# PERFORMANCE EVALUATION OF BANDAL-LIKE STRUCTURES FOR SEDIMENT MANAGEMENT IN BRAIDED JAMUNA RIVER

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## ABSTRACT

In sand-bed braided Jamuna River, the performance of conventional structures have shown mixed experiences of failure/success to protect the erodible river bank. While, bandal-like structures (traditionally used for increasing navigation depth) might be an alternative measure of bank protection and stabilize the minor channels in a long term scale. Laboratory experiments confirmed the potentiality of bandal-like semi-permeable structures to accelerate the near bank sedimentation and mid channel bed degradation. Nevertheless, performance of bandal-like structures in real-world unsteady regime is not confirmed yet. Therefore, a set of prototype bandal-like structure was implemented along the right bank of 1500 m reach of the Jamuna River at Kazipur in Bangladesh to investigate spatial and temporal changes of flow field and sediment deposition around the structures during high and low flow period. Measurements were executed during high (July) and low flow (November) period over the river reach using ADCP and Echo-sounder to capture the changes of flow and sedimentation. It is found that during the period of monsoon (July, 2018), near bank bed was elevated by about 5˜6 m behind the structure. However, as the water level goes higher during the monsoon, high velocity (2˜3 m/s) impaired the structure due to excessive scouring (˜7 m) and vortex from the toe of the structure. The structure was eventually washed away and subsequently the deposited sediment was also washed away partly. Confronting the real-world, bandal-like structure shows promising results on managing minor channels in sand-bed braided Jamuna River.

*Keywords*: Bandal-like Structure, Sedimentation, Jamuna River, ADCP, Braided River.

## 1. INTRODUCTION

Sand-bed braided river Brahmaputra-Jamuna is characterized by the dynamic nature of flow and sediment transport (Best et al., 2007). During the last 40 years (1973-2013), land loss along 220 km long reach of Jamuna (in Bangladesh) initiates at an alarming rate than its land gain (CEGIS, 2018). Thus, river width increases around 8.5 km to 12 km in some reaches during this mentioned period (Sarker et al., 2014). To protect this erodible river bank, conventional structures like groyne, spurs, revetment etc. have been implemented several times along both banks of Jamuna River (Sarker et al., 2011). It has a mixed experience of failure/success which cannot always be ended up with an ultimate resolution for its intensely braided morphology consisting of first, second or third-order channels (Bristow, 1987). While, bandal-like structures (made of naturally available materials) might be an alternative measure to bank protection and stabilize the second or third order channels of the river course (Rahman et al., 2004).

The practice of bandal-like structures for maintaining navigational channel during low flow time in Indian-Subcontinent is an indigenous approach which supports the prospect of this structure. Bandal-like structures separate sediment-laden flow into two layers where the upper layer (low sediment concentration) diverts to the main channel through the impermeable portion of bandal and causing bed degradation. In contrast, the lower layer (high sediment concentration) passes through bandal and occurring sedimentation behind it due to low velocity over there (Rahman et al., 2003).

Effectiveness of bandal-like structures was investigated through few laboratory experiment (Rahman et al., 2004; 2005; 2006 and Hasegawa et al., 2018) and numerical simulation (Zhang et al., 2010; 2016; Nakagawa et al., 2011 and Teraguchi et al., 2011) which confirmed the potentiality of bandal-like semi-permeable structures to accelerate the near bank sedimentation and mid-channel bed degradation which eventually exaggerate the navigability of the channel. It is found that bandal-like structures are effective to reduce local scour around the structures and sedimentation in the downstream comparing with the conventional structures like groynes (Nakagawa et al., 2011). Moreover, a laboratory research shows that the large ratio of the permeable and impermeable portion of bandal-like structures significantly affect the sediment deposition volume around the structures (Hasegawa et al., 2018). However, the functioning of bandal-like structures in real-world unsteady regimes is not confirmed yet. Therefore, more investigation on bandal-like structures for a large sand-bed river like Brahmaputra-Jamuna is required to better apprehend the real-world unsteady flow and sediment pattern around the structures.

In this study, the performance of bandal-like structures at an eroding reach of the Jamuna River is thoroughly inspected in spatial and temporal scales during high flow and low time to analyze the flow and sedimentation process around bandal-like structures.

