EXPERIMENTAL STUDY ON SUSPENDED SEDIMENT TRANSPORT TO REPRESENT TIDAL BASIN MANAGEMENT

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The main purpose of Tidal Basin Management is to get suspended sediment deposits gradually under a controlled system. When a cut is made at an appropriate point of embankment, muddy water enters the tidal basin during high tide, depositing a portion of suspended sediments on the basin before flowing back towards the ocean during low tide. An attempt has been made to study through laboratory experiments to precisely look into the suspended sediment transport at entrance of beel. With change of outflow at side basin or tidal beel and change of sediment concentration at inlet, the transportation and deposition of sediment are investigated. Transportation and deposition of suspended sediment mainly depend upon direction of flow and magnitude of outflow discharge at side basin. Better understanding of sediment transport phenomena increases the effectiveness of Tidal Basin Management.

Key Words: TBM, Beel, Side Basin, Sediment Concentration

1. INTRODUCTION

Bangladesh is the biggest delta of the world formed by sediments carried by the Ganges-padma, Brahmaputra-jamuna and Surma-meghna river system. Life in Bangladesh has been, is and will always be defined by the vast quantities of water and sediment that flow through the country¹⁾. In fact, the entire country is formed by the sediments from the Himalayas and the Bay of Bengal²⁾. The Ganges-Brahmaputra River System (**Fig.1**) carries the world's highest annual sediment load at one billion tons^{3),4)}.

Construction of numbers of polders is one of the flood resilient approach. The siltation problem in rivers causes riverbeds to become higher than the adjacent crop lands, and vast area lower than the polders are permanently kept water logged. The drainage congestion and sedimentation has been major issues over the years in river basins of Bangladesh. The decrease of flushing flow from upstream and substantial reduction of tidal flooding area along the river by constructing polders caused severe siltation over a long stretch of the river.

Introduction of certain areas as tidal flood plain to deposit sediment on the floodplain rather than on the river itself and rotation of that lowlands is current

practice of tidal basin management (TBM). Beel is low-lying depression in the floodplain that generally contain water throughout the year⁵⁾. The present practice of TBM is to connect the river with the selected tidal beel by constructing a link canal⁶⁾. This is a natural water management process with very little human interventions but it needs strong participation and consensus with a great deal of sacrifice by the stakeholder for a specific period (3 to 5 years or even more) depending on the tidal volume and the area of the beel⁷⁾. Most studies focused on sediment deposition relating to supply of varying inflow discharge. This research tries to analyze various scenarios under constant inflow discharge. It aims to study sediment transport and deposition in the tidal beel to effectively understand TBM.

Fig. 1 The catchments of the Ganges, Brahmaputra and Meghna

Source: www.jrcb.gov.bd/image/Basin_map.jpg

Fig.2 Morphological state of rivers before the coastal embankment project¹⁾

2. SEDIMENT TRANSPORT PROCESS

(1) Pre-coastal embankment project

Before the coastal embankment project, which commenced in the 1950s, the quantity of water flowing through the rivers during high and low tide is high; the volume available for the water to fill up (in the floodplains) is very large. In other words: the tidal prism of these rivers was very high, making the sedimentation process relatively slow. Sedimentation occurred mainly on the low-lying floodplains (**Fig.2**).

(2) Post-coastal embankment project

Under the USAID funded project, 37 polders and 1566 kilometers of embankments were constructed in the southwest delta⁸⁾. The polders were considered to be successful in their early years of operation, because they decreased floods and created stability in agricultural areas²⁾. The polders also dramatically decreased the volume of tidal water stored in the floodplains, because the embankments prevented water from entering them. **Fig.3** shows the process of sedimentation even slow has led to a gradual build-up of sediment in the rivers.

(3) Drainage congestion late 1980s

In the 1980s, riverbed sedimentation started to cause drainage congestion. The siltation problem in rivers caused riverbeds to become higher than the adjacent crop lands and vast area lower than the polders became permanently water logged.

Fig.3 Morphological state of rivers after the coastal embankment project¹⁾

Fig.4 Development of waterlogging in beels adjacent to 'dying' river¹⁾

Fig.5 River morphology under tidal river management¹⁾

Fig.4 shows that the interaction between flood plain and river has been cut off. Waterlogging caused considerable economic, social and environmental problems. Especially during monsoon season when precipitation is extremely high, waterlogging was big problem in beels.

(4) Tidal River Management

On October 29th, 1997, the local population at beel Bhaina cut their embankment turning the 1000 hectare beel into a tidal basin as they hoped that the sediment-laden water would raise the land of their beel and thereby improve drainage⁹⁾.

Fig.5 shows how sediment settles in beel after introduction of certain area as tidal basin. As the tidal prism increased, the cross section of the river downstream of selected beel increased. Sediments started depositing on the floodplain rather than on the river itself. In case of beel Bhaina, sediment was deposited raising its land level by an average of 78 centimeters¹⁰⁾.

