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A Scale Model Study on the Effectiveness of Revetment against Possible Unification of Jamuna-Bangali River

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Abstract

An undistorted physical model study has been carried out to determine the effectiveness and design parameters of the revetment to be constructed to prevent the unification of Jamuna and Bangali river at Debdanga under Sariakandi upazila in the district of Bogra. The revetment has been placed on the right bank of Jamuna river downstream of Mathurapara Hard Point to combat river bank erosion for ensuring non-unification of these two rivers. The study included observing flow patterns and flow concentration around the structure, which is subjected to different angle of flow attack. The study reveals that 1.273km revetment having side slope 1:2 and launching apron having length 26m and average thickness 2m appears to work satisfactory for bank protection. The maximum value of the design parameters in terms of scour & velocity around the end of launching apron of revetment was found 9m & 2.58m/s respectively for normal flow condition; 12.15m and 3.68m/s respectively for oblique flow condition.

Introduction

Due to erosion of the right bank of the Jamuna river at Debdanga located about 50 km upstream of the Jamuna Bridge, the distance between the Bangali and the Jamuna river is about 300 meter and has developed a threat of possible unification of the Jamuna with the Bangali river. Such unification through breaching of the Brahmaputra Right Embankment (BRE) into the Bangali may jeopardize the communication network over the Jamuna Bridge. Especially the Nolka Bridge will be under threat due to this unification and thus the approach road of Jamuna Multipurpose Bridge will be hampered. So, the present situation demands the bank protection works to prevent the unification of the Jamuna-Bangali River.

Under these circumstances River Research Institute (RRI) was given the task of conducting an undistorted physical model study to determine the extent of local scour at and around the proposed structure with different angle of flow attack. In addition flow patterns and flow concentration with different angle of flow attack and the maximum flow velocities at and around the proposed structure was also determined to assess the effectiveness of the proposed structure.

The Figure-1 shows the satellite image of Jamuna and Bangali River. It is observed from the figure that the Jamuna River is very close to the Bangali River at Debdanga. The right bankline of the Jamuna has been progressively moved towards the west and has developed a threat of possible unification of the Jamuna with the Bangali river at Debdanga.

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Methodology

The scale model is set-up using the existing facilities of RRI. An open-air model bed of RRI having dimension of 80mx40m has been used for setting up the model. The area reproduced in the model is about 4.0km river reach covering about 1.25km upstream and about 2.75km downstream of the Mathurapara Hard Point and an average river width of about 1.0km from right bank of the Jamuna river.

The bathymetry of March 2003 surveyed by IWM is used in the model for test T0 to T4 and the recent bathymetry surveyed by BWDB is used for test T5 & T6. The bed material in the model is composed of fine sand (D_{50}=0.18mm) in the movable portion and some portion is fixed by cement-plastering the bed at the inflow and outflow section. The prototype cross-sectional data of surveyed sections are converted to model to prepare the model bed. The maximum water level is 19.06mPWD at Mathurapara (IWM Station ID: 15J) on the Jamuna river which is recorded on 1988. This water level has been considered for model study. The discharge is calculated as 13180 cumec corresponding to that water level for 950m river width from right bankline of the Jamuna river.

Figure-1: Satellite images of Jamuna and Bangali river for different years

The calibration test plus six application test runs with structural intervention along the right bank of Jamuna river downstream of Mathurapara Hard Point have been conducted. Test T0 contributed to the calibration of the model. The application tests T1 through T6 are carried out with a view to observe the performance of the bank protection structure to prevent river bank erosion downstream of Mathurapara Hard Point. Each application test was run with both Froude's discharge to determine flow velocity, flow lines etc and scour discharge to determine the scour depth. Scour discharge is run until equilibrium bed level has been reached in the model.

Data Collection

The prototype data required for simulating the dominating processes in the scale model were bathymetric data, hydrometric data, bank & bed material data, design data of revetment etc. The bathymetric data of March 2003 is obtained from Institute of Water Modelling (IWM) and the recent bathymetry is obtained from BWDB. The historical discharge and water level data are collected from IWM. Several numbers of bed and bank material samples are collected from different location of the study area and have been analyzed in the Sediment Laboratory of RRI. Detail design & drawings of the revetment and X-Bars are collected from Design Circle-VI of BWDB, Dhaka.

Test Description

An undistorted physical model was constructed considering horizontal and vertical scale of 1:90. The model has been designed fulfilling the Froude's model law. The scour velocity in the model was such that sufficient sediment transport has been ensured in the model and the model has been expected to reach the dynamic equilibrium condition by running about 16-20 hours. Reynolds number was maintainned high enough to ensure rough turbulent flow in the model. The basic design parameters for the model study along with some derived parameters and the corresponding scales are shown in **Table-1.**

Table-1: Hydraulic and morphological parameters for the model study

Description	Unit	Prototype	Model	Scale
Length, L	m	4000	44	90
Average width, W	m	950	10.56	90
Average water depth, h	m	9.0	0.100	90
Water surface slope, i	-	0.000075	0.000075	1
Average velocity, v	m/s	1.70	0.17926	9.49
Average cross-sectional area, A	m^2	7750	0.957	8100
Critical velocity, v_{cr}	m/s	0.402	0.243	1.65
Discharge, Q	m^3/s	13180	0.172	76843
Discharge for scour simulation, Q_s	m^3/s	-	0.294	-
Median particle diameter, D_{50}	m	0.00020	0.00020	1
Dimensionless particle diameter, D_*	-	4.480	4.480	1
Shields parameter, θ	-	2.045	0.023	90
Critical Shields parameter, θ_{cr}	-	0.054	0.054	1
Chezy roughness co-efficient, C	m1/2/s	65	25	2.60
Froude number, Fr	-	0.181	0.181	1
Shear velocity, v_*	m/s	0.081	0.009	9.49
Critical shear velocity, v_{*cr}	m/s	0.01317	0.01317	1
Particle Reynolds number, Re_*	-	2.196	2.196	1
Reynolds number, Re	-	12754839	14939	853.81

Model Calibration

Calibration is done for matching the model with the prototype condition. The velocity distribution at the calibration section (JB-032) was measured and compared with the prototype value as shown in **Figure-2**.

From this figure it is evident that the measured values found in the model are very close to the prototype value.

Test Runs

The calibration test plus six application test runs with structural intervention along the right bankline of Jamuna river have been conducted in the model. One structural intervention is shown in **figure-3**. The objectives and test conditions of the model study are described in **Table-2.**

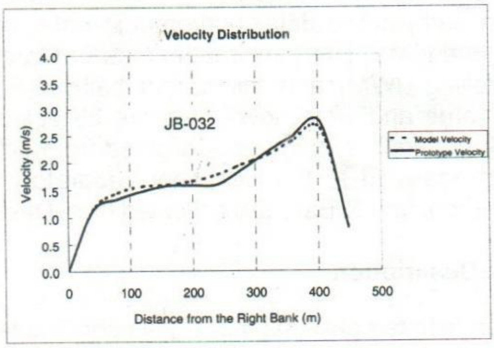


Figure-2: Comparison between prototype and model velocity

Table-2: Objectives and test conditions of the model study

Test No	Objectives	Test Conditions
T0	Calibration of the model.	March 2003 bathymetry with existing structures i.e. Mathurapara Hard Point & BRE.
T1	To observe the effectiveness of revetment as well as optimization of spacing of cross-bar and to finalize the design parameters.	Same as Test T0 plus ▪ 1273m revetment proposed by BWDB as shown in **Figure-3.** ▪ 3 Nos. cross-bar proposed by BWDB
T2	To observe the effectiveness of revetment as well as optimization of spacing of cross-bar and to finalize the design parameters under flow attacking condition.	Same as Test T1 plus ▪ Angle of flow attack 47 degree with revetment
T3	To observe the effectiveness of revetment as well as optimization of spacing of cross-bar and to finalize the design parameters under flow attacking condition.	Same as Test T1 plus ▪ Angle of flow attack 39 degree with revetment
T4	To observe the effectiveness of revetment as well as optimization of spacing of cross-bar and to finalize the design parameters.	Same as Test T0 plus ▪ 1273m revetment proposed by BWDB ▪ 4 Nos. cross-bar
T5	To observe the effectiveness of revetment as well as optimization of spacing of cross-bar and to finalize the design parameters.	The recent bathymetry & bankline data obtained from BWDB with existing structures i.e. Mathurapara Hard Point & BRE plus ▪ 1273m revetment proposed by BWDB ▪ 3 Nos. of attracting type cross-bars.
T6	To observe the effectiveness of revetment as well as optimization of spacing of cross-bar and to finalize the design parameters under flow attacking condition.	Same as Test T5 plus ▪ Angle of flow attack 46 degree with revetment

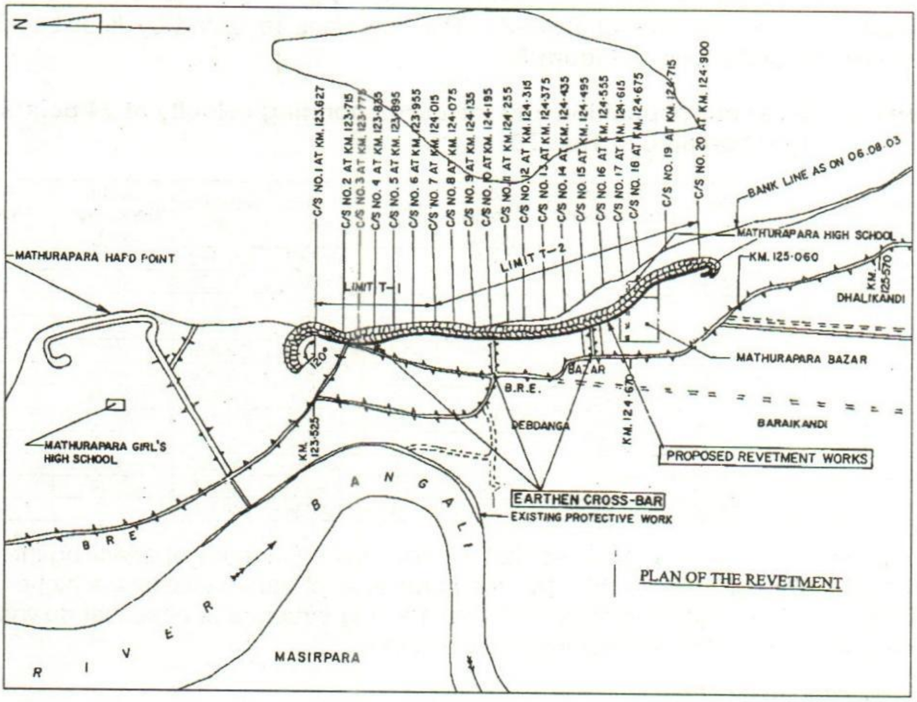


Figure-3: Revetment proposed by BWDB

Analysis and Interpretation of the Test Results

Calibration Test (T0)

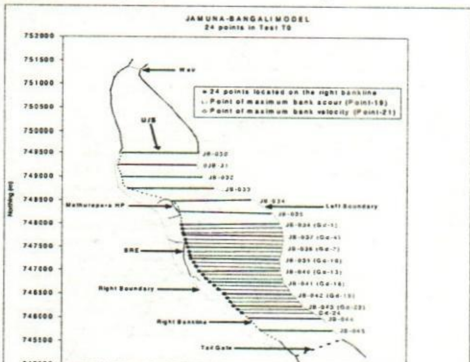


Figure-4: Location of 24 points for scour and velocity measurement in Test T0

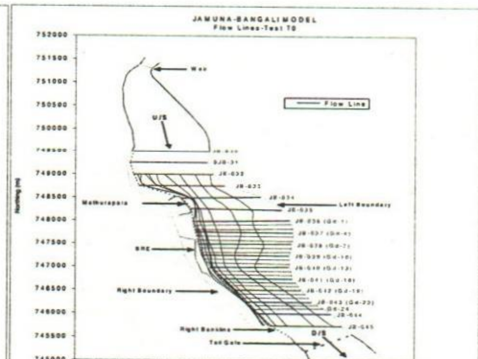


Figure-5: Flow lines in Test T0

In this test, the equilibrium scour depths and the corresponding velocities have been measured at 24 points (**Figure-4**) starting from upstream along right bankline and can be seen in **Table-3.** From this table, the maximum bank scour and the corresponding velocity are found 11.34m and 1.54m/s respectively (Point-19). The maximum bank velocity is found 2.23m/s at Point-21. The flow lines recorded by float tracking have been plotted and shown in **Figure-5.**

Table-3: Net scour/deposition and the corresponding velocity at 24 points along right bankline in Test T0

Point No.	Easting (m)	Northing (m)	Scour/ Deposition (m)	Flow Velocity (m/s)	Point No.	Easting (m)	Northing (m)	Scour/ Deposition (m)	Flow Velocity (m/s)
1	458380	747985	-2.52	2.03	13	458587	746988	-7.83	1.35
2	458392	747896	-4.50	1.85	14	458629	746908	-6.12	1.94
3	458404	747807	-4.77	1.66	15	458671	746829	-7.47	2.04
4	458411	747758	-5.67	1.61	16	458713	746750	-0.63	1.97
5	458425	747669	-3.96	1.85	17	458763	746675	-8.01	1.85
6	458439	747580	-3.60	1.27	18	458813	746600	-8.55	1.85
7	458453	747494	-2.25	1.67	19	458880	746500	**-11.34**	**1.54**
8	458468	747405	-1.80	1.85	20	458916	746418	-8.73	1.75
9	458483	747317	-4.77	1.37	21	458952	746335	-6.21	**2.23**
10	458494	747254	-4.68	1.51	22	458989	746250	-3.33	1.51
11	458524	747169	-5.40	1.66	23	459039	746175	-3.87	1.94
12	458553	747084	-5.85	1.37	24	459089	746100	-6.21	1.85

From the flow lines, it is observed that the flow has a tendency of attacking the bankline from JB-036 to JB-045. In this test, the magnitude of bank velocities is higher than the erodible velocity which indicates that river training structure is essential downstream of Mathurapara Hard Point to combat bank erosion.

Application Test (T1)

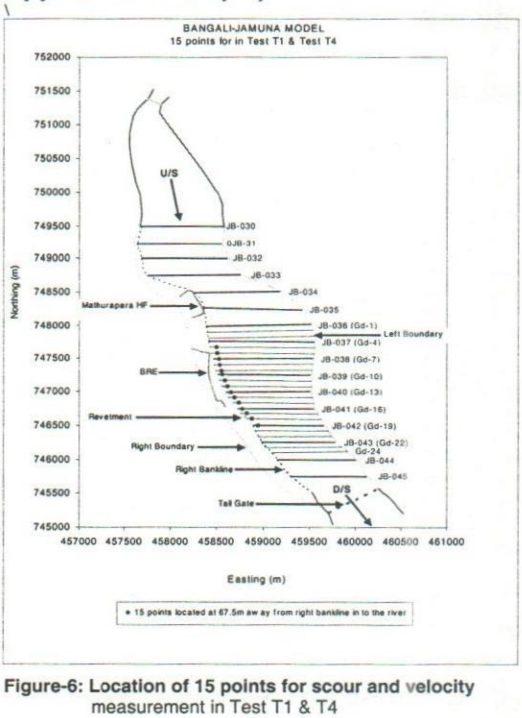


Figure-6: Location of 15 points for scour and velocity measurement in Test T1 & T4

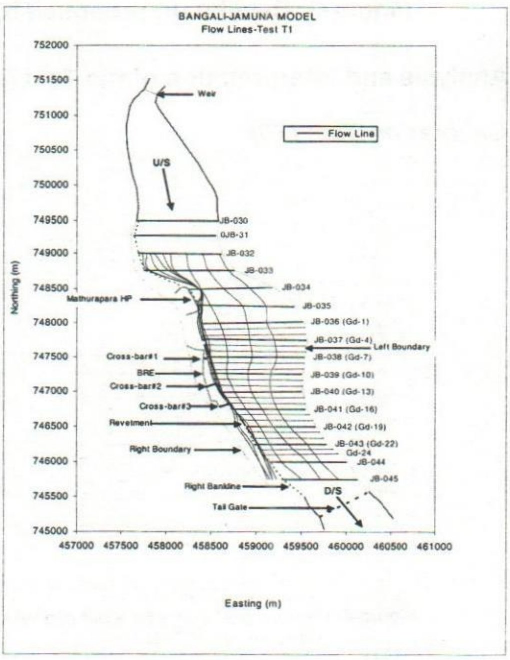


Figure-7: Flow lines in Test T1

In Test T1, the equilibrium scour depths and the corresponding velocities have been measured at 15 points which were 67.5m from the right bankline towards the river side (**Figure-6)** starting from upstream along the end of the launching apron of revetment and can be seen in **Table-4**.