## 2. METHODOLOGY

### 2.1 Installation of Prototype Bandal-like Structures

Due to severe erosion at the right bank of Jamuna River, 1500 m reach of the right bank of Jamuna River near Kazipur upazilla at Sirajganj, Bangladesh was selected to conduct the experiment. A set of five prototype bandals were installed at the right bank of Jamuna River near Kazipur. Locally available bamboo and Eucalyptus tree were used to set up the bandal-like structures. Among five bandals, the first bandal is bank attached and the rest of them are 30 m, 60 m, 90 m and 108 m apart from the river bank respectively (Figure 1). The first bandal was installed at 125 m downstream of shingrabari spur at a 30 degrees angle with the bank line. The first two sets of bandals were 100 m in length and the rest three bandals were 200 m individually. The total height of the bandal was 13.5 m where 7 m was placed underwater from the low water level of the river. Geo bags having 175 kg each were given in three layers at the river bed. The top 3 m of bandal was maintained impermeable by locally made tarjah.

Figure 1. Alignments of Bandal-like Structures at Kazipur

## 2.2 Field Measurement

Flow velocities and bathymetry around bandal-like structures were measured in the selected areas using moving boat acoustic Doppler current profiler (ADCP) and echo-sounding technique. The riverboat moved at speeds of 0.5-1.5 m/s during data measurements at 15-30m intervals. The position of the recording data was determined by Trimble SPS461 GPS Heading Receivers. The accuracy of horizontal and vertical DGPS positions is ±0.25m and ±0.50m. Flow velocity and discharge were measured using ADCP of 600 kHz (Workhorse Rio Grande 600 kHz, Teledyne RD Instruments, Inc.). The corresponding spatial coordinates were specified by the integration with GPS through RS-232 to the RR data stream. The ADCP was used for water depths 0.4~60m. The bathymetry measurements were carried out using a double beam Echo sounder (echo-trac CVM) with an ultrasonic frequency of 200 kHz, a sampling rate of 33 Hz. The device can be used for water depths 0.2~200m with an accuracy of ± 0.1% of depth. Measurements were conducted on 27th July 2018 and 3rd November 2018 during the high flow and falling stage respectively (Figure 2).

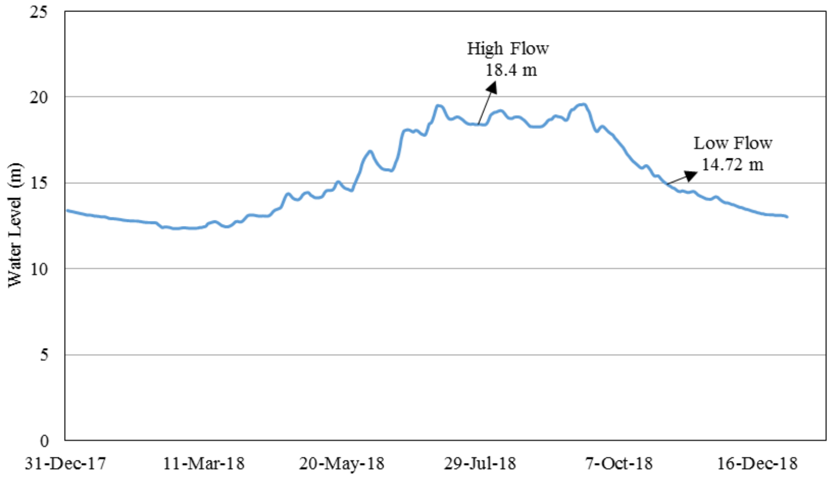


Figure 2. Water Level Variation around Bandal-like Structures at Kazipur

# 3. RESULTS AND DISCUSSIONS

## 3.1 Sedimentation around Bandal-like structures

As the water level went higher in the monsoon period, the whole structures were gone to fully submerge conditions. Throughout July 2018, bandal-like structures were better functioning in terms of sedimentation until washing away some of its parts due to inducing high velocity at the outer edge of the structure at the beginning of August 2018. High concentrated sediment passed through the lower permeable portion of the bandal-like structures and settled down because of the dropping down of velocity. From the bathymetry survey on 27th July 2018; bed level behind the 1st, 2nd and 3rd structure was elevated up to 5~6 mPWD (meter Public Works Datum, corresponds 0.46 m below mean sea level) (Figure 3). Conversely, due to damages of tarjahs at 4th bandal, high velocity induced flow entered through the structures and caused excessive scouring at the toe of both 4th and 5th bandal.

