	Jamuna (Bridge)	Foreign	33,000.00
Hard point	Jamuna in Sirajgonj	Foreign	21,000.00
Solid spur	Jamuna in kalitola	Foreign	2,500.00
Revetment (Geobags)	Jamuna	Foreign	2000-3000
Revetment	Jamuna	BWDB	3800-4000
RCC spur	Jamuna/Ganges	BWDB	950.00
RCC spur	Teesta	BWDB	350.00
Bamboo Bandalling	Jamuna (Branch Channel)	RRI	70.00

2 WORKING PRINCIPLE OF RIVER BANK STABILIZATION

The stabilization of a river course is mainly affected by the characteristics of the sediment-laden water flowing in the river. The available energy of the flow is utilized in transporting the sediment load as well as in overcoming the resistance due to the viscous action and the roughness of bed and sides. On account of the interdependence of the factors affecting the flows, there is an inherent tendency of these rivers to attain equilibrium. As such, whenever the equilibrium of a river is disturbed by the man-made structures or natural causes, the river tends to attain a new equilibrium condition by scouring the bed or by depositing the sediment on the bed or bank by changing its own plan-form. These changes can be either local or extended over a long reach. The behavior of a river can, therefore, result in the variation of the shape of the river cross-section and/or its plan-form. With the slight asymmetry in flow, an alluvial river tends to develop bends which are characterized by scour and erosion of sediment on the concave (i.e. outer) bank and deposition of sediment on the convex (i.e. inner) bank. Because of the curved flow lines around the bend, the flow is subjected to centrifugal forces and, hence, there is a transverse slope of the water surface due to the super-elevation of the water surface at the concave bank. As a result, the bottom water (moving with relatively smaller velocity) moves from the concave bank to the convex bank and also carries with it the bed material and deposits it near the convex bank. To replace this bottom water, water dives in from the top at the concave bank and flows along the bottom carrying sand and silt to the convex bank where it is deposited. This secondary motion is primarily responsible for the erosion of the sediment on the concave bank and the deposition of the sediment on the convex bank. The cross-section of the river at the bed thus becomes deeper at the concave bank (Fig. 1).



Figure(1a) Figure(1b)

Figure-1: Movement of water at the river bend

2.1 *River bank instability by the secondary currents at the bend*

Secondary currents are defined as currents which occur in the plane normal to the axis of the primary flow. They have been shown by Prandtl to be of two types: stress-induced currents driven by non-uniform boundary shear stress distributions in straight channels; and skew-induced currents caused by skewing of cross-stream vorticity into a longstream direction when the flow is curved. The influence of secondary currents on flow and sediment dynamics causes meander shifting through river bank erosion and bar sedimentation that leads to the planform evolution that is typical of meandering rivers (Thorne, 1991). Up until the late 1970s it was thought that secondary flow at a bend consisted of a single, skew-induced cell carrying fast surface water towards the outer bank and slow, near bed water towards the inner bank (Engelund, 1974) (Fig. 1a) Sediment transport is strongly influenced by the secondary flow pattern. On the upper, point bar platform bed material is transported laterally outwards, towards the point bar crest (Fig. 2). Sedimentation on the platform consists mostly of fines and wash load deposited due to decreasing flow discharge and intensity in the longstream direction. Sediment sorting occurs on the sloping point bar face. The largest, heaviest particles roll downslope under gravity against the inwardly directed near-bed secondary current, while lighter particles are swept inwards against gravity (Fig. 2). At the junction of the skew-induced cell and the zone of outward flow, near-bed currents converge and there is upwelling. Here sediment ladened, near bed water is carried up into the body of the flow by upwelling secondary currents. Often, bed material transport (both bed load and suspended load) is concentrated in a ribbon running below line of convergence and the accumulation of sediment there leads to the building a of a sharp ridge separating the upper, gently sloping point bar platform from the lower, steeper point bar face. In meandering rivers the crest follows the zone of convergence which is skewed across the channel from the outer bank at the bend entrance, to the inner bank at the bend exit. This topographic feature itself induces further strong circulations that play important roles in bed material sorting by size fraction and sediment pathways through the bend. So it is mentioned here that if the river bank instability is developed by the secondary currents, then there will be possibility for the river bank stabilization by retarding that current with construction of bamboo bandalling structures.