Table-4: Net scour/deposition and the corresponding velocity at 15 points along the end of the launching apron of revetment in Test T1

Point No.	Easting (m)	Northing (m)	Scour/ Deposition (m)	Flow Velocity (m/s)	Point No.	Easting (m)	Northing (m)	Scour/ Deposition (m)	Flow Velocity (m/s)
5	458493	747669	-1.62	2.04	13	458654	746989	-6.21	2.52
6	458507	747580	0.36	2.14	14	458697	746909	-6.21	2.43
7	458520	747494	1.17	1.37	15	458739	746828	-9.00	2.33
8	458536	747406	1.89	2.14	16	458781	746750	-6.84	**2.91**
9	458551	747317	-1.08	2.14	17	458830	746675	-5.04	**2.91**
10	458561	747254	0.63	1.75	18	458880	746599	-7.65	**2.91**
11	458591	747168	-5.85	2.33	19	458948	746500	**-9.45**	2.81
12	458621	747083	-6.48	2.14					

From **Table-4**, the maximum scour and the corresponding velocity are found 9.45m and 2.81m/s respectively (Point-19). The maximum velocity is found 2.91m/s at Point-16, 17 & 18.

The flow lines recorded by float tracking have been plotted and shown in **Figure-7**. From the flow lines, it is observed that the flow lines are parallel to the revetment but concentrated at the downstream end of revetment. Also the flow lines attack the bank downstream of proposed revetment.

Application Test (T2)

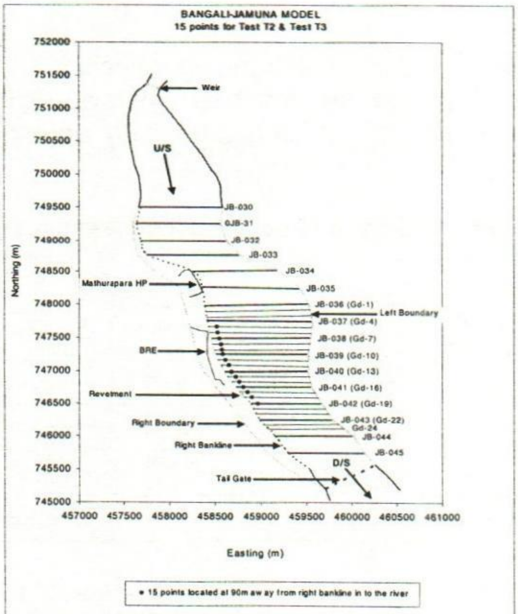


Figure-8: Location of 15 points for scour and velocity measurement in Test T2 & T3

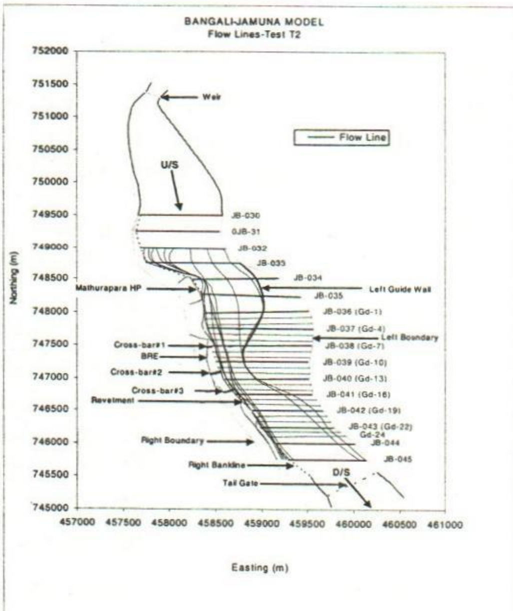


Figure-9: Flow lines in Test T2

In this test, the equilibrium scour depths and the corresponding velocities have been measured at 15 points which were 90m from the right bankline towards the river side (**Figure-8)** starting from upstream along the end of the launching apron of revetment and can be seen in **Table-5.**

Table-5: Net scour/deposition and corresponding velocity at 15 points along the end of the launching apron of revetment in Test T2

Point No.	Easting (m)	Northing (m)	Scour/ Deposition (m)	Flow Velocity (m/s)	Point No.	Easting (m)	Northing (m)	Scour/ Deposition (m)	Flow Velocity (m/s)
5	458515	747668	0.90	2.33	13	458677	746989	-8.91	2.62
6	458529	747579	-1.17	2.23	14	458719	746909	-9.99	2.81
7	458543	747494	-2.52	2.43	15	458761	746828	-9.99	2.52
8	458558	747406	-2.34	2.62	16	458803	746750	-10.53	2.23
9	458573	747317	-1.35	2.52	17	458853	746674	**-10.80**	**2.62**
10	458584	747254	-2.34	1.94	18	458903	746599	-9.90	2.62
11	458614	747168	-6.57	2.52	19	458970	746500	-9.27	**3.30**
12	458643	747083	-8.82	2.14					

From **Table-5**, the maximum scour and the corresponding velocity are found 10.80m and 2.62m/s respectively (Point-17). From this table, the maximum velocity is found 3.30m/s at Point-19.

The flow lines recorded by float tracking have been plotted and shown in **Figure-9**. From the flow lines, it is observed that under this condition the flow lines are parallel to the revetment but concentrated at the downstream end of revetment.

Application Test (T3)

In this test, the equilibrium scour depths and the corresponding velocities have been measured at 15 points which were 90m from the right bankline towards the river side starting from upstream along the end of the launching apron of revetment and can be seen in **Table-6**.

Table-6: Net scour/deposition and corresponding velocity at 15 points along the end of the launching apron of revetment in Test T3

Point No.	Easting (m)	Northing (m)	Scour/ Deposition (m)	Flow Velocity (m/s)	Point No.	Easting (m)	Northing (m)	Scour/ Deposition (m)	Flow Velocity (m/s)
5	458515	747668	-4.05	2.33	13	458677	746989	-14.13	2.62
6	458529	747579	-5.40	2.62	14	458719	746909	-12.51	2.62
7	458543	747494	-7.11	3.01	15	458761	746828	-12.96	2.72
8	458558	747406	-4.23	2.72	16	458803	746750	-12.60	2.81
9	458573	747317	-3.42	2.52	17	458853	746674	**-14.04**	**2.81**
10	458584	747254	-7.20	2.33	18	458903	746599	-13.23	**2.91**
11	458614	747168	-9.99	2.14	19	458970	746500	-11.34	2.62
12	458643	747083	-11.97	2.33					

From **Table-6**, the maximum scour and the corresponding velocity are found 14.04m and 2.81m/s respectively (Point-17). From this table, the maximum velocity is found 2.91m/s at Point-18.

The development of scour with time at Point-17 where maximum scour occurs around the revetment can be seen in **Figure 10**. From this figure it is evident that after a certain time interval scour has reached a certain value and scour is no longer occurring with time. In other words equilibrium condition has been reached in the model. The flow lines recorded by float tracking have been plotted and shown in **Figure 11.** From the flow lines, it is observed that under this condition the flow lines are parallel to the revetment and concentrated at the downstream end of revetment.

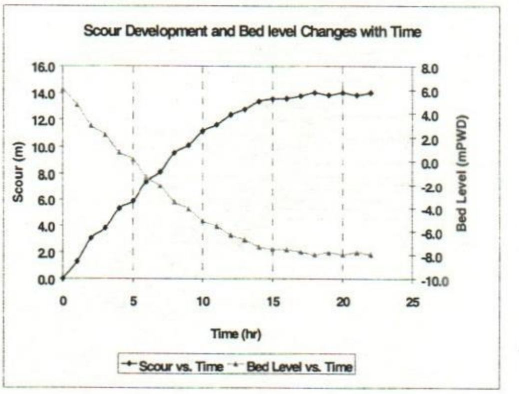


Figure-10: Development of scour with time at Point-17 in Test T3

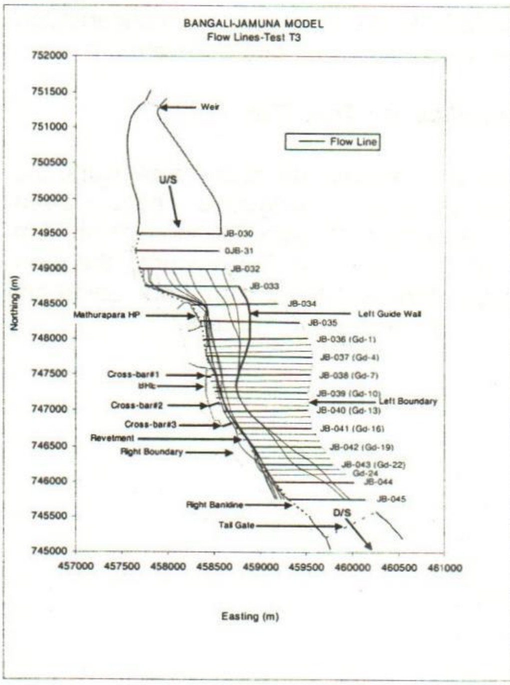


Figure-11: Flow lines in Test T3

Application Test (T4)

In Test T4, 1273m revetment and 4 nos. cross-bars (an additional cross-bar with respect to cross-bars in Test T1, T2 & T3) were constructed in the model.

In this test, the equilibrium scour depths and the corresponding velocities have been measured at 15 points which were 67.5m from the right bankline towards the river side starting from upstream along the end of the launching apron of revetment and can be seen in **Table-7.**

Table-7: Net scour/deposition and corresponding velocity at 15 points along the end of the launching apron of revetment in Test T4

Point No.	Easting (m)	Northing (m)	Scour/ Deposition (m)	Flow Velocity (m/s)	Point No.	Easting (m)	Northing (m)	Scour/ Deposition (m)	Flow Velocity (m/s)
5	458493	747669	0.72	2.23	13	458654	746989	-4.05	2.04
6	458507	747580	0.00	2.04	14	458697	746909	-4.23	2.43
7	458520	747494	1.08	2.23	15	458739	746828	-4.86	2.14
8	458536	747406	-0.45	2.14	16	458781	746750	-3.96	2.33
9	458551	747317	1.08	1.94	17	458830	746675	-6.30	**2.52**
10	458561	747254	0.90	1.94	18	458880	746599	-7.11	2.23
11	458591	747168	-1.35	2.14	19	458948	746500	**-9.72**	**2.52**
12	458621	747083	-2.61	2.14					

From **Table-7**, the maximum scour and the corresponding velocity are found 9.72m and 2.52m/s respectively (Point-19). From this table, the maximum velocity around the revetment is found 2.52m/s at Point-17 & 19.

The flow lines recorded by float tracking has been plotted and shown in **Figure-12.** From the flow lines, it is observed that under this condition the flow lines are parallel to the revetment but concentrated at the downstream end of revetment

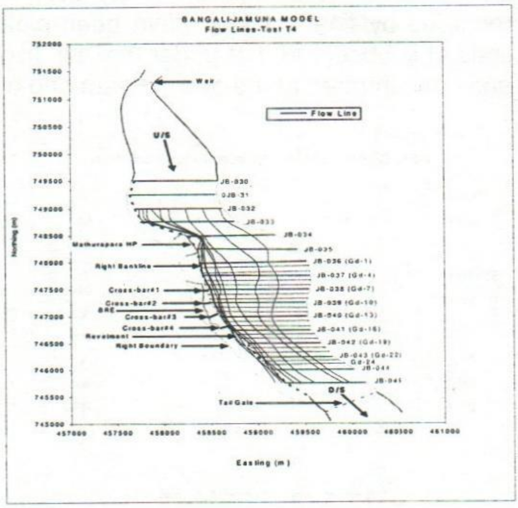


Figure-12: Flow lines in Test T4

Application Test (T5)

Here the equilibrium scour depths and the corresponding velocities have been measured at 18 points which were 67.5m from the right bankline towards the river side (**Figure-13**) starting from upstream and can be seen in **Table-8**.

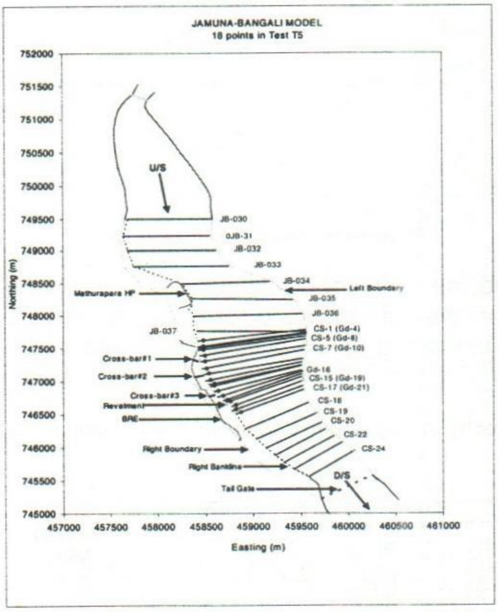


Figure-13: Location of 18 points for scour and velocity measurement in Test T5

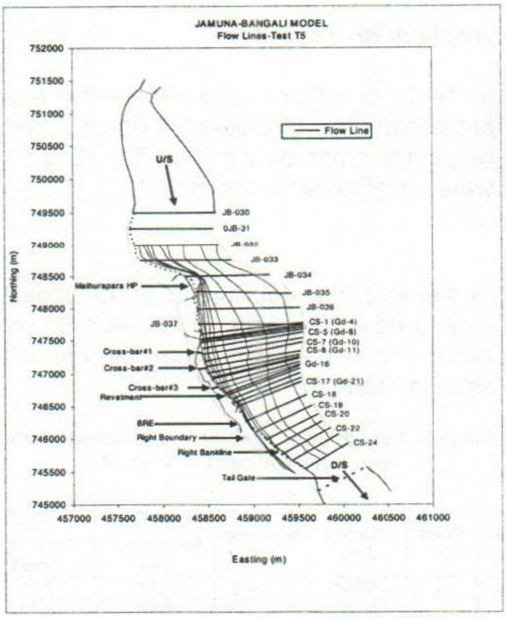


Figure-14: Flow lines in Test T5

Table-8: Net scour/deposition and corresponding velocity at 18 points along the end of the launching apron of revetment in Test T5

Point No.	Easting (m)	Northing (m)	Scour/ Deposition (m)	Flow Velocity (m/s)	Point No.	Easting (m)	Northing (m)	Scour/ Deposition (m)	Flow Velocity (m/s)
4	458481	747616	6.21	2.19	13	458596	746965	0.45	1.80
5	458479	747537	5.49	1.80	14	458599	746939	1.80	2.19
6	458479	747515	4.95	1.61	15	458640	746861	-0.09	1.90
7	458477	747482	3.15	1.61	16	458688	746790	4.23	1.80
8	458494	747395	-1.08	1.61	17	458732	746725	-3.33	2.19
9	458499	747304	-1.62	1.70	18	458764	746703	1.35	2.39
10	458516	747200	-1.80	1.80	19	458825	746646	-4.05	**2.58**
11	458538	747118	-0.09	1.61	20	458821	746577	**-9.00**	**2.58**
12	458553	747025	-0.81	2.00	21	458872	746533	-0.90	2.39

From **Table-8**, the maximum scour and the corresponding velocity are found 9.00m and 2.58m/s respectively (Point-20). The maximum velocity is found 2.58m/s at Point-19 & 20.

The flow lines recorded by float tracking has been plotted and shown in **Figure-14.** From the flow lines, it is observed that under this condition the flow lines are parallel to the revetment but concentrated at the downstream end of revetment.

The flow entered the flood plain between Mathurapara Hard Point and bend of BRE. The bent portion of the BRE functioned as another cross-bar and CC blocks of revetment have been displaced at the junction of bend of BRE and revetment due to the cross-flow along the BRE. CC blocks of revetment were affected due to the cross-flow along cross-bar#2 & #3. Bank erosion occurred downstream of proposed revetment and a sketch of right bank erosion observed in Test T5 is shown in **Figure-15.** From this figure it is observed that the right bank erosion ranges from 0 to 109m.