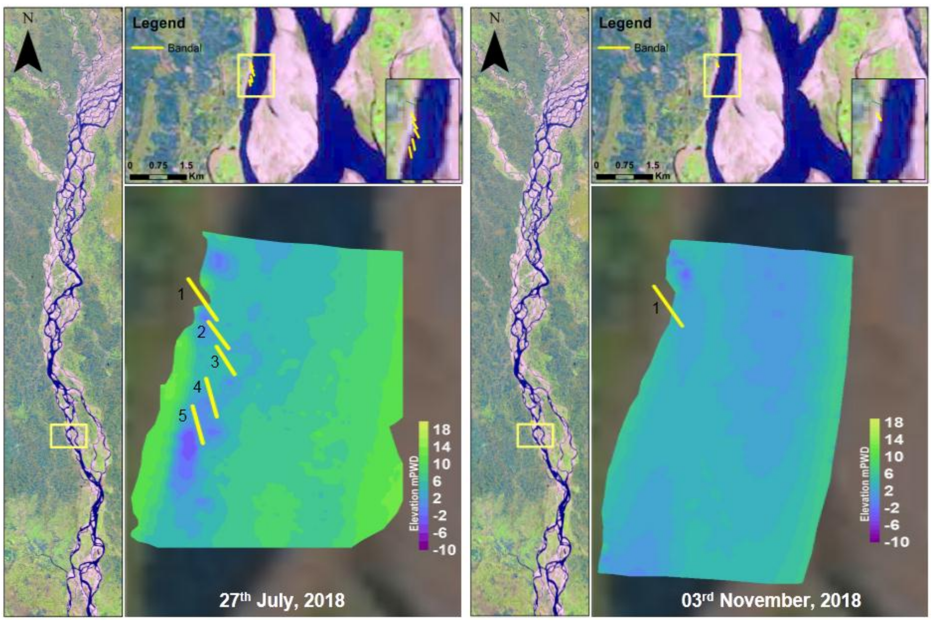


Figure 3. Bathymetry around Bandal-like structures location during high flow (left) and low flow (right)

During August 2018, high velocity around the structure triggered the continuous failure of the 2nd, 3rd, 4th and 5th bandal-like structures. As a result, all structures except the 1st one were washed out at the end of August 2018 which initiated the erosion of deposited sediments. Bathymetry of November 2018, during low flow, shows that the elevation behind bandal is 3~4 mPWD which was lower than the high flow time (Figure 3).

## 3.2 Flow Field around bandal-like structures

### 3.2.1 *Flow velocity (u, v) around Bandal-like structures*

Figure 4 depicts the (u, v) velocity distribution during high (left) and low (right) flow time. From 27th July 2018, it is noticeable that bandal-like structures were functioning well to divert the main flow from the river bank to the main channel near 1st~3rd bandals. Owing to excessive souring at the toe of 4th and 5th bandal, they were not able to divert the main flow efficiently to the rive side for main channel degradation. Accordingly, the main flow came towards the bank behind 4th bandal and hit the tarjah of 5th bandal which accelerated the local velocity (2~3 m/s) immediately to form multiple vertical vortexes. However, in November 2018 when all bandals other than 1st one washed away, the flow of the channel came towards the river bank which subsequently eroded the bed. On the other hand, 1st bandal was still functioning and diverted the main flow to the riverside. Thus, some portion of deposited sediment lingered behind the 1st structure after the high flow period.

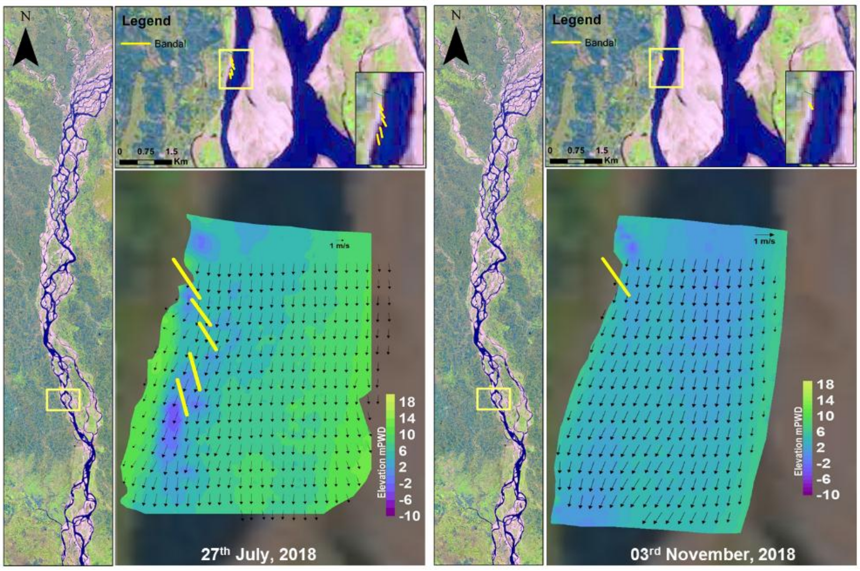


Figure 4. Flow velocity (u, v) around Bandal-like structures location during high flow (left) and low flow (right)

