EFFECTS OF A SERIES OF SOLID SPURS AT A BEND ON FLOW FIELD: A CASE STUDY IN BANGLADESH

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In the recent past solid spurs in a series have been constructed at many erosion prone areas of Bangladesh. The combined effects of such constructions are seen to be very well in stabilizing riverbank. Since solid spur is an active measure of bank protection it can modify the existing flow pattern. When constructed in a series at a bend to prevent the bend from migrating further they can have significant influence on the flow field at the bend. The thalweg position at a bend is very close to the bankline. Therefore, construction of such spurs extending into the river channel involves huge cost and also other difficulties. In mighty rivers like the Ganges and the Brahmaputra it is preferred to construct solid spurs in the floodplain. These spurs start functioning after a certain amount of bankline retreat between them. Scale model investigation can be an effective tool in determining the position, length, orientation and spacing of the spurs. This paper reports the effects of a series of proposed spurs to be constructed for the protection of Panka Narayanpur area of Nawabganj district on flow field. The spur locations have been determined from mathematical model investigation. The scale model study is employed to determine the likely extent of bankline retreat between the proposed spurs and consequent changes in the flow field. The outcomes from the study reveal the fact that substantial bankline retreat is likely to occur at pocket-2 (between spur 2 & 3) and pocket-3 (between spur 3 & 4) and the existence of the proposed flood control embankment might not be threatened unless any change occurs in the upstream boundary conditions.

Introduction

Panka Narayanpur area is situated on the left bank of the Ganges River in Chapi Nawabgang Sadar Upazila under Chapai Nawabgang district. The river is very erosion prone at this area. It has already eaten up vast cultivable land and homestead. A large number of government and public establishments are now under threat of erosion. So it is now an utmost need to protect the area from the severe erosion of the Ganges. Under this circumstance BWDB has taken up a project to protect the area from bank erosion. RRI is given with the responsibility to conduct a physical model study for the project to investigate the efficacy of a series of proposed solid spurs in protecting the area.

Objectives of the study

The objectives of the study are:

- To investigate the present flow pattern without any training works.
- To investigate the effects of the proposed spurs on flow field.
- To investigate the possible bankline retreat between the spurs and consequent changes in the flow pattern.
- To determine the minimum distance between the retreated bankline and proposed embankment in different pockets.

Methodology

Study Approach

The scale model study is conducted keeping the following major ends in view

- Identification of the erosion prone areas at Panka Narayanpur.
- Determination of flow pattern with proposed spurs and primary identification of possible bankline retreat between the spurs.
- Schematization of the bankline retreat and investigation of flow pattern in the embayment.
- Investigation of changes in the flow pattern due to bankline retreat.
- In order to meet the above requirements the study is planned to be conducted as a fixed bed flow model. In this regard geometric distortion of the model is needed not only to cover a length of about 20-km but also to fulfill the roughness condition of the model. It is to be mentioned here that in an undistorted sand-bed model it is almost impossible to fulfill the roughness condition.

Model design

The model is a distorted model with horizontal scale 1: 280 and vertical scale 1:100. The bed of the model is moulded with sand i.e. it is a sand bed model. From the selected geometric scales the scale for other parameters are determined and shown in the following table (Table1).

Table 1: Scale conditions for the different basic and derived parameters

Parameter	Unit	Scale
Velocity (V)	(m/s)	10
Time (T)	(s)	28
Slope (I)	(-)	0.357
Froude number (Fr)	(-)	1
Reynolds number (Re)	(-)	1000
Discharge (Q)	(m^3/s)	280000
Specific discharge (q)	(m^2/s)	1000
Chezy's coefficient (C)	($m^{0.5}$/s)	1.67
Manning's coefficient (n)	(s/$m^{0.33}$)	1.29

Non-fulfillment of roughness condition in the model may cause deviation in the above scales that should be noticed and taken into account during interpretation of test results.

Model set-up

The riverbed has been reproduced in the model according to the bathymetric survey data of October' 2001. An open-air model bed of 35m x 100m long has been used for setting up the model. A standard sharp crested weir is used to measure the model discharge according to Rehbocks formula. A point gauge is installed upstream of the weir at a sufficient distance to avoid the effect of curvature during recording of the water level.

Atmospheric air pressure is maintained below the nappe to reduce the drag effect with the help of a perforated pipe. A stilling pond is constructed to dissipate the energy of incoming flow and hollow bricks and bamboo screens have been used to adjust the distribution of flow at the inflow section. The water levels in the model at different locations are recorded with three point gauges. The water level in the model is controlled by operating tailgates constructed at the downstream end of the model. Provision is made to minimize erosion of the model bed during the filling operation.