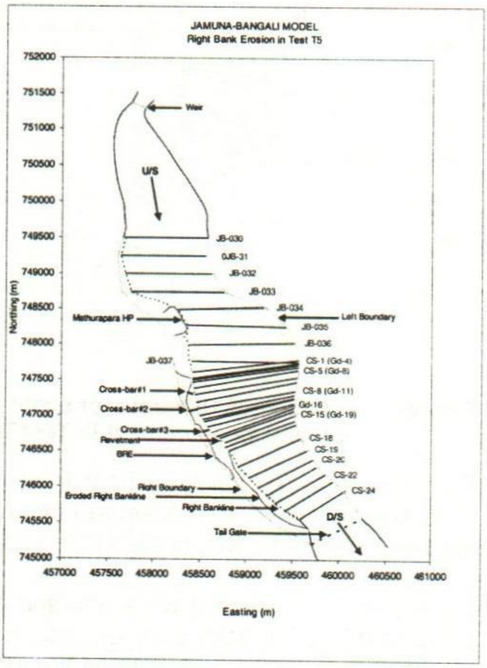


Figure-15: Observed right bank erosion in Test T5

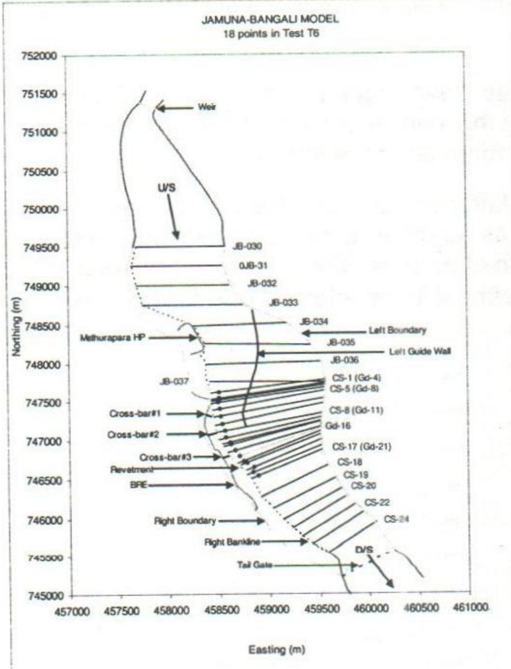
Application Test (T6)

In this test, the equilibrium scour depths and the corresponding velocities have been measured at 18 points which are 90m from the right bankline towards the river side (**Figure-16**) starting from upstream along the end of the launching apron of revetment and can be seen in **Table-9**.

From **Table-9**, the maximum scour and the corresponding velocity are found 12.15m and 3.10m/s respectively (Point-18). From this table, the maximum velocity is found 3.68m/s at Point 20 & 21.

Table-9: Net scour/deposition and corresponding velocity at 18 points along the end of the launching apron of revetment in Test T6

Point No.	Easting (m)	Northing (m)	Scour/ Deposition (m)	Flow Velocity (m/s)	Point No.	Easting (m)	Northing (m)	Scour/ Deposition (m)	Flow Velocity (m/s)
4	458503	747619	2.16	2.23	13	458617	746972	-4.77	2.81
5	458501	747541	-0.09	2.33	14	458621	746946	-6.12	2.72
6	458501	747519	0.27	1.85	15	458661	746869	-6.03	2.91
7	458499	747486	-1.17	2.23	16	458709	746799	-9.90	3.30
8	458516	747400	-0.81	2.91	17	458752	746735	-10.26	3.39
9	458521	747309	-3.60	2.43	18	458784	746713	**-12.15**	**3.10**
10	458538	747206	-4.86	2.91	19	458845	746657	-6.03	3.39
11	458560	747124	-5.13	2.72	20	458841	746587	-9.09	**3.68**
12	458575	747031	-4.41	2.72	21	458892	746543	-5.40	**3.68**



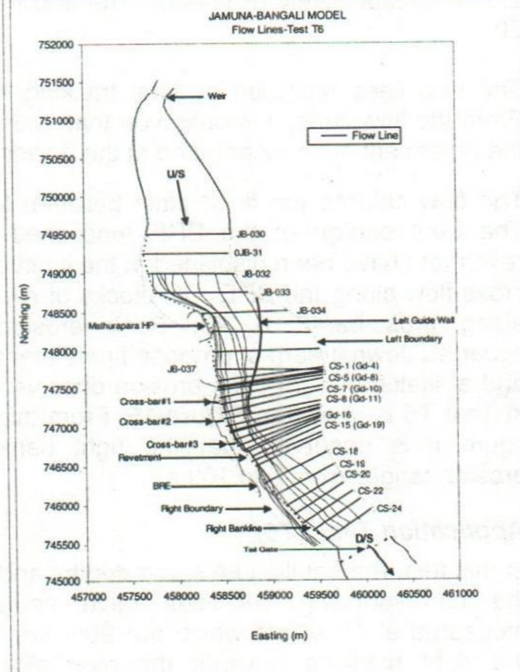


Figure-16: Location of 18 points for scour and velocity measurement in Test T6

Figure-17: Flow lines in Test T6

The flow lines recorded by float tracking has been plotted and shown in **Figure-17**. From the flow lines, it is observed that under this condition the flow lines are parallel to the revetment but concentrated at the downstream end of revetment.

CC blocks of revetment were affected due to the cross-flow along cross-bar#2. Along cross-bar#3, CC blocks of revetment were highly affected due to the cross-flow and CC blocks have been settled down at the junction of cross-bar#3 with the revetment. Strong eddy formation happened near CS-16 and subsequent vortex has been occurred near CS-17. Due to this reason, scour and subsequent deposition occurred downstream of

CS-15. The revetment was highly attacked by the thrust of flow near CS-15 which has been observed in the model.

As a result, CC blocks have been disappeared away through displacement and rolling from the slope pitching and launching apron of revetment. In that case CC blocks should be kept ready for emergency dumping if necessary. Bank erosion occurred downstream of proposed revetment and a sketch of right bank erosion observed in Test T6 is shown in **Figure-18**. From this figure it is observed that the right bank erosion ranges from 0 to 123m.

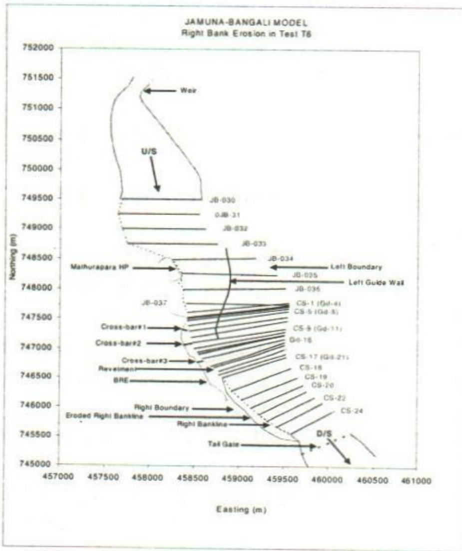


Figure-18: Observed right bank erosion in Test T6

Conclusions

The following conclusions are drawn from the study:

- 1273m revetment proposed by BWDB from chainage 123.627km to 124.900km is reproduced in the model and is found to work effectively except CS-15 where the revetment was highly attacked by the thrust of flow. As a result, CC blocks were disappeared away through displacement and rolling from the slope pitching and launching apron of revetment. In that case CC blocks should be kept ready for emergency dumping if necessary.
- The maximum scour developed around the end of launching apron of revetment is 9.00m in normal flow condition and 12.15m in oblique flow condition (at an angle of attack of 46^0 with the revetment).
- The maximum velocity developed around the end of launching apron of revetment is 2.58m/s in normal flow condition and 3.68m/s in oblique flow condition (at an angle of attack of 46^0 with the revetment).

Acknowledgement

- The authors are grateful to Roads & Highway Department (RHD) for financial support to conduct the scale model study at RRI. The authors are also grateful Bangladesh Water Development Board for supplying the preliminary design of the revetment.

11.0 References

IWM (2004): Morphological study for erosion prediction and mitigative measures at the vicinity of the Jamuna Bridge and structural measures against possible unification of the Jamuna and Bangali River.

River Survey Project (1996a): FAP24, Final Report, Main Vol, No.1.

River Survey Project (1996b): FAP24, Special Report No.3, Bathymetric Surveys.

River Survey Project (1996c): FAP24, Special Report No.7, Geomorphology and Channel Dimensions.

RRI (2005): Physical model study of structural measures against possible unification of the Jamuna-Bangali river at Debdanga, Final Report.

Satellite Imageries of Jamuna and Bangali River, CEGIS, Dhaka.

Van Rijn C. (1984): Bed Forms and Alluvial Roughness, Sediment Transport, Part-III, ASCE Journal of Hydraulic Engineering, Vol. 110, No. 12.

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Comparison Of Hydraulic Conductivity Using Municipal Wastewater And TapWater of Different Types of Soil

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Abstract

An experimental investigation was carried out in Bangladesh Agricultural University (BAU), Mymensingh to compare hydraulic conductivity of different types of soil using municipal wastewater and tap water. For this purpose, the laboratory test was conducted of three types of soil samples (Sandy Loam, Loamy soil, Silty clay loam). The soil samples and municipal wastewater samples were collected from the selected location of BAU Campus, Mymensingh. The test result revealed that wastewater flow through the soil is reduced with consequent decrease in hydraulic conductivity due to soluble or suspended solids and soluble compounds (which seal the pore space of the soil) in the wastewater. The hydraulic conductivity decreased rapidly with respect to time in this case and after certain period of time it tends to zero. While in case of tap water, hydraulic conductivity is nearly constant due to free from considerable impurities. In irrigable soil, reduced hydraulic conductivity affects the flow due to impurities in water and thus creates water logging and other deleterious effects. In this paper, comparison of hydraulic conductivity using municipal wastewater and tap water of different types of soil is presented.

Introduction

Water is very essential for the human beings and plants. The utilization of water to plants through irrigation is different for different types of soil. Qualitatively, hydraulic conductivity is the ability of the soil to transmit water through its pores subjected to difference in pressure head and varies greatly in different types of soils. The water movement (hydraulic conductivity) through soil depends on the grain size distribution, porosity, shape and arrangement of pores, properties of the pore fluid and entrapped air or gas. Normally, municipal wastewater contains between 500 to 1000 mg. of solid matter per litre. These soluble compounds and suspended solids may affect hydraulic conductivity. Permeability is influenced by the size and shape of the pore spaces, through which water flows due to the specific weight and viscosity of the soil water.

A comparison of the withdrawals for definitely irrigation and municipal use provides motivation for utilizing wastewater as a source of supply for irrigation. All water is not suitable for irrigation for all crops. The unsatisfactory water may contain (i) chemicals toxic to plants or to persons using the plants as food. (ii) chemicals which react with soil to produce unsatisfactory moisture characteristics and (iii) Bacteria injurious to persons or animals eating plants irrigated with the water. In addition, hydraulic properties of soil, such as hydraulic conductivity and permeability affect suitability of water for use in irrigation. There are instances of using municipal wastewater in irrigation (Black, 1950).

Wastewater may also be source of irrigation in Bangladesh. But it is important to know the effect of municipal waste water before using it for irrigation to agricultural farms.

Ordinarily municipal wastewater contains between 500 and 1000 mg of solid matter per litre. The physical and chemical characteristics of wastewater vary from time to time. The solids in a wastewater consist of insoluble or suspended solids and soluble

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compounds dissolved in the water. About 40 percent of the solids in an average wastewater are suspended. This solid may float or settle and form objectionable sludge banks if discharge to a river. Some of the suspended solids settle quite rapidly but those of colloidal size settle slowly or not at all.

Objectives of the study

This study was undertaken to investigate the effect of wastewater on hydraulic conductivity which is an important parameter for suitability of water for irrigation. The specific objectives of this study are:

(a) To determine the variation in hydraulic conductivity of different soils using municipal wastewater and tap water for successive intervals of times.

(b) To compare of the hydraulic conductivity of the soil using the tap water and municipal wastewater

The results will help determine the suitability of municipal wastewater as a source of irrigation water from the view point of hydraulic conductivity of the soil.

Review of literature

Some available literature related to the subject matter is reviewed. Eastman (1973), in his study shows a comprehensive compilation about the water availability and irrigation water demand, direct land application of sewage, disease caused by the sewage irrigation and standard for sewage irrigation.

Reave et al. (1957), discussed that the concentration and chemical nature of the solution used for conductivity measurement is of extreme importance. Allison (1947) studied the various effects, viz. entrapped air, biological activity, swelling and slaking that interact to produce a resultant variation in the conductivity with time.

Water moves through a soil in response to the various forces acting upon it. Among these, pressure gradient as well as gravitational, absorptive and osmotic forces are noteworthy. In addition, thermal and electrical gradient may impose forces upon the water in soil and affect its movement under certain circumstances (Hutchinson, 1958).

One of the basic physical relationships used to describe the flow of water in soils is flux equation, Darcy's law which relates the flux of water, V to the driving force as follows:

$$V = -\left(\frac{k\rho}{\eta}\right)\nabla\varphi \quad \text{-------------- (i)}$$

where, k = Permeability of soil or porous medium.

ρ = Density of the fluid.

η = Fluid viscosity and

$\nabla\varphi$ = Driving force per unit mass of water.

Darcy's law may also be written in terms of the hydraulic gradient.

$V = k\nabla H$ ------------ (ii)

In this equation, V is the volume of flux of water i.e. volume of water passing through the unit cross-sectional area of soil per unit time, ∇H is the hydraulic gradient or the space rate of change of hydraulic head H in the direction of flow and k is the conductivity of the soil to water. The water moving force is expressed as the negative gradient of a hydraulic head composed of gravitational and pressure head, i.e.;

$H = h + z$ .... (iii)

Where h = pressure head and
z = gravitational head.

The pressure head is numerically equal to the soil water tension or suction but of opposite sign when the soil water tension is expressed in units of length of a column of water.

The conversion from conductivity to permeability can be made by the use of the equation;

$$\acute{K} = \frac{\kappa\eta}{\rho g} \text{ .... (iv)}$$

Where, $\acute{K}$ = Permeability of the soil.
κ = Hydraulic conductivity of the soil.
g = Acceleration due to gravity
η = Viscosity of the fluid.
ρ = Density of the fluid.

The conductivity has the dimension of a velocity, while the permeability has the dimensions of a length squared.

The fact that conductivity appears as a proportionality factor in Darcy's law, it does not necessarily mean that hydraulic conductivity is or must be a constant. Because of the various chemical, physical and biological processes that take place in the soil, change of conductivity may occur when water is passed through a soil. A change in the exchangeable ion status of a soil may greatly affect the ability of the soil to conduct water. Physical transfer of the smaller particles in the soil samples as a result of the flow of water may occur with resultant changes in conductivity. Microbial activity within the sample may affect the conductivity, particularly when water is passed through the soil sample for long period of time or when the sample has been submerged for a long time in water.

Darcy's law is not universally valid for all liquid flow through all porous media. Analysis of various forces acting upon the water passing through a porous medium shows that

Darcy's law is applicable under condition such that inertial forces are negligible compared to viscous forces. The range of validity of Darcy's law can be demonstrated by measuring the flux of water resulting from a series of applied hydraulic gradient. The result should be a linear relation between the flux and hydraulic gradient. If the applied hydraulic gradient is too large, the resulting flux will be less than predicted by Darcy's law (Hubert and King, 1957)

Methodology and experimental procedures

In this study two types of laboratory analysis were performed. One for determine the types of soil and other to determine the hydraulic conductivity.

Collection of Municipal Wastewater Samples

The municipal wastewater samples were collected from the different surface drains of Mymensingh municipality at regular interval of time. Thus a sufficient amount of representative sample of municipal wastewater was collected. The collected wastewater samples were used in the experiment to find the effect of the municipal wastewater on hydraulic conductivity in samples of irrigated soils. The average concentration of collected wastewater samples was 850 mg. of solid matter per litre of wastewater.

Collection of Soil Samples

For the purpose of determining the hydraulic conductivity, the soil samples are collected in undisturbed condition with the help of a core sampler, pressed into the soil to obtain samples. The sample no. A was collected at a depth of 3 to 8 inch from the site that is located beside the department of Irrigation and Drainage, Faculty of Agricultural Engineering and Technology of Bangladesh Agricultural University (BAU), Mymensingh. The sample no. B and C were collected at depths 2 to 5 inch respectively form the Bangladesh Agricultural University Farms, Mymensingh. Sufficient amount of the representative soil samples (total number of sample is 9 which of each 3 sample represent each) were collected for conducting mechanical analysis.