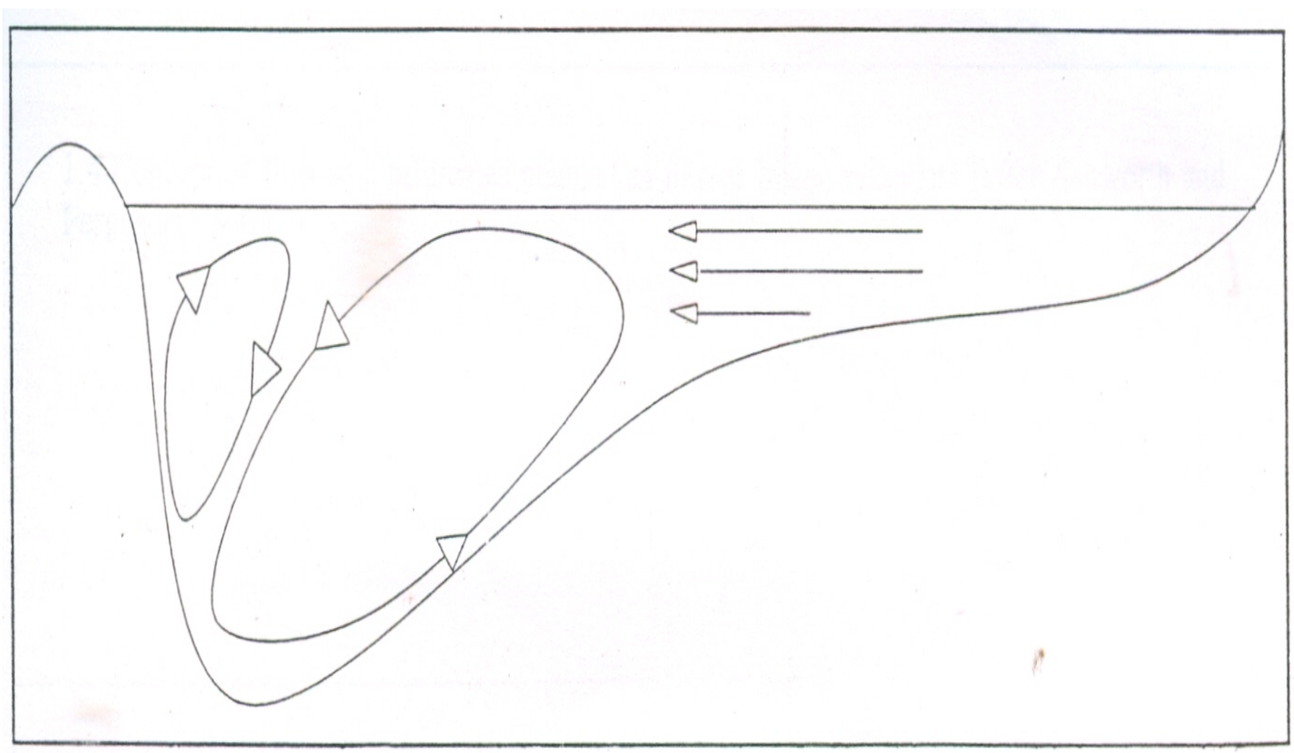


Figure-2. The conceptual diagram of secondary current near the erosive river bank and send bar

3 RIVER BANK STABILIZATION PROCESS

The low cost bamboo bandalling structures are constructed at the river bank at a certain angles with water flow direction usually 30 to 40 degrees depending the flow intensity and stream power with the particular spacing such as 2 to 3 times of the bandals length. The typical bamboo bandalling structures are shown in figure.3. It was observed that water flow diverted towards the main river due to Bandals resulting maximum velocity accumulated away from the river bank whereas comparatively less velocity appeared near the river bank where bandals are placed resulting sediment deposition. This near bank sedimentation of the river gives us an indication for the river bank erosion protection which is very low cost.