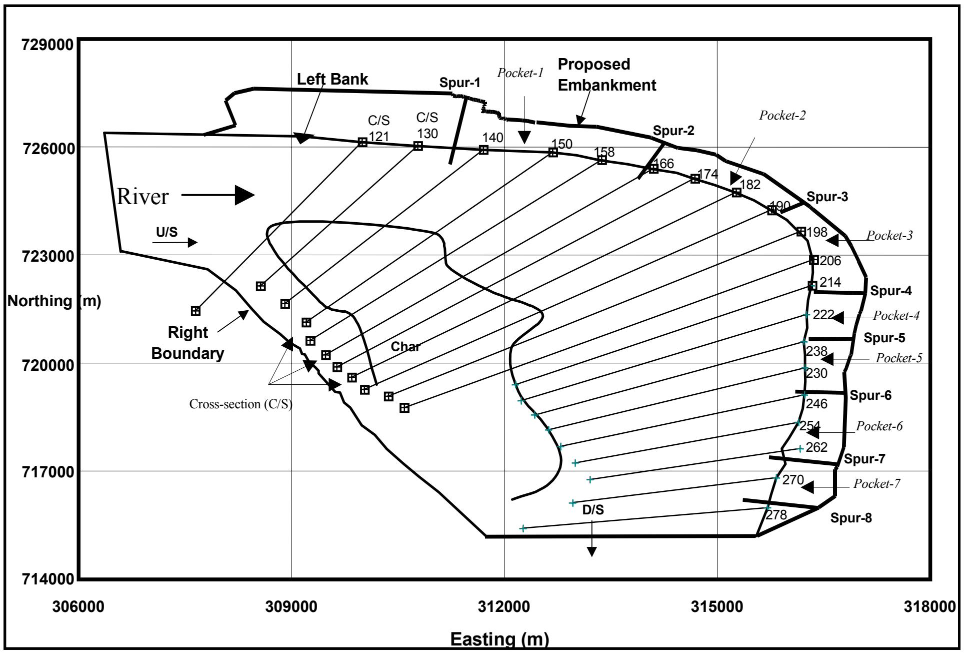

Figure 1: River layout and position of spurs and cross-sections in model

Test scenarios

The test scenarios of the model study appear in the following table (Table 2).

Table 2: Test scenarios of the Panka Narayanpur model study

Test No.	Type of test	Test description	Discharge (m^3/s)
T0	Base run	Without intervention	71,656
T1	Application test	8(eight) BWDB proposed spurs	
T2	Application test	Retreat of bankline in pocket 2,3,4,5 and 6	
T3	Application test	Retreat of T2 bankline in pocket 2,3 & 5	
T4	Application test	Retreat of T3 bankline in pocket 2 &3	

T5	Application test	As in T4	32,207
T6	Application test	Retreat of T5 bankline in pocket 2	

Discussions on test results

During the study with the bathymetry and bank position of October'2001 a total of seven tests have been conducted including the base run. The results of each test and comparison of the results between different tests have been made. In the course of the study different measurements are taken systematically so that the effects of the proposed spurs can be investigated properly. From the analysis of the recorded data the following discussions are made as to the effects of the proposed spurs on flow field and the retreat of the bank line in different pockets in between the spurs. Discussions are also made regarding some other important aspects.

Changes in the flow pattern

It is noticed from the test result that after construction of the spurs near bank flow concentration will be reduced from c/s-140 to c/s-218 and from downstream of c/s-234 to c/s-254. Elsewhere except at pocket-7 the near bank flow concentration will increase. It means the influence of the spur-1 and spur-2 extends upto the head of the spur-4. However, due to ineffectiveness of the spur-3 the reduction in the near bank flow concentration is not significant from c/s-178 to c/s-218. As a result the bank there is still vulnerable to erosion. The same holds for the river stretch from c/s-234 to c/s-254. It means that except pocket-1 and 7 entire bank could be subjected to erosion despite the presence of the spurs.

The third test (T2) is conducted with certain amounts of bank retreat in pocket-2, 3,4,5 and 6. The test results show that retreat of bank position in pocket-2 and 3 not only reduces the near bank flow concentration there but also improves the situation downstream. It mainly happens due to the fact that the spur-3, 4 and 5 that were almost inactive before now play some role in deflecting the oncoming flow away from the new bank. However, near bank velocity within a distance of 56 m from the bank still remains high enough to erode the bank.

The fourth test (T3) is carried out by further shifting the bank position leftward in pocket-2, 3 and 5. It is seen that it has caused more near bank flow concentration from downstream of c/s-190 to c/s-254. It points to the fact that a further shift in the bank position attracts more flow towards the bank near pocket-2 and 3 but the downstream spurs (spur-3, 4 and 5) are not effective enough to deflect all the oncoming flow well away from the bank. The flow lines for the test appear in Figure 4. It should be noted here that the above mentioned situation does not have any negative influence on the flow velocity very close to bank (within 56 m). On the other it is reduced noticeably compared to the T2 situation. However, its negative influence is observed on the magnitude of reverse flow velocity.