Soil Classification

Firstly to determine the types of soil (textural classification of the sampled soils) the mechanical analysis of soil samples was performed by hydrometer method and the results obtained are shown in Table 1. The types of soil were determined by using the Marshall triangle. Based on the percentage of sand, silt and clay obtained from the mechanical analysis, soils in sample no. A was found to be sandy loam, the samples B and C being loamy soil and silty clay loam, respectively.

Experimental Setup and Data Collection

In this study, constant head permeameter method is used to determine hydraulic conductivity. A schematic diagram of the constant head permeameter system for conductivity measurement is shown in Figure 1. In this method, the constant head of water was maintained by a continuous inflow cases a steady flow of water through the soil. The water flowing through the soil was collected in a graduated container. Hydraulic conductivity was computed from Darcy's law by measuring volume of flow in unit time. The experimental data was recorded at an equal interval of time 4 hours and simultaneously the corresponding temperature of the water was recorded. The volume of water passed through the soil was recorded in cubic centimetre. Then the hydraulic conductivity was computed from Darcy's law by using the formula and the value of K was expressed in cm. per day.

$$K = \frac{QL}{AtH} \quad \text{cm / day}$$

Where, A = Cross-sectional area of the sampler in cm^2,
t = Time in day,
L = Length of the sample in cm,
H= Hydraulic head (length of the sample + height of water above soil)
Q = Volume of water passed in cm^3.

For the sample no. A (sandy loam soil), the cross-sectional area was 45.5 cm^2, the length was 12.7 cm and the hydraulic head was 25.4 cm. In both cases of sample no. B and C (loamy soil and silty clay loam soil), the cross-sectional area, the length and the hydraulic head were 24.5 cm^2, 7.88 cm and 13.95 cm respectively. The values of the hydraulic conductivity was determined by using regular tap water and municipal wastewater for the representative soil samples are presented in Table 2 and Figures 2, 3, and 4 respectively.

Result and discussion

The effect of municipal wastewater and tap water on hydraulic conductivity of three soil samples, at the rate of decrease more in magnitude compared to tap or fresh water. The hydraulic conductivity decreased rapidly with respect to time in this case and after certain period of time it tends to zero.

Since fresh water is free from any insoluble or suspended solid matter, there is not much effect of such water on hydraulic conductivity. But municipal wastewater contains of solid mater in the form of suspended and soluble compounds and for this reason soil pore space is gradually sealed, and consequently water can not pass through it. As a result, hydraulic conductivity decreases and water logging condition is created i.e. standing water on the soil surface appears.

Sample no. A may be classified as moderate slow conductivity using tap water (8.87 cm/day) but slow by using wastewater (4.15 cm/day). Sample no. B shows slow conductivity class by using tap water (7.41 cm/day) but very slow by using wastewater (3.56 cm/day). Sample no. C shows very slow conductivity by using tap water (3.60 cm/day) and very very slow by using wastewater (1.37 cm/day).

Conclusion

Results of this limited experience show that there is no remarkable effect or change on hydraulic conductivity in case of regular tap water. But it shows a substantial change in hydraulic conductivity when municipal wastewater used. Hydraulic conductivity decreases with respect to time and after certain time, the water can no longer pass through the soil because wastewater contains insoluble or suspended solids and soluble compounds. As a result, water logging was created due to clogging of soil pore spaces.

For the irrigation use, hydraulic conductivity is an important parameter. It is clear that the hydraulic conductivity in case of tap water is nearly constant although there is slight variation in results. But with municipal wastewater the hydraulic conductivity reduces to almost zero after some time. Thus municipal wastewater does not seem to be suitable for irrigation without treatment. The wastewater may be used for irrigation in sandy soils from the stand point of hydraulic conductivity. In other soils of slow or very slow conductivity classes, the drainage and water logging problems may be encountered.

From a public health standpoint, direct application of wastewater and sewage to lands for irrigation of plants is likely be hazardous. Wastewater may be used to irrigate cotton, flux, nursery stock and other crops which are not used for human consumption. In that case, a portion of the suspended solids in the raw wastewater should be removed before application on land to prevent clogging of soil.

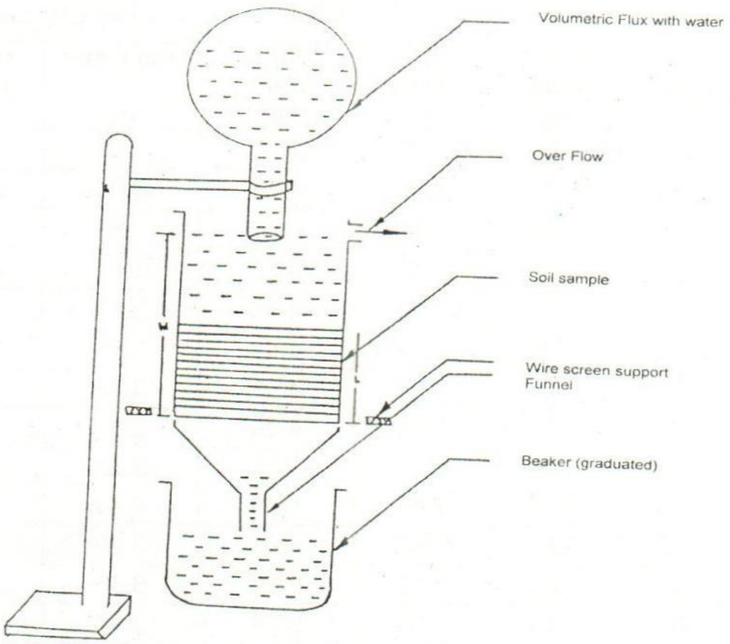

Figure 1: Schematic diagram of the constant head permeameter system used for hydraulic conductivity measurement.

Table 1: Types of soils

Sample No.	% of Clay	% of Silt	% of Sand	Type of Soil
(1)	(2)	(3)	(4)	(5)
Sample -A	15	25	60	Sandy Loam
Sample –B	25	40	35	Loamy soil
Sample -C	33	40.8	26.2	Silty clay Loam

Table 2: Hydraulic conductivity (cm/day) of soils for Tap water and Waste Water

Soil Type	*Sandy loam*		*Loamy Soil*		*Silty Clay Loam*	
Time (hr)	**Tap Water**	**Waste Water**	**Tap Water**	**Waste Water**	**Tap Water**	**Waste Water**
(1)	(2)	(3)	(4)	(5)	(6)	(7)
0	9.05	5.62	7.62	4.7	3.88	2.49
4	9.12	5.54	7.62	4.78	3.88	2.49
8	9.05	5.44	7.55	4.56	3.81	2.38
12	9.02	5.42	7.62	4.56	3.74	2.35
16	8.95	5.34	7.42	4.43	3.74	2.21
20	8.92	5.32	7.42	4.43	3.81	2.02
24	8.85	5.27	7.35	4.35	3.76	1.94
28	8.95	5.14	7.48	4.28	3.67	1.79
32	8.98	5.02	7.55	4.22	3.67	1.73
36	8.98	4.98	7.44	4.08	3.74	1.66
40	9.02	4.82	7.48	4.02	3.60	1.59
44	8.50	4.68	7.42	3.95	3.60	1.38
48	8.82	4.48	7.35	3.74	3.67	1.34
52	8.92	4.42	7.35	3.67	3.60	1.17
56	8.95	4.28	7.44	3.58	3.53	0.97
60	8.5	3.96	7.42	3.39	3.53	0.89
64	8.78	3.76	7.05	3.25	3.60	0.83
68	8.50	3.42	7.36	3.04	3.67	0.72
72	8.80	3.16	7.35	2.98	3.53	0.55
76	8.98	2.96	7.44	2.75	3.46	0.44
80	8.92	2.64	7.35	2.56	3.39	0.28
84	8.82	2.37	7.35	2.22	3.43	0.21
88	8.98	2.12	7.35	2.05	3.22	0.17
92	8.92	1.92	7.26	1.8	3.25	
96	8.50	1.65	7.26	1.52	3.25	
Average	**8.87**	**4.15**	**7.41**	**3.56**	**3.60**	**1.26**

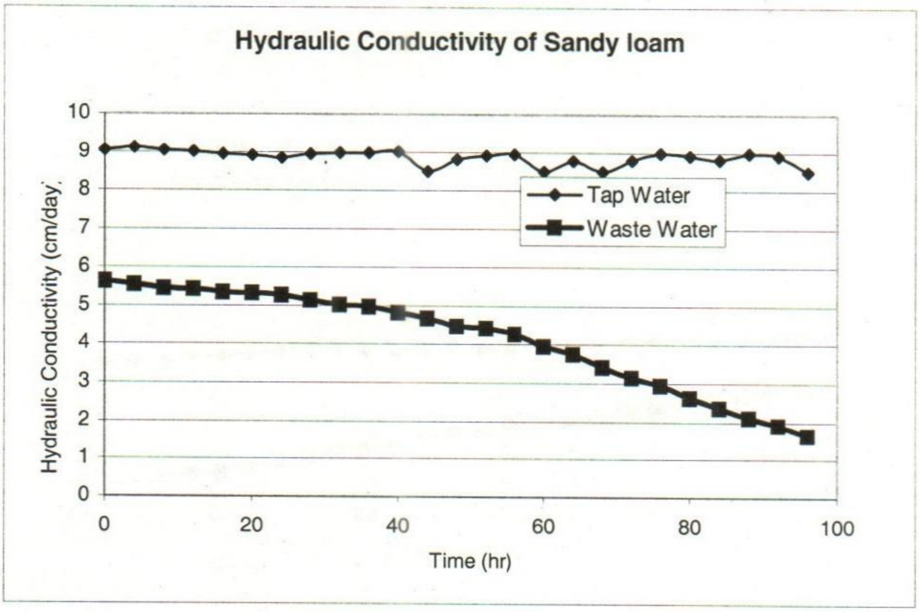

Fig. 2: Hydraulic Conductivity of Sandy loam soil

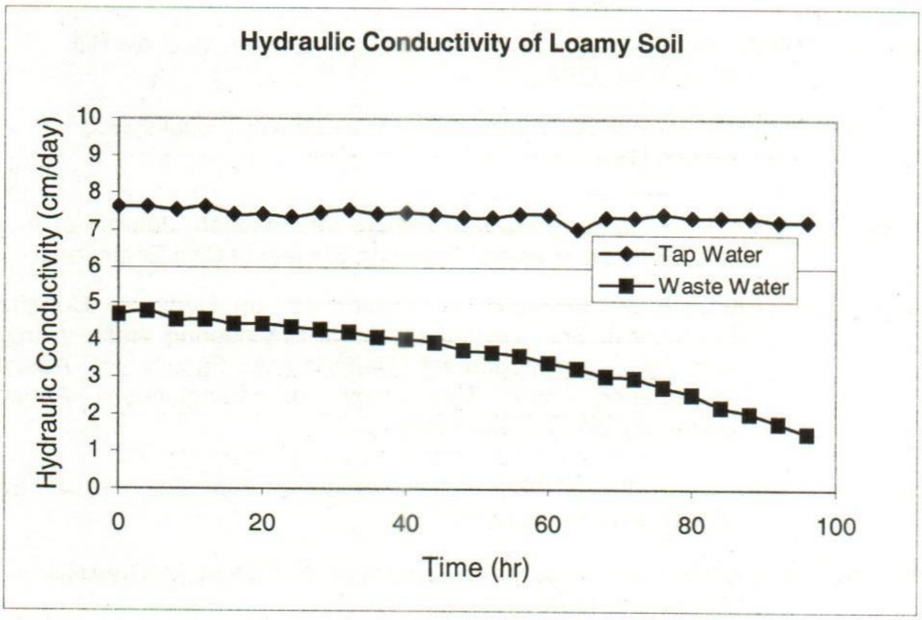

Fig. 3: Hydraulic Conductivity of loamy soil

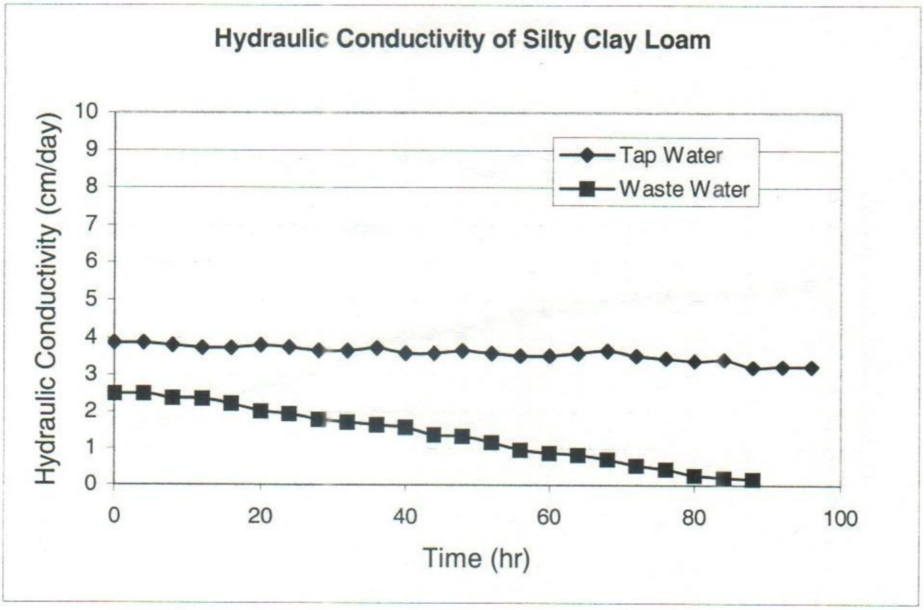

Fig. 4: Hydraulic Conductivity of Silty Clay Loam Soil

References

Allison, T.E. (1947): Water Movement Through Soil, 6th Edition, McGraw Hill Publishers, USA.

Black, C.A. (1950): Methods of Soil Analysis, Vol.1, McGrawHill Publishers, 5th Edition,USA.

Eastman, P.E. (1973): Municipal wastewater reuse for irrigation, Journal of Irrigation and Drainage division, American Society of Civil Engineers.

Hossain, M.A. (1994): Effect of Municipal Wastewater on Hydraulic Conductivity. Bachelor of Science in Agricultural Engineering thesis in Irrigation and Water Management Department, Faculty of Agricultural Engineering and Technology of Bangladesh Agricultural University(BAU), Mymensingh.

Hubbert, F.D. and King, T.L. (1957): Fundamentals of Soil Science, 4th Edition, McGraw Hill Publishers, USA.

Hutchinson, F.T. (1958): Water Supply and Sewerage, 4th Edition, McGrawHill Publishers, USA.

Reave et al. (1957): Water Resources Engineering, 3rd Edition, McGraw Hill Publishers, USA.

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Selection of Length of Revetment and Bankline Prediction for Faridpur Town Protection Using Distorted Scale Model Study

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Abstract

A distorted physical model study has been carried out to optimize the length of revetment to protect Faridpur Town and Char Bhadrasan area with horizontal scale of 1:200 and vertical scale of 1:60. The revetment has been placed to combat riverbank erosion along the right bank of Padma river. The study reveals that 5650m revetment at two separate places having side slope 1:2 is required for the protection of study area. The study also included observation of flow patterns and flow concentration around the structure. Bankline has been predicted using (100-yr return period) dominant discharge of 23,263 m3/s with and without proposed structure within the study reach.