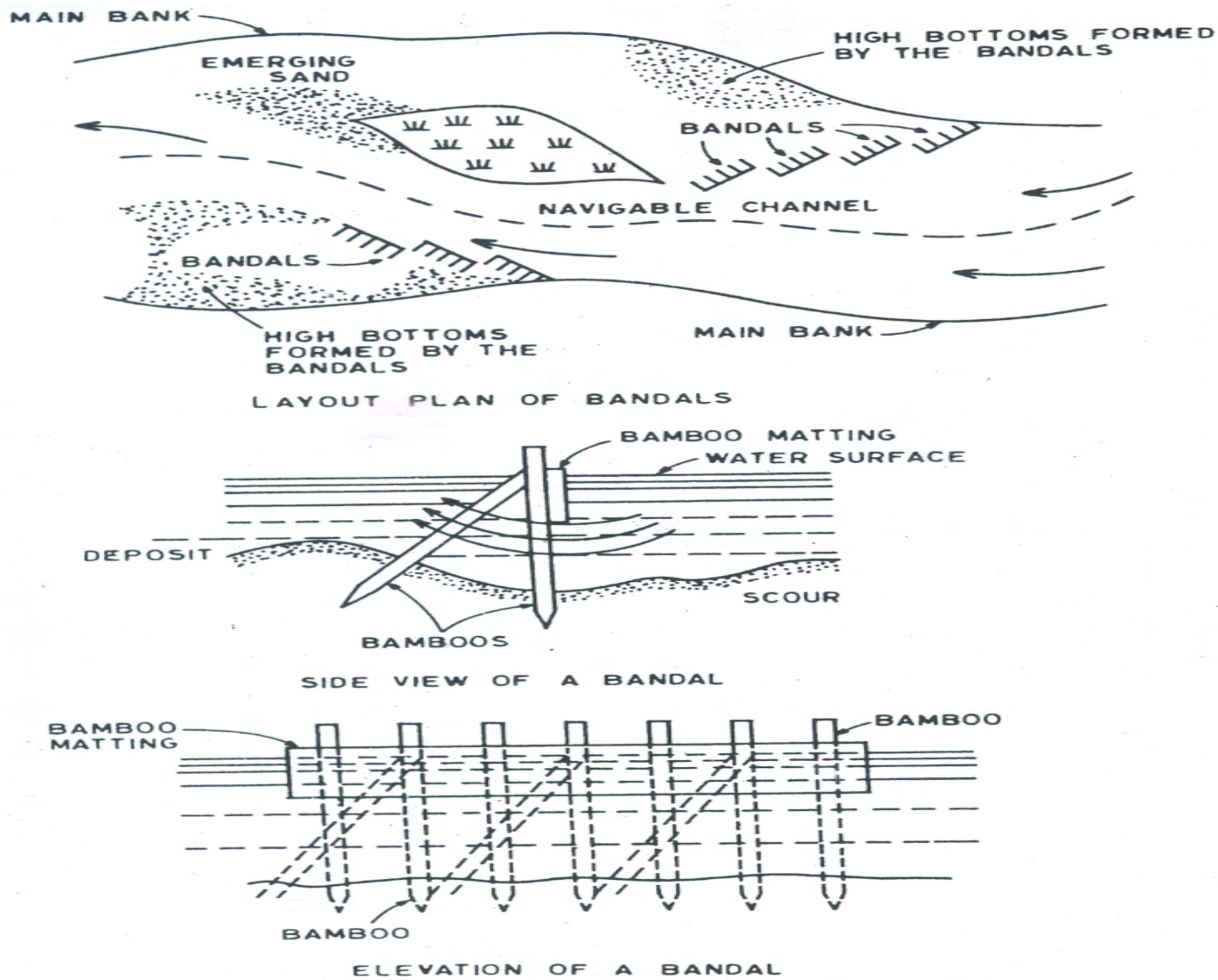


Figure 3. Working principles and design of bamboo bandals

The above working principle was the beginning of the bamboo bandalling work and using here as references so that within the lower half of the flow depth, major portion of the sediment flow is concentrated, whereas, within the upper half water discharges are more. It is also mentioned that in the Indian sub-continent bandals are commonly applied to improve or maintain the flow depths for navigation during low water periods in alluvial rivers. The characteristics of bandals are that they are positioned at an angle with main current and there is an opening below it while the upper portion is blocked.It is mentioned that as an empirical rule the blockage of the flow section should be about 50% in order to maintain the flow acceleration (Rahman et al., 2003), but in this paper it mentioned that the flow depth is blocked by bamboo chatai for about 40% and the result is very good with huge sedimentation behind the bandals. There is a pressure difference at the upstream site and downstream of the constructed bandals. The higher pressure is in the upstream of bandals than that of the bandals in the downstream site. Due this pressure difference, water flow is forced along with the