### 3.2.2 *Flow velocity (v, w) around Bandal-like structures*

For better understanding the flow pattern around bandal-like structures, three cross-sections have been considered to inspect (v, w) flow where 1st, 2nd and 3rd section was taken just before the 1st bandal, middle of 3rd and 4th bandal and just after the 5th bandal respectively (Figure 5).

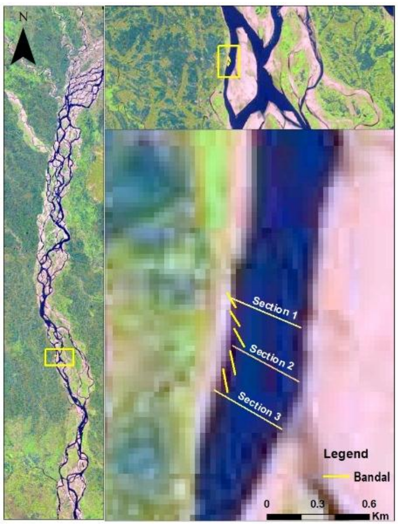


Figure 5. Flow velocity (v, w) sections around Bandal-like structures location

Figure 6 illustrates the (v, w) velocity for the high flow period (27th July 2018) around bandal-like structures for selected three sections where section 1 easily clarified the high velocity before the 1st bandal-like structures (>1.5 m/s). This high-velocity region formed multiple vortexes around the structure which ultimately initiate vertical scouring. Moreover, disturbance of the main flow through tarjahs accelerated the (v, w) velocity field. Similarly, in the middle of 3rd and 4th bandal vertical scouring was formed up to 16 m deep which is more concentrated than the 1st section which was primarily occurred for the failure of the bandal-like structure. As the flow headed for the downstream of the bandal-like structures, scouring and vortex was abridged (Section 3; Figure 6).

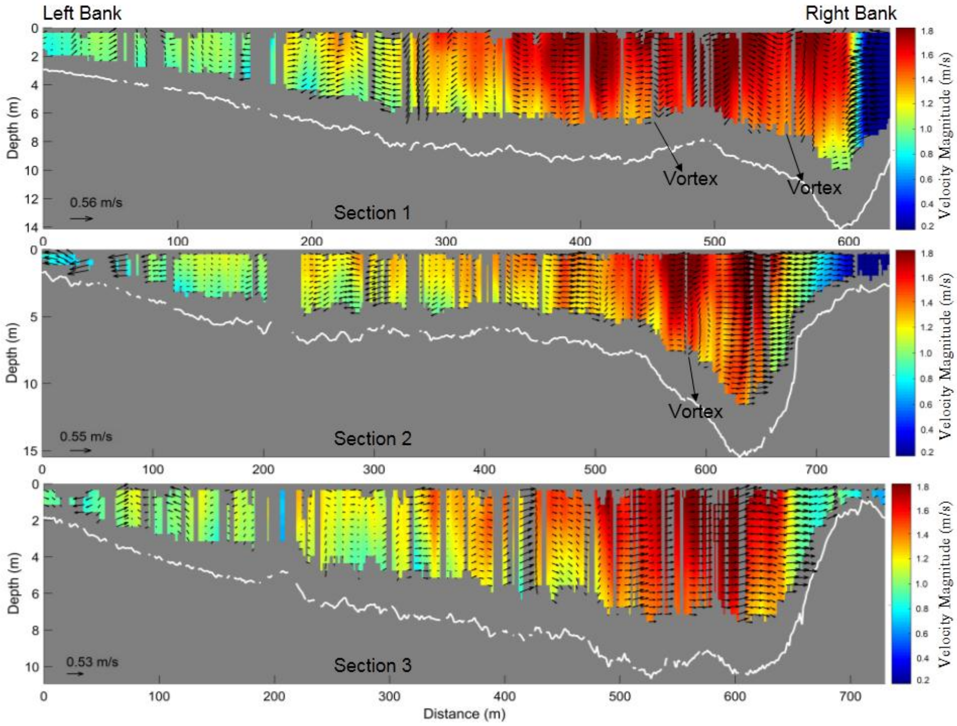


Figure 6. Flow velocity (v, w) before (Section 1), middle (Section 2) and after (Section 3) the Bandal-like structures during high flow period