Introduction

The right bank of the Padma river at Faridpur Sadar and Char Bhadrasan Upazila of Faridpur district has become vulnerable to severe erosion. From the available data it appears that the river has been divided into two channels following the development of a char in 1993 at 4.0km downstream of Goalanda Ghat. The south channel that flows parallel to Faridpur town has become prominent in the recent years, resulting in severe bank erosion in 10km stretch of the river. The river already eroded more than 4500 hectares of valuable land in the last few years. The survey in September 2005 shows further increase in the curvature of the river bank due to erosion. The right channel causes severe bank erosion near Faridpur town, which is at present just 770m away from the Padma river. It is envisaged that urgent sustainable measures have to be implemented after having adequate information from planform analysis and from physically based model studies. The morphological behavior of the river could be further assessed from the satellite of the river planform during the last twenty years (**Figure-1**). The historical satellite images of the Padma river from 1984 to 2005 were collected from CEGIS to assess the planform changes including bankline changes along the vulnerable area. It is seen from the images that the two channels (south and north) of the river have a periodic to and fro movement towards the land. The right bankline movement of Padma river in the problem area in different years can be seen in **Figure-2.**

Under these circumstances, River Research Institute (RRI) was given the task of conducting an undistorted physical model study to identify the erosion prone area within the study reach, to determine the optimum length & location of revetment, to see the flow pattern and flow concentration zones, and to observe the possible bank erosion and sedimentation along the right bank. The problem area of the Padma river near Faridpur town and Char Bhadrasan Upazila under Faridpur district can be seen in **Figure-3.**

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[1] Senior Scientific Officer, [2] Director (Hydraulic Research), [3] Principal Scientific Officer
[4] Scientific Officer and [5] Scientific Officer (Addl. Charge), RRI, Faridpur

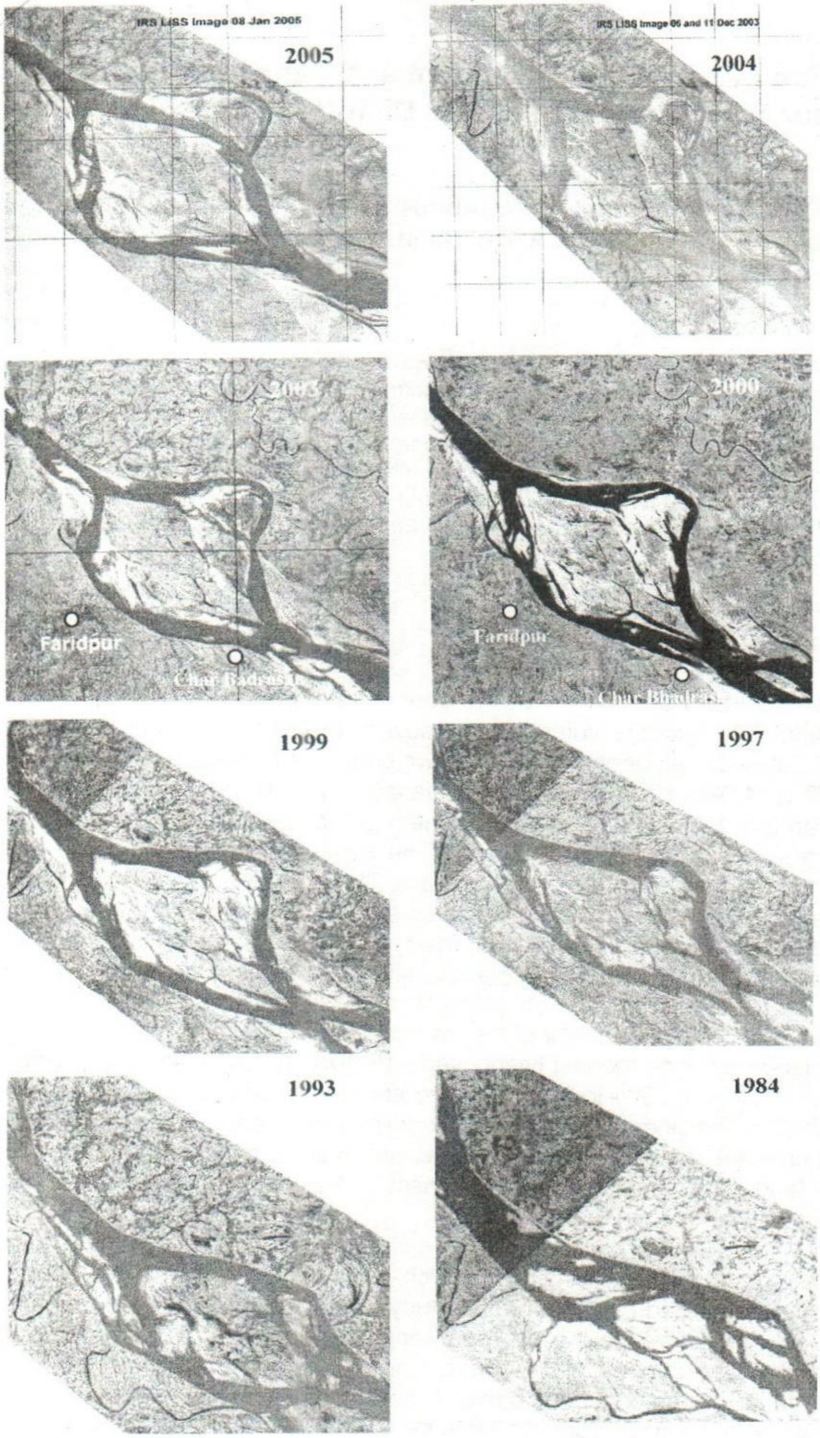


Figure-1: Historical satellite images of the Padma river from 1984 to 2005

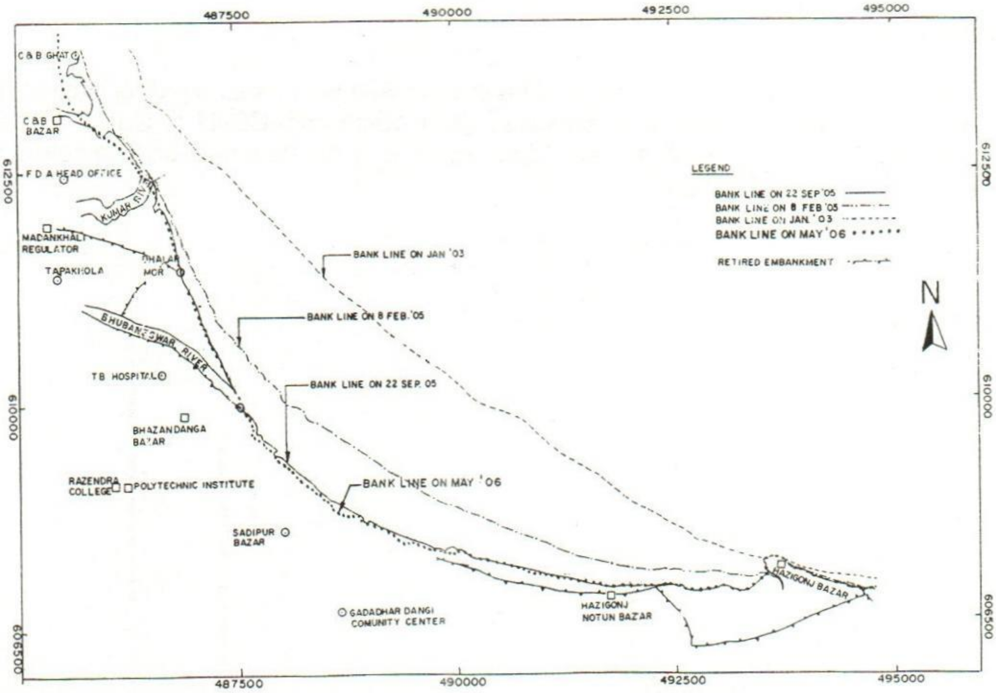


Figure-2: Right bankline movement of Padma river in the problem area in different years

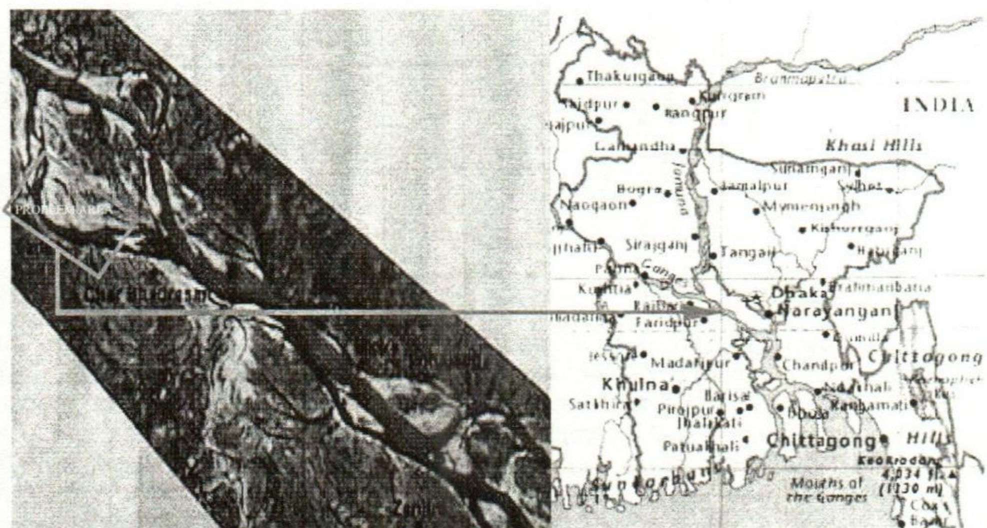


Figure-3: Problem area of Padma river near Faridpur town and Char Bhadrasan Upazila

Methodology

An open-air model bed of RRI having dimension of 80mx40m was used for setting up the model. The length of the study area was about 10km from CS-41 to CS-95 with an average river width of about 2.0km from right bankline of the Padma river. The set-up of the model is shown in Figure-4.

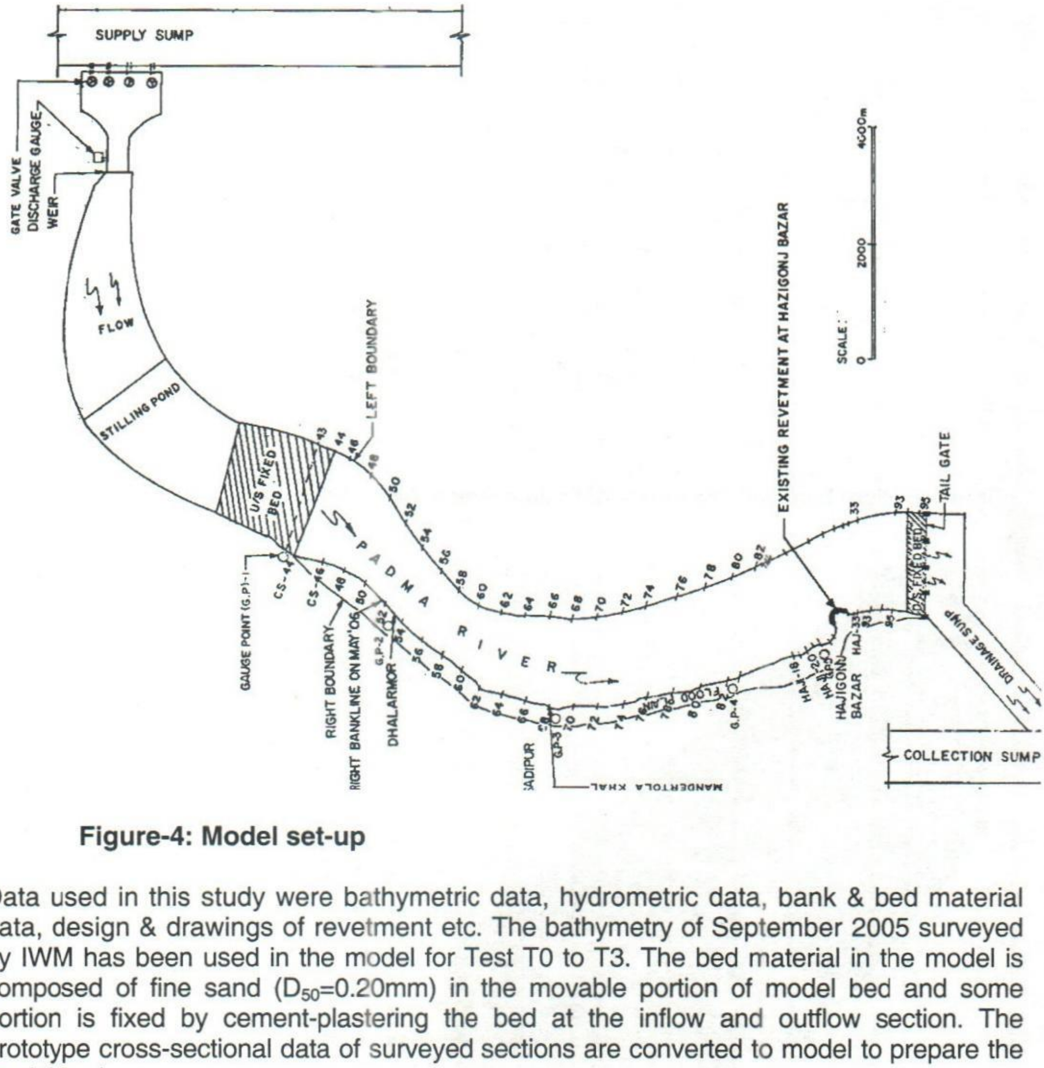


Figure-4: Model set-up

Data used in this study were bathymetric data, hydrometric data, bank & bed material data, design & drawings of revetment etc. The bathymetry of September 2005 surveyed by IWM has been used in the model for Test T0 to T3. The bed material in the model is composed of fine sand (D_{50}=0.20mm) in the movable portion of model bed and some portion is fixed by cement-plastering the bed at the inflow and outflow section. The prototype cross-sectional data of surveyed sections are converted to model to prepare the model bed.

The 100-years return period of water level 9.41 mPWD at Dhalarmor on the Padma river supplied by IWM was considered for model study. The corresponding discharge was calculated as 29,079 m^3/s for about 1.8km river width from right bankline of the Padma river. The dominant discharge considered in the model is 80% of 29,079cumec i.e. 23,263 m^3/s.

Three application test runs T1 through T3 have been conducted to find out the location of the bank erosion within the study area. Test T0 contributed to the calibration of the model. Test T1 through T3 is carried out also for the optimization of the length of bank protection works.

The calibration test run (T0) was conducted with the discharge 29,078cumec corresponding to 100-yr return period water level in order to measure the flow velocity and with the dominant discharge in order to predict the bankline under 100-yr flood condition with no project condition. The application tests T1 through T3 were also conducted with the same discharge.

Data Collection

Prototype data required for simulating the dominating processes in scale model were bathymetric data, hydrometric data, bank & bed material data, design & drawings of revetment etc. The bathymetric data of September 2005 was obtained from Institute of Water Modelling (IWM). The discharge and water level data were also collected from IWM. Four nos. of bed & bank material samples were collected from different location of the study area and have been analyzed in the Sediment Laboratory of RRI. Detail design & drawings of the revetment were collected from Executive Engineer, O&M Division, BWDB, Faridpur.

Model Design

The model was constructed considering horizontal scale of 1:200 and vertical scale of 1:60. The model has been designed fulfilling the Froude's model law. The vertical scale was selected in such a way that sufficient water depth was ensured in the model for velocity measurement and the length scale allowed the model to be accommodated into the open-air model bed of RRI. Reynolds number was kept high enough to ensure rough turbulent flow in the model. The basic design parameters for the model study along with some derived parameters and the corresponding scales are shown in **Table-1**

Table-1: Hydraulic and morphological parameters for the model study

Description	Unit	Prototype	Model	Scale
Length, L	m	10000	50	200
Width, W (CS43)	m	1800	9.0	200
Water depth, h	m	8.34	0.139	60
Water surface slope, i	-	0.00005	0.000167	0.30
Average velocity, v	m/s	1.96	0.25	7.75
Cross-sectional area, A	m^2	14802	1.233	12000
Critical velocity, v_{cr}	m/s	0.395	0.25	1.55
Chezy roughness co-efficient, C	$m^{1/2}/s$	94	57	1.66
Discharge, Q	m^3/s	29079	0.313	92952
Dominant discharge, Q_{dom}	m^3/s	23263	0.250	92952
Median particle diameter, D_{50}	m	0.0001	0.00020	0.500
Dimensionless particle diameter, D^*	-	2.240	4.480	0.500
Shields parameter, θ	-	2.528	0.070	36.000
Critical Shields parameter, θ_{cr}	-	0.107	0.054	1.998
Froude number, Fr	-	0.217	0.217	1.000
Shear velocity, v^*	m/s	0.064	0.015	4.243

Description	Unit	Prototype	Model	Scale
Critical shear velocity, v_{cr}	m/s	0.01317	0.01317	1.000
Particle Reynolds number, Re*	-	1.097	2.196	0.500
Reynolds number, Re	-	13655559	29382	464.76
ST by E-H	m^3/s	3.718	0.000004343	856255

Model Calibration

Calibration was done for matching the model with the prototype condition. The velocity distribution at the upstream section (CS-43) was simulated in the model at the upstream boundary of the model. The velocity distribution at the calibration section was measured and compared with the prototype value. A comparison between prototype and model velocity is shown in **Figure 5.** From this figure it is evident that the simulated values found in the model are very close to the prototype value.