sediment below the opening of the bandals and the surface current is being forced towards the main river channel. So, much sediment is supplied from the upstream site to the river bank. There is reduced flow velocity behind the bandals near the river bank resulting sedimentation over there. The bamboo bandalling structures are constructed from the left bank of the Jamuna branch channel and protruded towards the main river channel near the Shaheed Salahuddin Cantonment, Bhuapur, Tangail as in figure-4a and before the bandal construction the eroding river bank is looked like as in figure-4b (IEB, 2010).

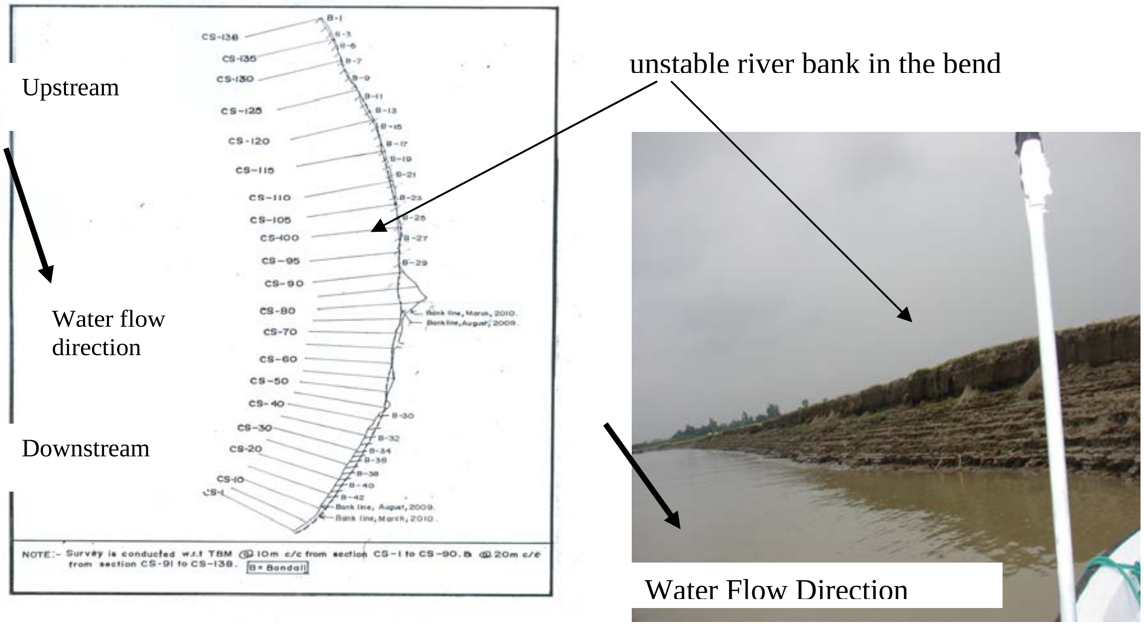


Figure-4a: Index map of the study river reach

Figure-4b: Eroding unstable river bank before bandals construction

The condition of the river bank before taking the erosion protection by the bamboo bandalling structures, it was very steep slope. The channel near the river bank was very deep. In this situation bamboo bandalling was constructed. The initial river bank conditions were seen as in figure 3 in above. This low cost Bandalling structures are constructed on the left side in the Jamuna river branch channel from up stream to downstream at 40 degree angles with the water flow direction i.e. the bank line is shown in figure 5.