The fifth test (T4) is conducted by making more shift in the bank position in pocket-2 and 3. It is done because in the previous test near bank flow velocity there is found to be more than 1 m/s. The results from this test show that the magnitude of flow velocity very close to the new bank (within 56 m) is improved a bit. This velocity is now found to be less than 1 m/s.

The sixth test (T5) is conducted with a low discharge (bankfull discharge) to see the near bank velocity situation. During this test all other test conditions except discharge are kept the same as test T4. The test results show substantial increase in the magnitude of near bank flow velocity in pocket-2 whereas a bit increase is noticeable in pocket-3.

The seventh test (T6) aims to see the effects of a further retreat in the bank position in pocket-2 on near bank flow velocity. The test results show that such a retreat has resulted in a near bank velocity having magnitude less than 1 m/s in both the pocket-2 and 3.

It can be concluded from the outcomes of the above mentioned tests that the total amounts of bank retreat that has made during the study will result in a situation where near bank velocity will be insignificant or not so high to erode the bank.

Retreat of bank line

It is important to note here that prior to a particular test bank positions have been retreated based on the flow lines observed in the previous test. The flow lines are seen to have assumed an elliptical shape. So the bank retreat is done accordingly. It can be seen from the table that maximum bank line retreat has to make along c/s-206 and c/s-210. The river bank is seen to be most vulnerable at pocket-2 and 3. Therefore, major bank line shift is required there.

Table 3**:** Total shift in the bank positions along different cross-sections

C/S No.	Total bank position retreat (m)
178	98
182	294
186	275
190	205
198	168
202	280
206	420
210	448
214	350
222	98
226	188
234	154
238	207
242	140
254	118
258	322
262	42

Minimum distance

The minimum distance is defined here as the minimum distance between the bank and the embankment. Minimum distance may not occur at the same location in all tests. The minimum distances measured at different pockets in different tests appear in the following table (Table 4). It is important to notice from the above information that minimum distance after the retreat of the bank line at pocket-2 and 3 is 184.8 m and 221.2 m respectively. It means the proposed embankment there is not quite safe from being eroded in case of occurrence of an unusually high flood event and also due to sudden changes in the upstream conditions of the river. However, the minimum distances found in the other pockets can be considered as safe if outflanking does not occur at pocket-2 and 3.

Table 4: Minimum distances between the bank and embankment at different pockets in different tests

Pocket No.	Initial minimum distance between embankment and bank line (m)	Minimum distance (m)				
		Q = 71.656 m3/s			Q = 35,207 m3/s	
		Test T2	Test T3	Test T4	Test T5	Test T6
1 (between spur 1 & 2)	728	No cut	No cut	No cut	No cut	No cut
2 (between spur 2 & 3)	468	333.2	291.2	240.8	240.8	184.8
3 (between spur 3 & 4)	426	322	310.8	221.2	221.2	221.2
4 (between spur 4 & 5)	661	456.4	456.4	456.4	456.4	456.4
5 (between spur 5 & 6)	546	421	361.2	361.2	361.2	361.2
6 (between spur 6 & 7)	566	515.2	515.2	515.2	515.2	515.2
7 (between spur 7 & 8)	661	No cut	No cut	No cut	No cut	No cut

Difference in upstream and downstream water level at different spurs

During the test upstream and downstream water levels are measured at the junction of the earthen shank and RCC part of each spur. From the measurements of water levels the difference between upstream and downstream water levels has been calculated for every spur. The results are shown in Table 5.

Table 5: Difference in upstream and downstream water levels at different spurs

Spur No.	Upstream and downstream water level difference (m)		
	Test T4 (Q=71,656 m^3/s)	Test T5 (Q=35,207 m^3/s)	Test T6 (Q=35,207 m^3/s)
1	0.5	0.4	0.4
2	0.4	0.3	0.3
3	0.2	No water	No water
4	0.3	0.3	0.3
5	0.2	0.3	0.3
6	1.1	0.7	0.8
7	0.6	0.2	0.2
8	1.2	1.2	1.2

From the information presented in the table it can be seen that the water level difference is greater than 1 m at spur-8 for the two different discharges whereas at spur-6 the difference is greater than 1 m only for a very high discharge.