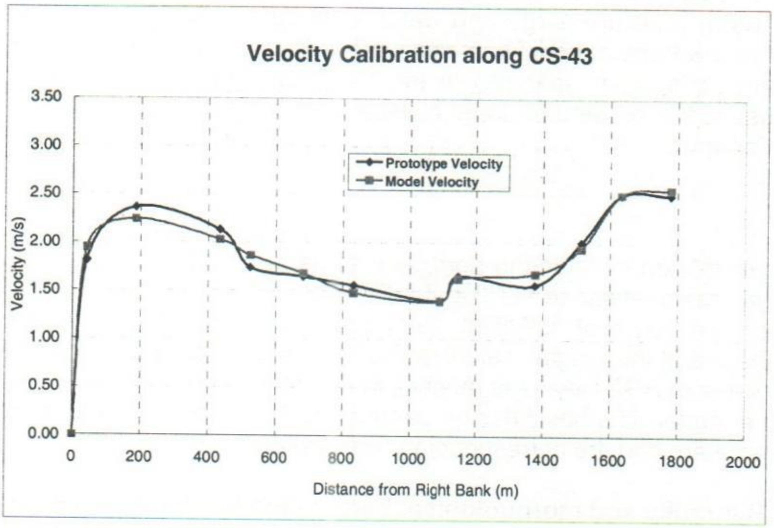


Figure 5: Comparison between prototype and model velocity at the calibration section

Test Runs

Test T0 contributed to the calibration of the model i.e. to simulate the model with the prototype condition. Test T1 through T3 were carried out for the optimization of the length of bank protection works. The key objective of the application tests was to optimize the length of bank protection works to prevent erosion of the right bank of Padma river. In Table-2, the objectives and test conditions of various tests are presented.

Table-2: Objectives and test conditions of the model study

Test No.	Objectives	Test Conditions
T0	Calibration of overall distorted model and bankline prediction under 100-year flood condition with no project condition.	September 2005 bathymetry with existing structures i.e. existing revetment (410m) around Hazigonj Bazar.
T1	To verify the recommended option (1st year) proposed by IWM for mitigating the erosion problem and bankline prediction under 100-year flood condition with this option.	Test condition T0 plus (i) 2000m revetment starting from Dhalarmor to the downstream along the right bank (ii) 500m and 100m revetment respectively placed at the upstream and downstream of existing revetment bordering the Hazigonj Bazar.
T2	To verify the recommended option (1st, 2nd & 3rd year) proposed by IWM for mitigating the erosion problem and bankline prediction under 100-year flood condition with this option.	Test condition T1 plus (i) 1100 m revetment from completed end of 1st year revetment to Mandertola Khal (ii) 950m revetment from Kumar offtake to Dhalarmor bordering the Faridpur town.
T3	To see the effectiveness of new option, which is suggested by RRI based on Test T2 for mitigating the erosion problem.	Test condition T2 plus 1000m revetment from Kumar offtake to C&B Ghat proposed by RRI to combat the existing bank erosion problem.

Analysis and Interpretation of the Test Results

Calibration Test (T0)

In Test T0, the bathymetry of September 2005 with existing structures i.e. existing revetment (410m) around the Hazigonj Bazar was reproduced in the model. The flow lines were recorded by float tracking as shown in Figure-6.

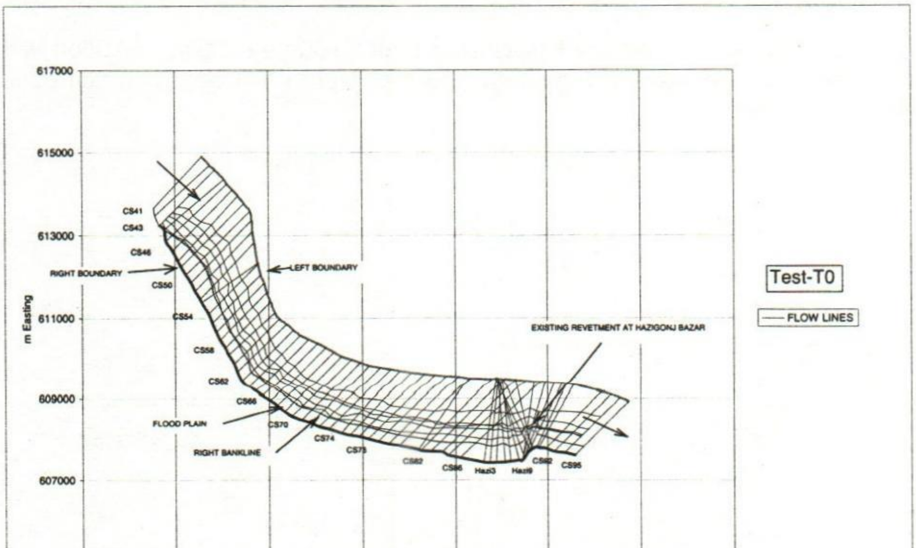


Figure-6: Flow lines in Test T0

It can be seen from the flow lines that significant flow concentration occurs along the right bank from C&B Ghat to Mandertola Khal and flow concentration also observed up to 2000m downstream of Mandertola Khal. In these reaches the right bank has been attacked by the flow and result in bank erosion.

Back flow can be seen to occur at immediate upstream and downstream of existing revetment bordering the Hazigonj Bazar. A thrust of flow has been observed near Hazigonj Bazar which itself acts as a hard point. Field condition and model study imply that it is required to strengthen and repair some existing revetment at Hazigonj Bazar.

Table-3: Bank velocity in Test T0

CS No	Bank Velocity (m/s)	CS No	Bank Velocity (m/s)	CS No	Bank Velocity (m/s)
CS-44	0.91	CS-66	1.06	Hazi-4	**0.00**
CS-46	1.85	CS-68	0.60	Hazi-6	1.10
CS-48	2.16	CS-70	1.45	Hazi-8	0.00
CS-50	2.63	CS-72	1.06	Hazi-10	0.00
CS-52	1.92	CS-74	1.38	Hazi-12	**3.25**
CS-54	1.69	CS-76	1.06	Hazi-14	2.55
CS-56	1.05	CS-78	0.91	Hazi-16	0.00
CS-58	2.00	CS-80	0.91	Hazi-18	0.00
CS-60	0.99	CS-82	0.91	CS-92	1.69
CS-62	0.60	CS-84	0.60	CS-94	2.08
CS-64	1.06	CS-86	1.38		

The bank velocities measured in the model were in the range of 0 to 3.25 m/s as shown in **Table-3.** The magnitude of bank velocities is higher than the erodible velocity which indicates that bank protection work is essential to combat bank erosion in the study area. The bank velocities and flow lines in this test have been used as reference value to be compared with the application tests.

The bankline predicted by dominant discharge under 100-year flood condition with no project condition can be seen in **Figure-8.** The maximum bank retreat which occurred near C&B Ghat is 258m.

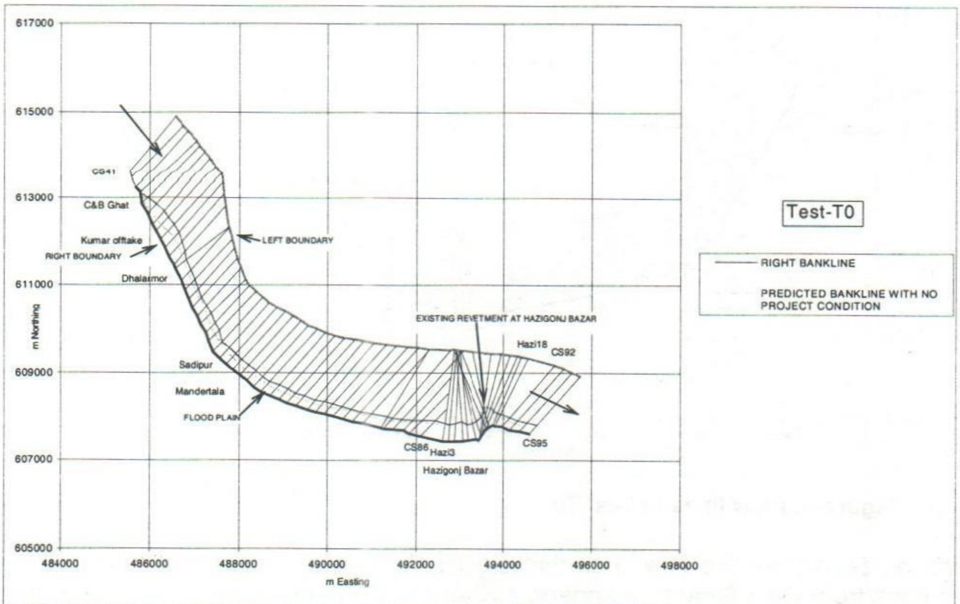


Figure-8: Predicted bankline under 100-year flood condition with no project condition in Test T0

Application Test-1 (T1)

In this test, the existing revetment in Test T0 plus 2000m revetment starting from Dhalarmor (in between CS-53 to 54) to the downstream along the right bank plus 500m and 100m revetment respectively placed at the upstream and downstream of existing revetment have been reproduced in the model.

In Test T1 the flow lines were recorded by float tracking as shown in **Figure-9**. From the figure it can be seen that the flow lines are more or less parallel to the revetment constructed from Dhalarmor to 2000m downstream.

Significant flow concentration occurs along the right bank in the upstream and downstream reaches of constructed revetment indicating that revetment should be extended both at the upstream and downstream direction. In these reaches the right bank has been severely attacked by the flow and result in bank erosion. The flow lines and bank velocities indicate that bank protection works is essential to combat bank erosion upstream and downstream of constructed revetment. Back flow occurs at upstream and downstream of existing revetment bordering the Hazigonj Bazar but no bank erosion occurs at these places due to the construction of proposed revetment.

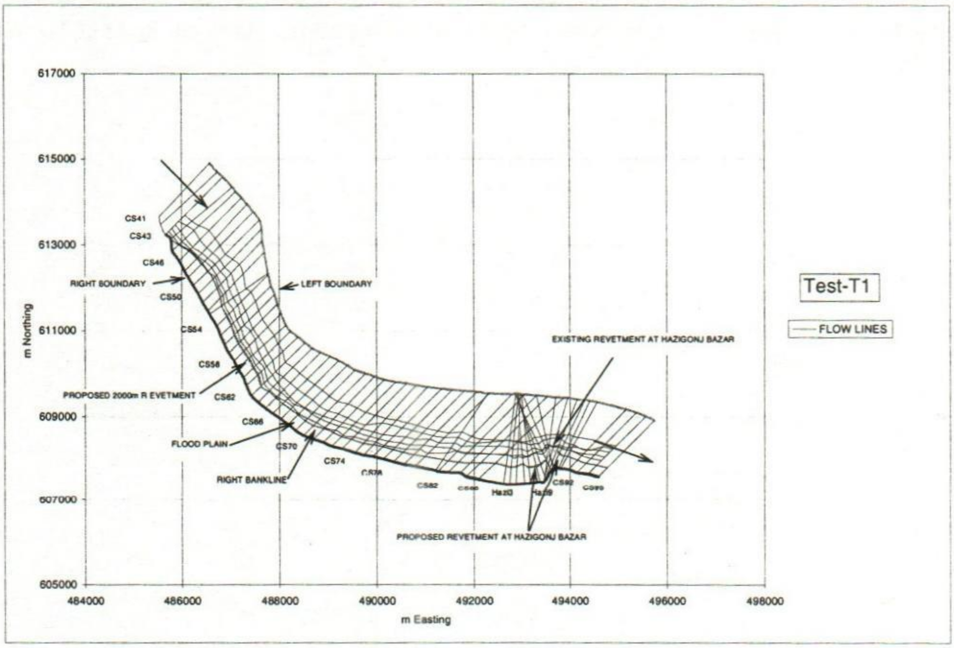


Figure-9: Flow lines in Test T1

The bank velocities measured in the model were in the range of 0.0 to 2.63m/s as shown in Table-5.

Table-5: Bank velocity in Test T1

CS No	Bank Velocity (m/s)	CS No	Bank Velocity (m/s)	CS No	Bank Velocity (m/s)
CS-44	1.05	CS-66	1.84	Hazi-4	**0.00**
CS-46	2.00	CS-68	1.52	Hazi-6	1.14
CS-48	2.00	CS-70	1.84	Hazi-8	0.00
CS-50	2.40	CS-72	1.68	Hazi-10	0.00
CS-52	1.52	CS-74	1.21	Hazi-12	1.69
CS-54	2.08	CS-76	1.68	Hazi-14	**2.63**
CS-56	0.73	CS-78	2.00	Hazi-16	0.00
CS-58	1.45	CS-80	1.68	Hazi-18	0.00
CS-60	0.89	CS-82	1.22	CS-92	1.06
CS-62	0.50	CS-84	0.91	CS-94	2.10
CS-64	1.76	CS-86	1.22		

The bankline predicted by dominant discharge with 2000m revetment can be seen in **Figure-10**. The maximum bank retreat occurred at the same place as in Test T0, which was 248m.

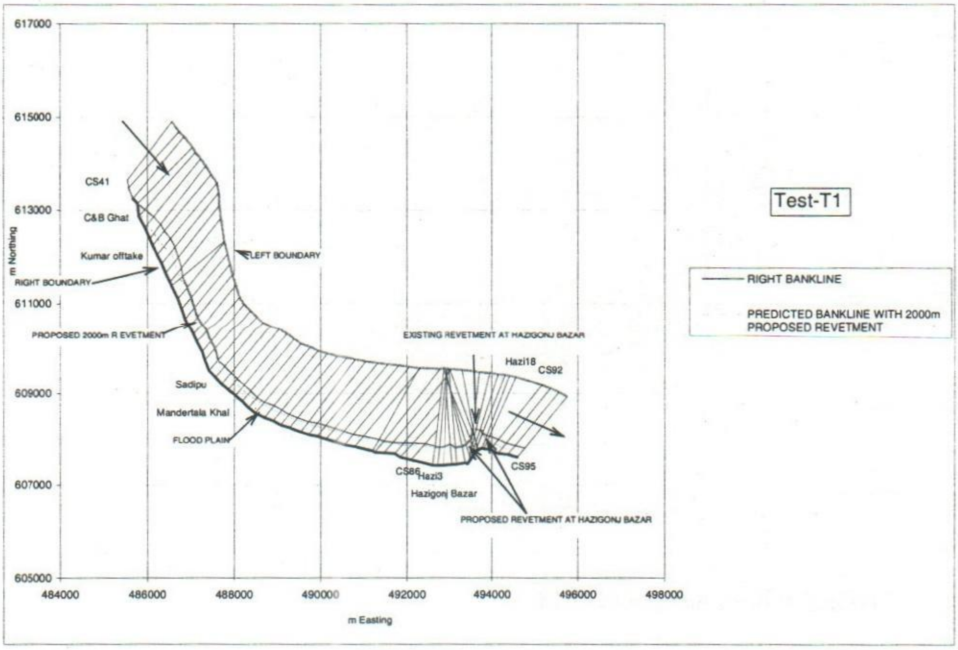


Figure-10: Predicted bankline under 100-yr flood condition with no project condition in Test T1

Application Test (T2)

In this test, the existing & proposed revetment in Test T1 plus 1100m revetment from completed end of 1st year revetment to Mandertola Khal (CS62) plus 950m revetment from Kumar offtake (CS49) to Dhalarmor have been reproduced in the model.

In Test T2 the flow lines were recorded by float tracking as shown in **Figure- 11**. It can be seen from the figure that the flow lines are more or less parallel to 4050m revetment constructed from Kumar Offtake to Mandertola Khal. Significant concentration of flow occurred along the right bank in the upstream and downstream reaches of constructed revetment and result in bank erosion. In the upstream reach the right bank has been highly attacked by the flow and result in severe bank erosion. Therefore it is necessary to extend the revetment at the upstream direction.