Figure-5a

Figure-5b

Figure 5: Stabilization of river bank with the aid bamboo bandalling structures

As in figure 5(a), the study team is visiting the bandalling construction site during flood whereas there is huge sedimentation behind and between the constructed bandals is seen as in the figure 5(b) after flood. The sedimentation behind the bamboo bandalling structures is responsible for the flow field behind the bandal like structures. There is an idea gathered by the flume study set up as in figure-6 so that at the upstream of the bamboo bandalling structure no disturbance in the velocity vector field whereas the velocity vector field as in figure-7 is disturbed behind the bandal location and reduced in magnitude . This is due to the effect of the bamboo bandalling structures constructed near the river bank in the laboratory flume river (Rahman et al., 2009) .

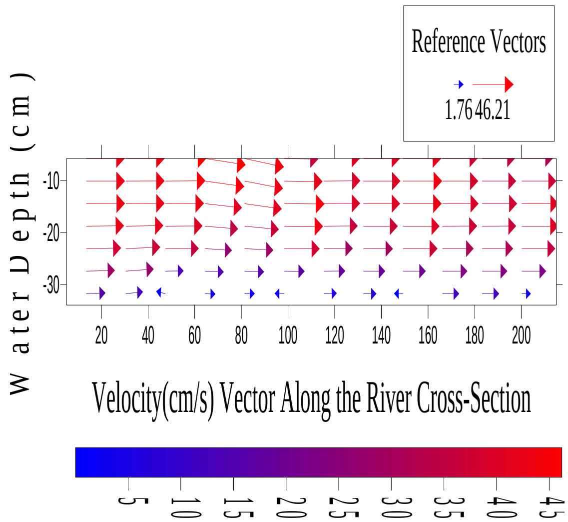


Figure 6.Velocity vector at u/s of the bamboo bandalling

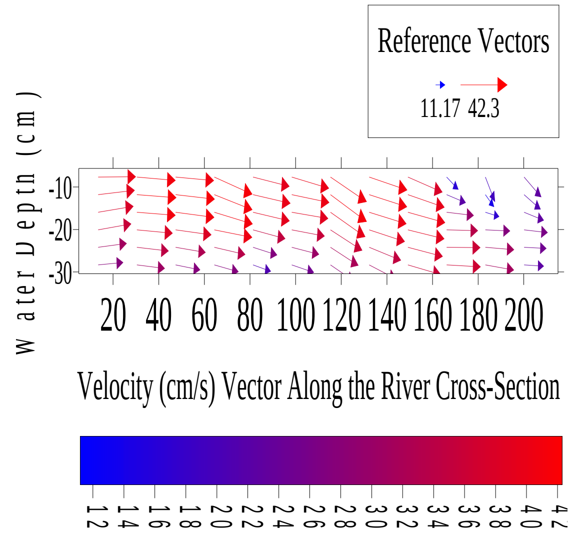


Figure 7. Velocity vector at d/s of the bamboo bandalling

So it can say that bamboo bandalling structures are capable for stabilizing river course by the mail flow diversion away from the river bank as well as disturbing the induced secondary current. If the bamboo bandalling structure functions optimistically, the river can get sufficient time for its adjustment and new main river course and bank line stabilization.

4 DATA COLLECTION AND ANALYSIS

The river bathymetry data is collected from the cross- section 1 through cross- sections 138 over a bending length of river reach 1.5 km as in figure-4a. For the better analysis, from the 1.5 km river reach, four cross-sectional data are considered three reaches such as the 0.50 km downstream reach, 0.70 km middle and 0.3 km upstream reach. For the analysis, the cross-section no. 5 is taken from the downstream 0.50 km reach whereas two cross-sections no.86 & 88 are taken from the middle 0.70 km reach and that of one cross-section no. 106 is considered as in figure-8, 9(a) & 9(b) and 10 respectively. The bed level, water level data are collected in this problem area with reference to a Temporary Bench Mark (TBM) near the Bangabandhu Bridge East Guide Bund.