Velocity around the spurs

During the tests the magnitude of flow velocity around the spurs has been measured. The measured velocities indicate that at the very beginning i.e. when no bank retreat occurs at any pocket the RCC part of spur-6, 7 and 8 will be under tremendous thrust of oncoming flow. On the other hand the same will experience moderately high thrust at spur-1. After a certain amount of bank retreat at different pockets (test T4 situation) heavy thrust of oncoming flow on RCC part will occur at spur-6 and 8 whereas the same of the spur-1, 3,4, 5 and 7 will face moderately high thrust.

Near bank flow velocity

From the measurements of velocity during different tests it is seen that the entire river reach is under threat of erosion without any protective works. After the introduction of the proposed spurs erodible near bank velocity occurs at all pockets except pocket-1 and 7. However, certain amount of bank retreat will improve the situation at pocket-4, 5 and 6 and no more erodible velocity will occur there within a distance of 56 m from the left bank. On the other hand at pocket-2 and 3 a substantial amount of bank line retreat will only ensure occurrence of a low magnitude (< 1 m/s) near bank velocity.

Conclusions

The study is carried out to investigate the performance of eight BWDB proposed spurs to protect the Panka Narayanpur area from the erosion of the river Ganges. The position, length and orientation of all the spurs are prefixed and there is no scope to change any of these in the model study. The model investigation is intended to see the effects of the proposed construction on flow field and also on the likely bank erosion in between the spurs. Therefore, the outcomes of the study provide comprehensive information regarding near bank flow concentration, near bank velocity, velocity around and at the head of the spurs etc. on the one hand and regarding amounts of likely bank line retreat at different pockets on the other. The following conclusions are drawn from the outcomes of the study hand:

- The entire river reach is under threat of erosion without any protective measure
- The introduction of the proposed spurs will not prevent the bank at pocket-2, 3,4,5 and 6 from being eroded if no additional protective measure is taken to this end.
- A certain amount of bank erosion will improve the situation at pocket-4, 5 and 6 in terms of magnitudes of near bank (new bank) velocity.
- At pocket-2 and 3 a substantial amounts of bank retreat (maximum 468 m and 586 m respectively) from the original bank position is necessary to have a near bank velocity less than 1 m/s.
- In order to have a near bank velocity on the order of less than 1 m/s the minimum distances left between the bank and the embankment at pocket-2 and 3 are 184.8 m and 221.2 m respectively.
- Without any retreat in the bank line at pocket-2,3 and 4 the effect of the spur-3,4 and 5 on flow is almost negligible.
- With the progress of bank erosion in pocket-2 and 3 the magnitude of reverse flow velocity in the downstream pockets will increase.
- At a very high discharge the RCC part of spur-1, 4,6,7 and 8 will be subjected to heavy thrust of oncoming flow. Initially this thrust will be moderately high at spur-4 and very high at spur-7 but with the retreat of bank line at pocket-3 the thrust will increase at spur-4 and decrease at spur-7.
- At a low discharge (bankfull discharge) the magnitude of velocity at the head of the spur-2 and 3 is higher than that at a high discharge.
- For both a high and a low discharge maximum difference between upstream and downstream water levels occurs at spur-8 and it is 1.2 m.
- Retreat of bank position at pocket-2 and 3 attracts the nearby flow towards the new bank but it has little impact on the distant flow.
- The magnitudes of flow velocity at the head of the spur-1, 6,7 and 8 indicate that large scour hole will form near the head of those spurs.
- High magnitude of flow velocity at the head of the spur-6, 7 and 8 occurs due to poor performance of spur-3, 4 and 5 in deflecting the oncoming flow.

As mentioned earlier the above conclusions have been drawn investigating the performance of a series of proposed spurs with predetermined specifications. One or several changes in those specifications would result in different findings and therefore different conclusions. Scale model investigation can be employed as an effective tool to determine the most suitable specifications that meet all the requirements. It is apparent from the present study that series of spurs can be fairly considered to prevent a river bend from being eroded.

Recommendations

Based on the findings from the study the following recommendations are made:

- The minimum distances between the bank and the embankment at pocket-2 and 3 are very less. Therefore, special precautionary measure should be taken there to protect the embankment and to prevent likely outflanking.
- The basic design and construction requirements should be fulfilled properly so that the RCC part of the spur-1, 6,7 and 8 can withstand the tremendous thrust of the oncoming flow.
- After completion of the construction of the spurs the future developments should be monitored for several years and quick measure should be taken to prevent any negative development.
- In case of taking any additional protective measure scale model investigation is recommended to determine the most suitable option to this end.

Reference

1. RRI (2002)," Physical model study for the protection of Panka Narayanpur area from the erosion of the Ganges river", Model Study, Final Report, September 2002.
2. RRI (2002)," Physical model study for the protection of Panka Narayanpur area from the erosion of the Ganges river", Model Study, Draft Final Report, May 2002.