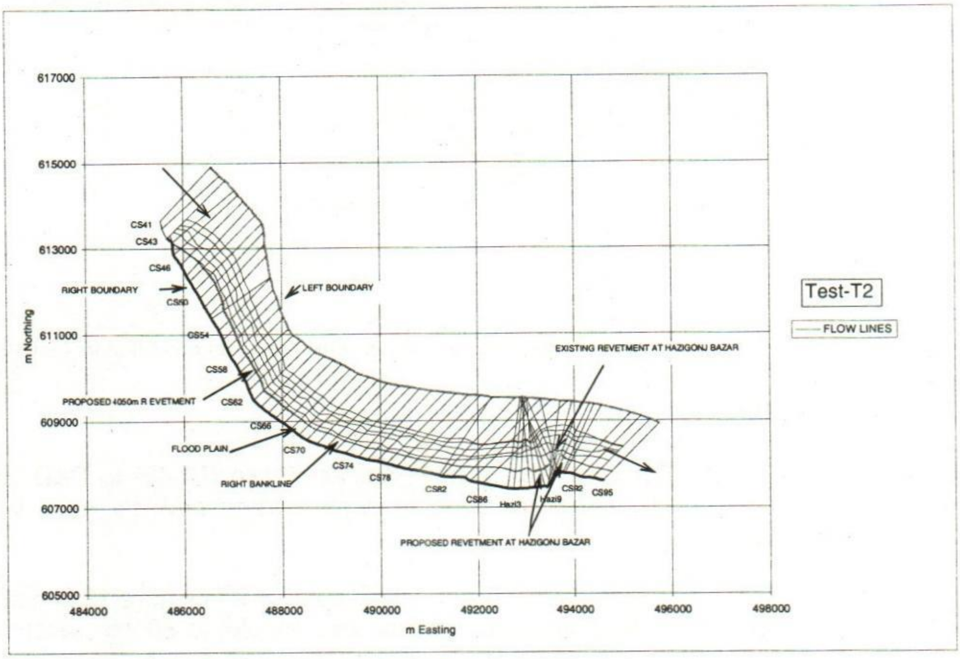


Figure-11: Flow lines in Test T2

The flow velocities measured in the model along the bank were in the range of 0 to 2.94m/s as shown in **Table-7**.

Table-7: Bank velocity in Test T2

CS No	Bank Velocity (m/s)	CS No	Bank Velocity (m/s)	CS No	Bank Velocity (m/s)
CS-44	0.75	CS-66	1.45	Hazi-4	0.00
CS-46	1.53	CS-68	0.99	Hazi-6	0.91
CS-48	1.69	CS-70	1.61	Hazi-8	0.00
CS-50	2.00	CS-72	1.06	Hazi-10	0.00
CS-52	1.53	CS-74	1.14	Hazi-12	**2.94**
CS-54	1.38	CS-76	1.69	Hazi-14	2.49
CS-56	1.22	CS-78	1.38	Hazi-16	0.00
CS-58	0.91	CS-80	1.30	Hazi-18	0.00
CS-60	1.22	CS-82	1.45	CS-92	1.38
CS-62	0.60	CS-84	1.06	CS-94	1.69
CS-64	1.22	CS-86	1.69		

The bankline predicted by dominant discharge under 100-yr flood condition with 4050m revetment can be seen in **Figure-12.** The maximum bank retreat is 234m which occurred at the same place as in **Test T0**.

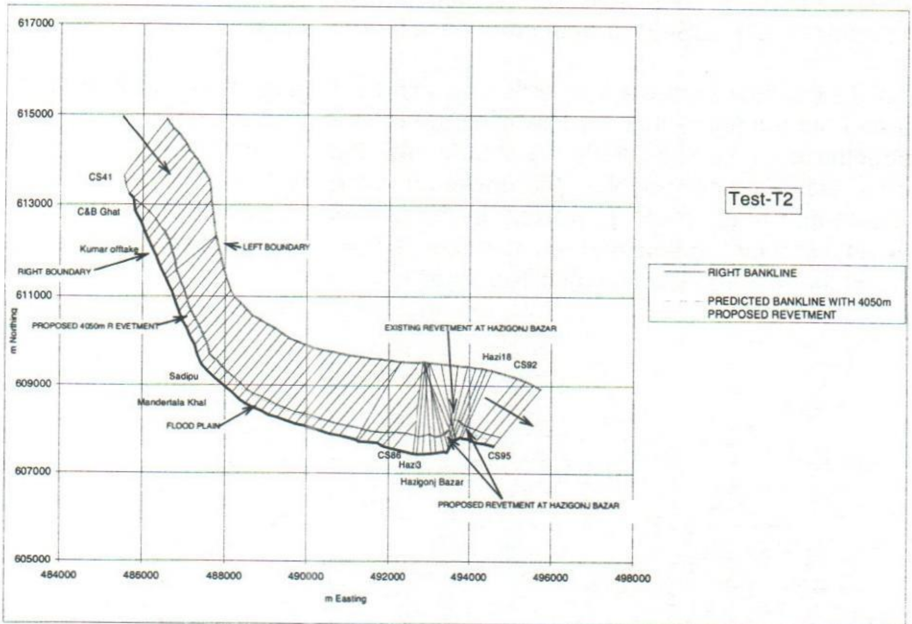


Figure-12: Predicted bankline under 100-yr flood condition with no project condition in Test T2

Application Test (T3)

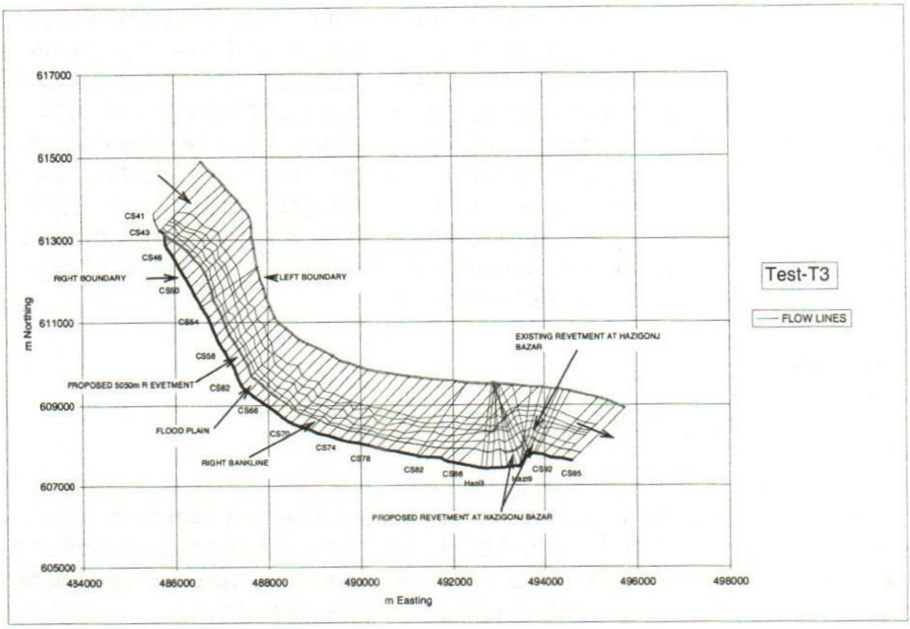
In this test, Test T2 with 1000m revetment from Kumar offtake (CS49) to C&B Ghat (CS44) proposed by RRI to combat the existing bank erosion problem have been reproduced in the model.

In Test T3 the flow lines were recorded by float tracking as shown in Figure-13. It can be seen from the figure that the flow lines are more or less parallel to 5050m revetment constructed from C&B Ghat to near Mandertola Khal. Some flow concentration occurs along the right bank in the downstream reach (up to 2000m downstream from Mandertola Khal) of constructed revetment.

Table-9: Bank velocity in Test T3

CS No	Bank Velocity (m/s)	CS No	Bank Velocity (m/s)	CS No	Bank Velocity (m/s)
CS-44	0.91	CS-66	1.40	Hazi-4	0.00
CS-46	2.16	CS-68	0.00	Hazi-6	0.75
CS-48	2.16	CS-70	0.91	Hazi-8	0.00
CS-50	1.85	CS-72	0.91	Hazi-10	0.00
CS-52	0.91	CS-74	1.00	Hazi-12	2.64
CS-54	1.38	CS-76	1.30	Hazi-14	2.51
CS-56	0.52	CS-78	1.85	Hazi-16	0.00
CS-58	0.75	CS-80	1.30	Hazi-18	0.00
CS-60	1.30	CS-82	1.06	CS-92	1.52
CS-62	0.50	CS-84	0.91	CS-94	1.68
CS-64	1.10	CS-86	1.06		

The bank velocities measured in the model were in the range of 0 to 2.64m/s as shown in **Table-9**.



The bankline predicted by dominant discharge under 100-year flood condition with 5050m revetment can be seen in **Figure-14.** In Test T3, the maximum bank retreat occurs at downstream of termination (CS-67), which is 48m. In this test, the bank erosion at different cross-sections at downstream of Mandertola Khal is relatively low. This is due to extension of revetment at upstream i.e. up to C&B Ghat.

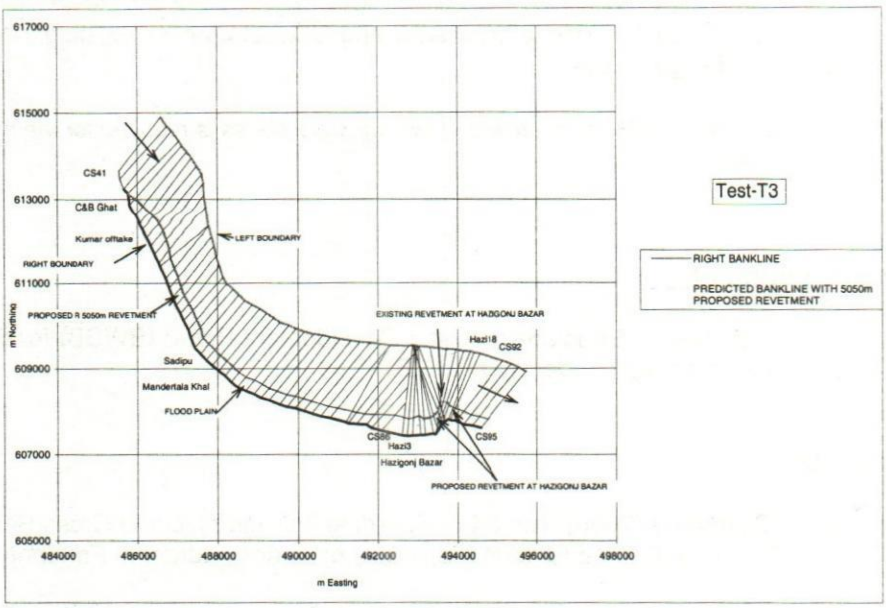


Figure-14: Predicted bankline under 100-yr flood condition with no project condition in Test T3

Discussion

One calibration test and three application tests were conducted in the model. The key interest was to find out the optimization of the structural intervention by iterative testing and bankline prediction under 100-yr flood condition. Test T0 i.e. calibration test was mainly focused on identifying the erosion prone areas along the right bank and Test T1 through T3 were the possible alternative options to prevent the bank erosion mitigation by providing bank protective device such as revetment. The key method used in the analysis for identification of possible location of flow attack was the flow line and flow velocity. The model study has been conducted on the basis of river bathymetry of September 2005. After this period bed level, bank line, thalweg and morphology of river might be changed and due care should be given to asses these changes before construction of bank protection works in the field.

Conclusions

The following conclusions are drawn from the study:

- Severe bank erosion observed in the right bank upstream reach of study area i.e. near C&B Ghat to Mandertola Khal. Significant flow concentration occurred along the right bank from C&B Ghat to Mandertola Khal and flow concentration was also observed up to 2000m downstream of Mandertola Khal and as a result bank erosion also occurs in this reach but the magnitude is relatively low.

- The maximum bank retreat which occurs near C&B Ghat is 258m without proposed structure within the study reach. But the maximum bank retreat occurs at downstream of revetment termination which is 48m with recommended structure within the study reach.

- Back flow occurs at immediate upstream and downstream of existing revetment bordering the Hazigonj Bazar.

- *The study reveals that 5650m revetment at two separate places is required for the protection of the study area.*

Acknowledgement

The authors are grateful to Bangladesh Water Development Board (BWDB) for financial support to conduct the scale model study at RRI.

References

Globe Survey Company (2006): Report on Bankline Topographic and Cross Section Survey of Padma River in the vicinity of Char Bhadrason, Faridpur.

IWM (2006): Feasibility Study for Protection of Flood Embankment of Faridpur-Barisal Project (Faridpur Unit) and Faridpur Town from the Erosion of the River

Padma in the Sadar and Char Bhadrasan Upazila under Faridpur District, Final Report, Volume-1, Main Report.

River Survey Project (1996a): FAP24, Final Report, Main Vol, No.1.

River Survey Project (1996b): FAP24, Special Report No.3, Bathymetric Surveys.

River Survey Project (1996c): FAP24, Special Report No.7, Geomorphology and Channel Dimensions.

RRI (2007): Physical Model Study of Erosion Protection of Faridpur Town and Char Bhadrasan Area Project, Draft Final Report.

Satellite Images of Padma River, CEGIS, Dhaka.

Van Rijn C. (1984): Bed Forms and Alluvial Roughness, Sediment Transport, Part-III, ASCE Journal of Hydraulic Engineering, Vol. 110, No. 12.

Tech. j. River Res. Inst. 11(1): 40 - 48, 2009 (February)

Selection of Pile group by Flume study for the Paksey Roadway bridge

Syed Md. Anwaruzzaman [1] and Md. Rafiqul Alam [2]

Abstract

A flume study was conducted at River Research Institute, Faridpur to find out the best option of pile configuration for Paksey Road-way bridge. This study was accomplished mainly to observe and quantify the relative performance of steel racking pile and straight concrete piles. It prevails from the test results that in different test alternatives straight concrete pile experienced more scour than that of the steel racking pile. Maximum scour observed from the flume tests is 22m (Corresponds to -37 m PWD) with 300 angle of attack and it occurred at straight concrete pile but it was 16.7m (Corresponds to -31.7 m PWD) for steel racking pile. So having considered the least scour value, the steel racking pile is the best option.

Introduction

For the construction of Paksey road bridge about 100m down stream from the existing Hardinge Rail bridge over the Ganges river to connect Kushtia district in the south and Pabna district in the north of the river. The pile groups was designed and their performance was tested in a flume of RRI. The designer of the bridge designed two kinds of pier group. The Pier group-A has four raking piles of steel caisson and Pier group-B has also four concrete piles with no raking. The Paksey Bridge Construction Project (PBCP) authority felt the necessity to conduct a flume test with a view to select the best pier group and accordingly the flume study was done by Hydraulic Research Directorate of RRI in September 1999.

A number of formulae exist to calculate the maximum scour depths at single bridge pier.

The most widely used is $\frac{d_s}{b} = k\left(\frac{D}{b}\right)^{0.3}$ (1)

Where d_s= Scour depth, b= Thickness of pier: D = Water depth. And K = 1.5 for square or rectangular piers, 1.35 for circular piers. The formula indicates that the maximum scour depth is practically independent of current velocity (above a certain value) and grain size (below certain value). No generally applicable formula exists for the calculation of scour in case of pier group/pile group embankment, groin, spur or break water. For this it may be necessary to perform model tests/research works if information on scour depths and extension are needed.

U.C. KOTHYARI, K. G. RANGA RAJU and R.J .GARDE of India have studied on "Live bed scour around cylindrical bridge piers". They have developed an equation for the computation of maximum scour depth around circular bridge piers in uniform sediment during live bed condition which is given below:

$$\frac{D_{se}}{d} = 0.99\left(\frac{b}{d}\right)^{0.67}\left(\frac{D}{d}\right)^{0.4}\alpha^{-0.3} \qquad (2)$$

Where, D_{se} is equilibrium scour depth

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$$\alpha = \frac{(B-b)}{B}$$, B is center to center spacing between the piers.

b is thickness of the pier, d is size of the sediment.

Inglis (1949) has developed the following scour formula:

$$\frac{d_t}{b} = 2.32\left(\frac{q^{\frac{2}{3}}}{b}\right)^{0.78} \qquad (3)$$

Where d_t =total scour depth below high water level in meter.

b = width of pier in meter.

q = discharge per unit width of pier in meter.

Blench (1962) stated the following formula:

$$\frac{d_t}{y} = 2.43\left(\frac{b}{y}\right)^{0.25} \qquad (4)$$

Where, y= normal approach flow depth in m.