(5) TBM

The "rotating basin" option was the best from an environmental perspective. This natural water management process with very little human interventions where it needs strong participation and consensus with a great deal of sacrifice by the stakeholders for a specific period is TBM.

The Bangladesh Water Development Board (BWDB) and the Institute for Water Modelling (IWM) have been conducting research in the area and have come up with a rotational tidal basin plan, in order to maintain the tidal prism in the Hari river and prevent future drainage congestion¹¹⁾ (**Fig.6**).

Fig.6 The IWM plan for rotational tidal basins in the Hari-Mukteswari river¹¹⁾

3. OBJECTIVE OF RESEARCH

The aim of this research is to study the suspended sediment transport and deposition in the tidal beel to effectively understand tidal basin management. Suspended sediment transport plays an important role in the evolution of coastal environment. Hence, observation and modeling of suspended sediment concentration (SSC) is of immense interest to coastal oceanographers, engineers and coastal zone management authorities¹²⁾. In Bangladesh the suspended load of a river carries the majority of the sediment, while bedload transport accounts for approximately 10% of the suspended load¹³⁾.

In this context, an attempt has been made to study through laboratory experiments to precisely look into the suspended sediment transport. The selected flume is meandering in nature and side basin is attached with flume which represents the entrance of tidal beel in TBM. Side basin in flume is equipped with changing outflow discharge to represent nature of different tidal beel. The main objective of the research is to study transportation of sediment and monitor its deposition in side basin in different conditions by varying outflow discharge at side basin and varying sediment supply at source.

4. EXPERIMENTAL EVALUATION

The experiments were carried out in a flume located at the Ujigawa Open Laboratory (UOL) of Disaster Prevention Research Institute (DPRI), Kyoto University. The experimental facility is illustrated in **Photo.1** and schematic view of the experimental setup is shown in **Fig.7**. Several parameters were measured during the experimental studies, namely: 2D water surface velocity by PIV techniques, velocity by electromagnetic current meter, bed profile by laser displacement sensor, surface water level by ultrasonic sensor and water discharge by bucket method.

Photo.1 Experimental facility

Fig.7 Schematic view of the experimental setup

The flume used is reinforced concrete flume of re-circulating type with wooden base at bottom where water flows. The shape of side basin is limited to triangular shape particularly in this research due to unavailability of space. 3 portions were attempted to study precisely. They are inlet, side basin and outlet. 9 sampling points namely 1 – 9 representing inlet by 1-2-3, side basin/tidal beel by 4-5-6 and outlet by 7-8-9 as shown in **Fig.7** were adopted to study sediment behavior. All experiments were conducted using a constant flow discharge of 125 l/min (Q_w) in experimental flume, referred to as inflow and were limited to fixed bed. Dry sediment of mean diameter equal to 80 μ m and density 1.76 gm/cc was fed from adjustable sediment feeder.

Firstly two cases were investigated as Case 1 where outflow discharge from side basin was not allowed to flow and Case 2 where discharge of 50 l/min was allowed to flow using water pump. The maximum rate that can be given from sediment feeder available in laboratory is 110 gm/min (Q_s). To understand direction of sediment flow and final deposited bed level, the maximum rate was used in both cases for 4 hours. Turbidimeter was used in mentioned 9 sampling points to take concentration data continuously. Using siphon pipe of 4 mm, 500 ml of water was drawn in every 30 min taking a sample at inlet (1-2-3), side basin (4-5-6) and outlet (7-8-9) 2 cm below water surface to calculate concentrations after filtration then weighing and finally to make comparison with turbidimeter.

For Particle Image Velocimetry (PIV) measurement, the flow was seeded with powdered particles (PVC, polyvinyl chloride powder) with mean diameter equal to 50 μm . Sony HD camera was used to record the images. The PIV technique determines the velocity of water flow and its flow direction indirectly by measuring the velocity of tracer particles within the flow. Final bed level data were measured using laser displacement sensor. The output data of bed level measurements are analogical voltage values. They were saved in laptop computer using a data collection system (A/D conversion card – Keyence NR-110 and data logger software). Before the bed level measurement a calibration of equipment with predefined thickness as reference levels were used to determine relation between the voltages registered and measured bed level.

Secondly the outflow discharges of side basin were varied. Different cases from 0, 10, 25, 50, 65, 80 l/min were investigated for an hour each to understand transportation phenomena of suspended sediment. Sediment supply of 50 gm/min was allowed.

Finally adjusting speed and aperture of sediment feeder, 10, 25, 50, 65, 85, 95, 110 gm/min dry sediment were supplied with outflow discharge at side basin kept constant 50 l/min for an hour each to study the relationship of sediment concentration at side basin and outlet with sediment concentration at inlet. Same 9 sampling points were adopted to take measurements for sediment concentration.

5. RESULTS

In case 1 water discharge is confined towards outlet so most of the sediment is deposited on the way towards the outlet and very little sediment enters into side basin. But in case 2 around 40-50 % of flow is towards side basin so more sediment is deposited in side basin. The scenario of final bed level measured from laser displacement sensor after 4 hours of experiment for both the cases is shown in **Fig. 8**.