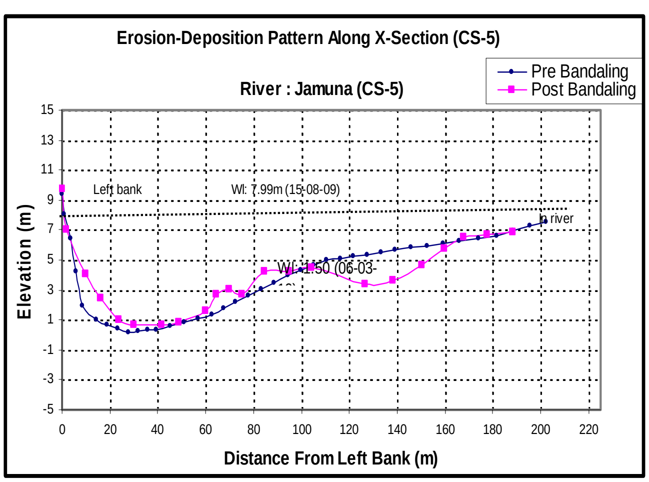


Figure 08: X-section within 0.5 km d/s reach of 1.5 km

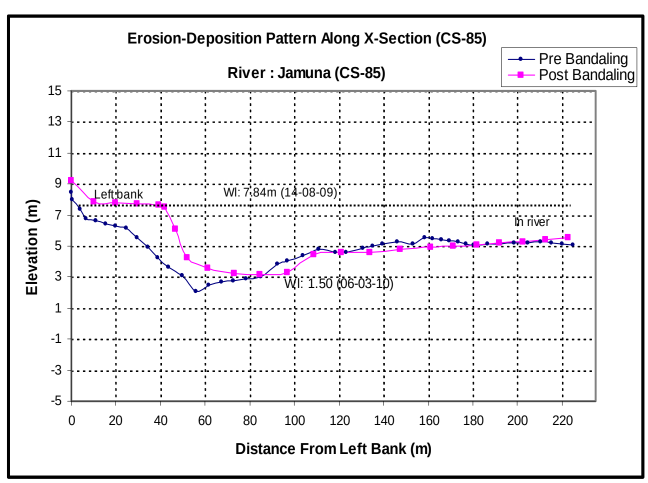


Figure 9(a): X-section within 0.7 km middle reach of 1.5 km

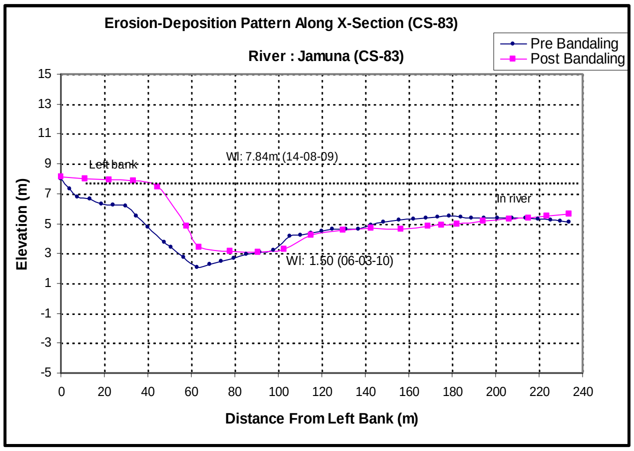


Figure 9(b): X-section within 0.7 km middle reach of 1.5 km

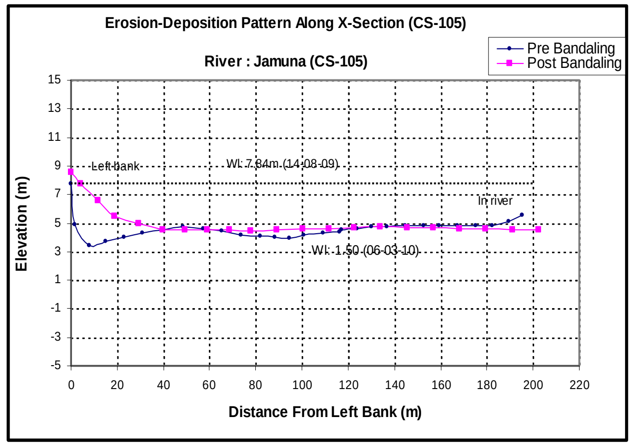


Figure 10: X-section within 0.3 km u/s reach of 1.5 km

5 RESULTS AND DISCUSSION

The constructed bamboo bandalling structure near the Shaheed Salahuddin Cantonment at the upstream of the Bangabandhu Bridge East Guide Bund, Bhuapur, Tangail are functioned well to the river bank erosion protection by stabilizing the river course through near bank sedimentation. It is evident from the above figures as in 9(a) and 9(b) also 5(b) so that there is about more than 30 m sedimentation towards the horizontal direction and about more than 3m sedimentation in the vertical direction near the river bank from at the middle 0.70 km river bending reach. At the upstream 0.30 km river reach as in figure-9, there is less sedimentation due beginning thrust of flowing water pressure, but there is a river bank erosion protection. This position will be improved if bamboo bandalling structures are constructed in further upstream of this reach. At the remaining downstream 0.50 km river reach as in figure-8, there is also less sedimentation due to direct impact of the flowing water trust, but river bank erosion protection.

It is also mentioned that even in some area of this reach, there is little bit bank erosion due to some unavoidable reason such as (i) there are so many sand businessmen & they are plying the sand loaded water vehicles as like as the cargo vessels or heavy barges or trailers that remove the deposited sediment soil from the river bank, (ii) within this reach, there is secondary current influence due to bend effect so that flowing water hit directly in the flood period, (iii) there is some public mini dredger parties conduct dredging operation to fill the some ditches or to collect sand for further away from the erosive reach, (iv) there is dredging operation downstream form many deep pool or reservoir in the downstream reach to fill low laying area of the Shaheed Salahuddin Cantonment for about 2(two) months during the 2010 flood season, and (v) due to this dredging operation, the morphology of this downstream area is seriously changed by forming nearby char just immediately upstream of this reach and (vi) bank erosion in this reach is accelerated although char erosion steps are on going to divert some portion of water flow from the upstream of this reach.