During the low flow period on 3rd November 2018, the contour of (v, w) velocity field seemed less concentrated than the high flow period. Velocity (v, w) was higher in the 1st section which is just before the 1st bandal-like structure. The transverse flow velocity is much higher in that region than w (vertical) flow (Figure 7). Alternatively, in sections 2 and 3 velocities (v, w) seemed steady than the high flow period. It is also noticeable that the flow depth of sections 2 and 3 was higher in the main channel which was previously higher near the river bank during the high flow period.

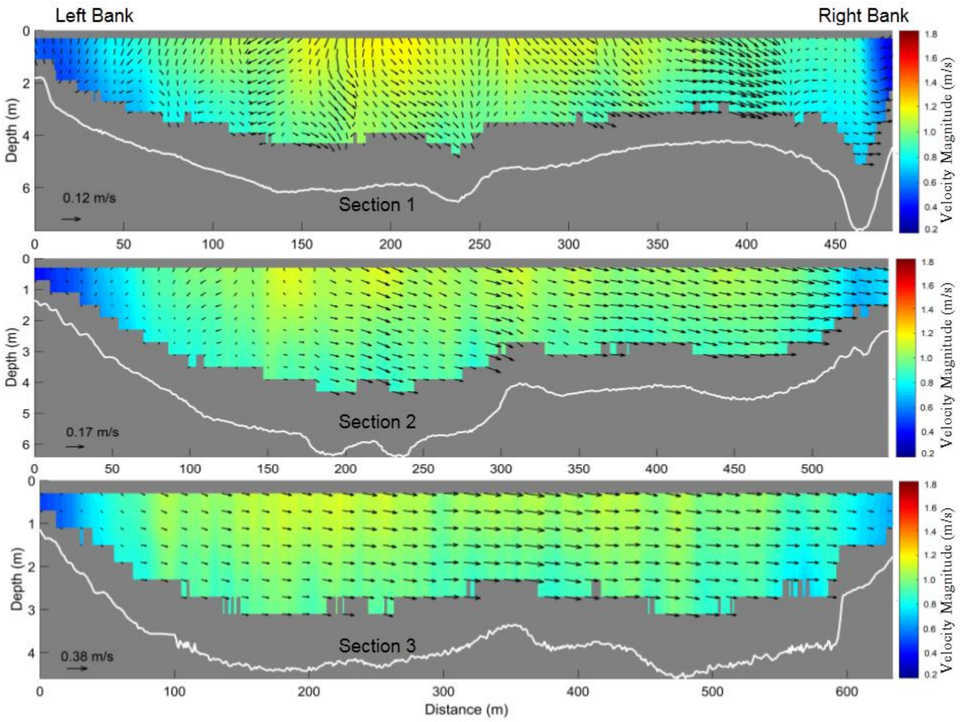


Figure 7. Flow velocity (v,w) before (Section 1), middle (Section 2) and after (Section 3) the Bandal-like structures during low flow period

## 4. CONCLUSION

The present study focused on the performance of bandal-like structures in sand-bed braided Jamuna River during high and low flow periods. Bandal-like structures performed well during the high flow period by causing sedimentation up to 5~7m until washing away some of its portions in the later period of monsoon. Nevertheless, becoming an active channel, the channel went up very wide during high flow at monsoon and continuous interruption of flow due to the impermeable upper portion (tarjah) of the bandal-like structure induced high-velocity region which subsequently washed away the structure. This high-velocity field stimulated multiple vortices around the structures which eroded a portion of sediment from the bandal field. Moreover, the structure operated adequately to divert the main flow to the river flank during the high flow period by constructing disruption through the impermeable portion. On this account, the main channel shifted from the bank even after washing away the major portion of the structure. Hence, bandal-like structures have a positive impact on managing minor channels by occurring sedimentation and forming a navigational channel in sand-bed braided Jamuna River under precise considerations of flow velocity and characteristics of the channel. Furthermore, to manage minor channels of the Jamuna River for Bangladesh Water Development Board's (BWDB) proposed long-term stabilization of the Brahmaputra-Jamuna River can be done with bandal-like structures.

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