Change in elevation between two cases is also calculated to see which parts of sediments that have been deposited in case 1 are transported towards side basin in case 2. Up to 26 mm of extra sediment deposition has been seen in side basin when water is allowed to flow from side basin (Fig. 9). It clearly shows that more the tidal flow in tidal basin more will be sediment transport and deposition.

In **Fig. 10**, photos in left sides are at a time of initiation of PIV and right sides are during PIV operation in both the cases. The flow direction is

directed towards outlet in case 1 and towards side basin in case 2.

Fig.8 Final bed level in case1 and case2

Fig.9 Change in elevation between two experimental cases

Fig.10 Surface flow visualization using PIV technique

In real scenario as in Bangladesh, transported sediment is finally deposited inside beel. But in this experiment, entry of tidal beel is only represented by side basin and whole tidal beel has not been incorporated. Thus sediment concentration is taken as primary indicator for this research rather than deposited thickness of sediments.

Fig.11 Sediment Concentration at 9 sampling points for case 1 and case 2

Fig.12 Sediment concentration at 9 sampling points with varying outflow discharge from side basin

The average value of water depth is 9.05 cm and average flow velocity is 6.97 cm/s. Even at the beginning of experiment it doesn't have any bed load, but sediment is deposited during experiment and it behaves as bed load which makes sediment concentration to increase with time in all sampling points as shown in **Fig. 11**. In case 1 sediment concentration at outlet (7-8-9) is greater than sediment concentration at side basin (4-5-6) whereas in case 2 sediment concentration at side basin (4-5-6) is greater than sediment concentration at outlet (7-8-9).

Fig.13 Sediment concentration at side basin and outlet Vs sediment concentration at inlet

With changing outflow discharge from side basin, sediment concentration at inlet (1-2-3) is almost constant. But it has significant effects in outlet (7-8-9) and side basin (4-5-6). Sediment concentration is increasing in side basin (4-5-6) whereas decreasing in outlet (7-8-9) with increase in discharge at side basin (**Fig. 12**). When higher outflow discharge is allowed to flow from side basin higher sediment is transported towards it and lesser sediment on the course of river.

Finally with varying sediment supply at inlet in sediment feeder, sediment concentration recorded at inlet has minimum value of 0.05 gm/l to maximum of 0.7 gm/l during experiment. It is obvious that increase in concentration at inlet will surely increase concentration at side basin and outlet. But distribution of sediment towards side basin to outlet is almost same in all conditions with ratio varying from 1.41 – 1.67 particularly in this case with 50 l/min outflowed from side basin (**Fig.13**).

6. DISCUSSIONS

Transportation and deposition of suspended sediment mostly depends upon the direction of flow and magnitude of discharge. Change in final bed level elevation between two cases clearly shows shift of sediment deposition from river towards side basin. In real scenario of TBM, if direction of flow is made easy towards selected tidal beel more sediment can be transported and deposited.

Moreover with increase in outflow discharge towards side basin, sediment transportation and deposition also increases. From this it can be inferred that in those tidal basins where more flow passes have more sediment transport and deposition. This might happen due to either large size of tidal basin, larger

water holding capacity of beel, steeper topography of beel, large size of opening of beel or proper orientation of intake of beel in tidal basin management.

Within the range of 0 – 0.7 gm/l sediment concentration at inlet, the distribution of sediment towards outlet and side basin seems almost same. Lateral widening of side basin doesn't happen in experimental flume therefore the ratio of sediment distribution is almost same for all types of sediment concentration at inlet from low to high. In reality when TBM is operated in selected beel, flow channels are laterally widened resulting more space for larger water and sediment discharge.

The current findings have some limitations of fixed bed, no tidal effect, constant inflow discharge, no lateral widening of side basin, shape of side basin etc. The results of this study are discussed in order to provide the qualitative and quantitative relationship between sediment transport with flow magnitude and direction. These results when interpreted in conjunction with numerical studies, other experimental studies or field based real data, provide important information for environmentally oriented design of hydraulics in river channels.

7. CONCLUSIONS

The present experimental work investigated the suspended sediment transport and deposition at side basin representing tidal beel to see the effectiveness of tidal basin management. A steady inflow scenario was tested with fixed bed condition. The outflow at side basin was changed from 0 to around 65 % of inflow and sediment concentration was changed upto 0.7 gm/l which also covers the real scenario in Bangladesh.

From the experimental study it can be concluded that deposition of suspended sediment mainly depends upon direction of flow and magnitude of discharge. Field based data of size of tidal beel, topographical condition of beel, sediment concentration at river, tidal effects on discharge, lateral widening process of channel, average deposition of suspended sediment in operated tidal basin are very much important to understand the phenomena of TBM precisely.

Once the phenomena of sediment concentration at side basin and outlet in constant inlet discharge is understood, the test setup can be adapted to account for movable bed, change in size of side basin and change in discharge due to tidal cycle. The current

findings have to be expanded in the next experiment and simultaneously have to be simulated numerically.

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