To protect this downstream 0.50 km reach, a series of bamboo bandalling should be constructed over the char land from the upstream river bank to divert some portion water flow from the thalweg line of the river bank. Further repair and maintenances are needed for the upcoming flood. If the bandals are constructed to erode the char to divert flow over the char, there will sedimentation at the 0.50 km reach area and there will be the river bank stabilization.

6 CONCLUSIONS

From the above result and discussions, it can be concluded that use of bamboo bandalling structures will be very much effective for the river bank erosion protection as well as the river bank stabilization. It can also be concluded that the bandals are working as a river bank erosion protection structures as well as river bank stabilization structures. In addition to this main conclusion, the flowing points should be taken in consider for better achievements for this special case study:

- any type of sediment soil near the river bank should not be removed by the human interference
- no further dredging operation should be allowed near the river bank of the problem area
- the activities of sand businessman should be restricted and not to remove sand randomly from the river bed near the stable bank

- constructed bamboo bandalling structures should be maintenance properly in every year before the upcoming monsoon
- in the bandals constructed area of the river bank stabilization, the sand loaded water vessels movement should be restricted

Previously constructed bamboo bandals are to be repaired before the up coming flood in the dry season.

7 RECOMMENDATIONS

The following recommendations should be considered for further study.

- For the river stabilization, some places of the whole 1.5 km reach, some more or less 20(twenty) new bamboo bandals in numbers that length 10 m each are to be constructed.
- To avoid the erosion near the tip of the Bangabandhu Bridge East Guide Bund, there will be needed to complete the selected 1.5 km river reach to construct bandals for making sedimentation near the east guide bund in lieu of erosion.
- Some hydraulics and morphological data should be collected from this 1.5 km river reach to get comprehensive result for this bamboo bandalling application.

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