Shen , Schneider and Karaki (1969) obtained the following relationship:

$$\frac{d_s}{y} = 2\left[F^2\left(\frac{b}{y}\right)^3\right]^{0.215} \qquad (5)$$

Arunachalam (1965) expressed as follows:

$$\frac{d_s}{b} = \left[\frac{y}{b} * \frac{1.95}{\left(\frac{y}{b}\right)^{\frac{1}{6}}}\right] - 1 \qquad (6)$$

Arunachalam recommends to use the "Lacey mean depth" for calculating the upstream flow depth.

Lacey's regime depth, d_e $=0.473 - \left(\frac{Q}{f_e}\right)^{\frac{1}{3}}$ where, Q is the maximum discharge in cusecs, d_e is the maximum depth of scour below highest flood level, f_e is equal to $1.76\sqrt{D_{50}}$

Larras (Acres 1970) presents a formula:

Maximum scour $d_s = 1.42b^{\frac{3}{4}}$ (7)

Where, b is the width of pier.

Kandasamy and Melville (1998) proposed a simple equation that can be used to predict the maximum local scour depth at either piers or abutments aligned perpendicular to the flow is as follows:

$$\frac{d_s}{k_s} = Ky^n L^{1-n} \tag{8}$$

Where, K=5, n=1 $\quad 0.04 \geq \frac{y}{L}$

K=1, n=0,5 $\quad 0.04 < \frac{y}{L} < 1$

K= 1, n=0 $\quad \frac{y}{L} \geq 1$

K=Coefficient

K_s=shape factor depending on $\frac{L}{y}$

L= the maximum lateral dimension of the pier or abutment.

A number of morphological studies were done in Jamuna, Ganges and Meghna River in recent time under Flood Action Plan (FAP). In Jamuna river Jamuna Multipurpose Bridge Project (1989) conducted morphological studies

Bhuiyan (1991) conducted "an experimental study on confluence scour" found that relative scour h_s/h (h= confluence scour and h_s is the average depth at u/s of tributaries) depends on the confluence angle. It is observed that if confluence angle is less than 30^0 there is less turbulence and scour is also less. Scour depth was found to be increased rapidly for angle of incidence 30^0 to 75^0.

Shahidul Alam (1996) conducted "a study of general scour of alluvial rivers" and found that the predicted depth of maximum scour of Surma River is 9.18 m, Upper Meghna River is 12.35 m and Brahmaputra River is 17.32 m, by using Lacey's equation which was found to be close to observed average depth. But in case of Teesta river, predicted depth by using Blench equation is 4.15 m, which is close to, observed average depth. It appears that while one regime equation is suitable for one river it may not be suitable for another river.

Objective of the Study:

The following are the main objectives of the flume study;

- To find out the bed scour just immediate upstream and downstream of the pier groups.
- To find out the maximum individual pile scour for both pier group for different angular position of piers with the direction of flow.
- To eventually select the best pier group in considerations of scour.

Methodology:

The study was conducted in a sand bed flume inside a model shed at RRI. The total length and width of the flume were 34m and 2.2m respectively. There was 18m mobile bed in between two fixed bed portions at up stream and down stream. Six point gauges were installed in the flume for recording water level during running condition. The two pier groups namely steel racking piles (A) and straight concrete piles (B) were installed at distance of 12m from the beginning of the mobile bed. Steel racking pier groups are consists of four piles having diameters 2.25m and straight concrete piles are consists of four piles having diameter 3m.The structures of the pile groups are shown in **Fig.-1**. In this study 1:90 geometric scale was selected to achieve the average velocity 0.53m/s and 0.32m/s, flume discharge 384lps and 77lps corresponds to river velocity 5m/s and 3m/s with 15m PWD and -5m PWD at the selected site of the Ganges river. Sediment feeding rate is estimated using Engelund-Hansen formula as given below

$$q_s^* = 0.05\sqrt{\left[(s_s - 1) * g * D_{50}{}^3\right] * Fr_g{}^2 * \tau_*}^{\,1.5}$$

Where $q^*_s = q_s/q$ = dimensionless sediment transport capacity per unit width of channel; q_s = sediment discharge per unit width; q=water discharge per unit width; $s_s = \rho_s/\rho$= sediment specific gravity; ρ_s =sediment mass density; ρ= water mass density; g= gravitational acceleration; D_{50} = median grain diameter' Fr_g = densimetric Froude number; τ_* = Shield's parameter. In case of test series-1 this feeding rate calculated as 11.6 ft.^{3}/h and in case of test series-2, 0.56 ft.^{3}/h.

Data Collection and Analysis:

A total of ten tests have been conducted for this flume study. Out of ten tests, the Test-1 was the calibration test. The rest nine tests (T-2 to T-10) were the application tests. Among application tests from Test-2 to Test-6 were executed under Test Series-1 and from Test-7 to Test-10 under Test Series-2. The salient features of calibration and application tests are given in the following table;

Table-1: Test Scenarios

Test	Test No.	Angle of Attack	Discharge (lps)	Desired velocity in flume (m/s)	Desired velocity in River site (m/s)	Initial bed level (mPWD)	Water Level (mPWD)
Calibration	T1	No Structure	384	0.53	5	-15	15
Series-1	T2	0^0	384	0.53	5	-15	15
	T3	5^0	384	0.53	5	-15	15
	T4	10^0	384	0.53	5	-15	15
	T5	20^0	384	0.53	5	-15	15
	T6	30^0	384	0.53	5	-15	15
Series-2	T7	0^0	77	0.32	3	-15	-5
	T8	5^0	77	0.32	3	-15	-5
	T9	10^0	77	0.32	3	-15	-5
	T10	20^0	77	0.32	3	-15	-5

Different Data have been collected during test runs (Test-T-2, to T-10). After data collection the raw data have been processed for different purposes. The inportant processed data according to the salient features stated in the above table are given below;-

Table-2: Maximum and Individual Scour Data

Test No	Innitial bed level	Max. scour in Trans-1	Max. scour in Trans-2	Individual pile scour for pile group-A				Individual pile scour for pile group-B			
				A-1	A-2	A-3	A-4	B-1	B-2	B-3	B-4
2	-15	-27.93	-0.18	-24.77	-27.02	-26.57	-25.40	-27.03	-28.83	-28.64	-28.11
3	-15	-27.93	-29.72	-24.77	-26.12	-25.58	-25.22	-28.11	-29.01	-28.02	-27.75
4	-15	-28.38	-30.63	-26.13	-27.30	-27.93	-26.13	-28.83	-31.08	-29.28	-28.83
5	-15	-31.53	-33.33	-28.38	-28.82	-30.71	-29.27	-32.61	-33.69	-34.41	-32.42
6	-15	-33.33	-35.58	-30.00	-30.62	-31.70	-29.45	-34.68	-36.92	-36.47	-36.03
7	-15	-23.4	-23.4	-20.73	-20.90	-20.54	-21.08	-24.15	-24.51	-24.33	-24.78
8	-15	-24.78	-25.23	-21.63	-21.17	-23.24	-22.16	-25.77	-25.76	-26.04	-25.49
9	-15	-23.42	-26.57	-22.08	-22.79	-24.32	-22.70	-26.13	-27.21	-26.13	-26.13
10	-15	-23.88	-23.88	-21.09	-22.26	-22.89	-22.17	-23.88	-25.23	-25.05	-23.69

Scour development in transect -1and transect -2 for pile group-1 and pile group-2 in test no.-6 is shown in table-3.

Table-3: Equilibrium scour (mPWD) at just immediate u/s(Trans-1) and d/s (Trans-2) of both pier Groups(T-6).

Dist. From L/B (m)	WL (m PWD)	Initial B/L (m PWD)	Scour at Trans-1 (m PWD)	Scour at Trans-2 (m PWD)
0.0	15.00	-15.00	-25.225	-25.225
0.2	15.00	-15.00	-25.225	-25.225
0.4	15.00	-15.00	-25.675	-25.945
0.5	15.00	-15.00	-26.125	-27.025
0.6	15.00	-15.00	-26.845	-27.745
0.7	15.00	-15.00	-28.825	-29.275
0.8	15.00	-15.00	-27.025	-30.625
0.9	15.00	-15.00	-25.675	-27.925
1.0	15.00	-15.00	-26.575	-28.105
1.2	15.00	-15.00	-28.375	-27.745
1.3	15.00	-15.00	-28.825	-28.825
1.4	15.00	-15.00	-31.705	-34.675
1.5	15.00	-15.00	-33.325	-35.125
1.6	15.00	-15.00	-31.525	-35.575
1.7	15.00	-15.00	-28.825	-33.325
1.8	15.00	-15.00	-28.645	-29.005
2.0	15.00	-15.00	-27.205	28.375
2.2	15.00	-15.00	-27.025	-28.825

Results and Discussion:

For the test series -1, the individual pile scour for all the tests is shown in **Fig.-2** for pier-A and in **Fig-3** for pier-B. For the test series -2, the individual pile scour for all the tests is shown in **Fig.-4** for pier-A and in **Fig.-5** for pier-B. The results of maximum scour value are shown in table-4. From these tests, it is observed that the higher the angle of attack with piles the greater the scour. It is also observed that the scour at pier-B has the higher value than the pier-A in all the tests series. Finally, it is observed in test-6 with 30^0 angle of attack that pier-B experienced the scour value as high as -37.0m PWD for pile-B2. Pile scour after test-T6 in dry bed condition is shown in **Fig-6** and **Fig-7**.

Table-4: Maximum individual pile scour

Test No	Pier Orientation with flow (Degree)	Water Level (mPWD)	Initial bed level (mPWD)	Individual Pile Scour in mPWD (dry bed)							
				A1	A2	A3	A4	B1	B2	B3	B4
T2	0	15	-15	-24.78	-27.03	-26.58	-25.41	-27.03	-28.83	-28.65	-28.11
T3	5	15	-15	-24.78	-26.13	-25.59	-25.23	-28.11	-29.01	-28.02	-27.75
T4	10	15	-15	-26.13	-27.30	-27.93	-26.13	-28.83	-31.08	-29.28	-28.83
T5	20	15	-15	-28.38	-28.83	-30.72	-29.28	-32.61	-33.69	-34.41	-32.43
T6	30	15	-15	-30.00	-30.63	-31.71	-29.46	-34.68	-36.93	-36.48	-36.03
T7	0	-5	-15	-20.73	-20.91	-20.55	-21.09	-24.15	-24.51	-24.33	-24.78
T8	5	-5	-15	-21.63	-21.18	-23.25	-22.17	-25.77	-25.77	-26.04	-25.50
T9	10	-5	-15	-22.08	-22.78	-24.33	-22.71	-26.13	-27.21	-26.13	-26.13
T10	20	-5	-15	-21.09	-22.26	-22.89	-22.17	-23.88	-25.23	-25.05	-23.70

Conclusions

This flume study was mainly intended to observe and quantify the relative performance of both the pier group in terms of scour at just immediate upstream and downstream and also around piles. Performance of option-A(steel racking pile) and option-B(straight concrete pile) for different angular position of the piers with the direction of flow was also observed. It prevails from the test results that in different test alternatives Pier-B experienced more scour than that of the Pier-A. Maximum scour found from the flume tests is 22m (Corresponds to -37 m PWD) with 30^0 angle of attack and it occurred at Pier-B. So having considered the least scour value, the Pier-A is the best option because its construction cost will be economical.

Referrence

Bhuiyan, M.R. (1991): An Experimental Study on Confluence Scour, BUET. Dhaka.

Blench, T. (1962): Discussion on scour on scour at bridge crossing by Laursen, E.M Trans, ASCE, Vol. 127, part-1.

Garde, R.J and Rangaraju K.G (1985): Mechanics of Sediment Transportation and Alluvial Stream Problems, second edition, pp. 409 to 427 India.

Inglis, C.C (1949): The Behavior and control of rivers and canals, Research publication no. 13, part-2, Poona India.

Kandasamy, J.K and Melville, B.W. (1998): Maximum Local Scour Depth at Bridge Piers and Abutments, Journal of Hydraulic Research(IAHR/AIRH Journal), Vol.-36, No.2.

Lacey, G. (1930): Stable channels in Alluvium, Proceedings of of the Institution of Civil Engineers, Vol.229.

Shahidul Alam, A.F.M (1996): A Study of General Scour of Alluvial Rivers, BUET. Dhaka.

Shen, H.W. schnedier, V.R and Karaki, S. (1969): Local Scour Around Bridge piers, Proceedings of ASCE, Vol. 95, No- HY-6, pp1919-40.

Training Materials (1989): Lecture Notes on River Hydraulics, DHI, Denmark.

U.C. Kothyari, K.G. Rangaraju and R.J. Garde (1992): Live-bed scour around cylindrical bridge piers, Journal of hydraulic research, Vol. 30 No. 5. India.

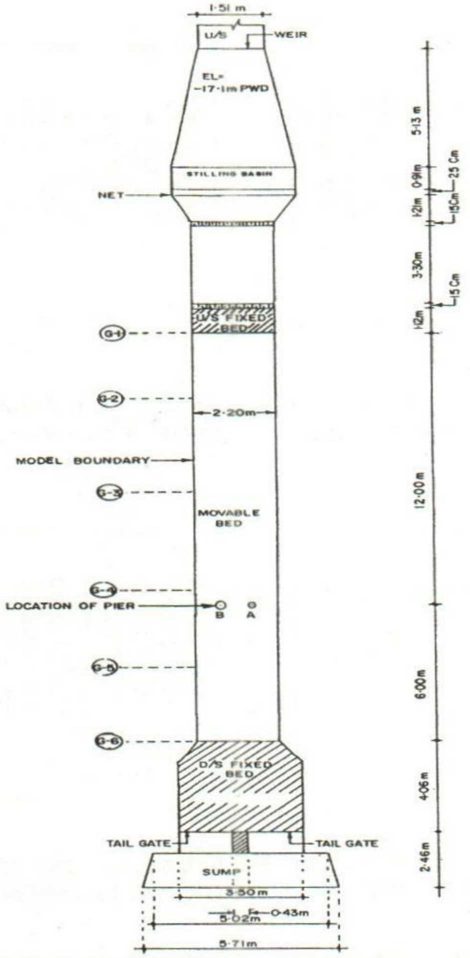

FIG. I : LAYOUT OF FLUME STUDY OF PAKSEY BRIDGE PIER SCOUR

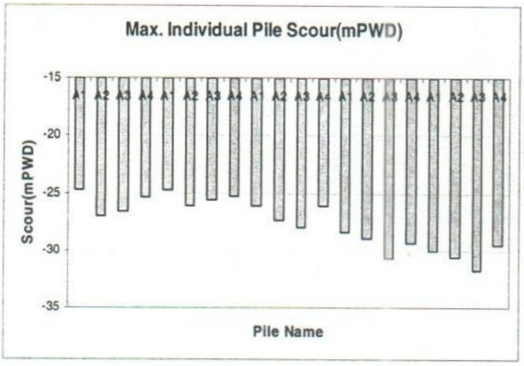

Fig. 2: Maximum Individual Pile Scour for Pier Group-A for Test Seties-1 (T2-T6).

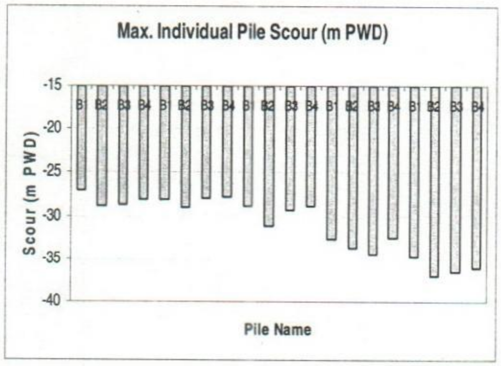

Fig. 3: Maximum Individual Pile Scour for Pier Group-B for Test Seties-1 (T2-T6).

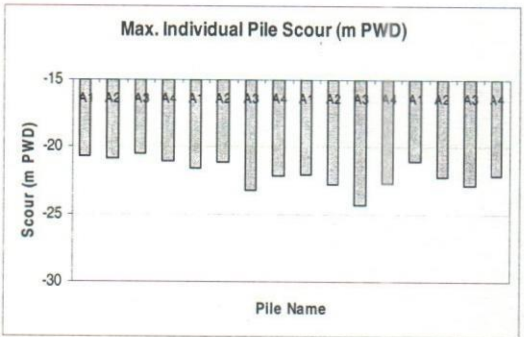

Fig. 4: Maximum Individual Pile Scour for Pier Group-A for Test Seties-2 (T7-T10).

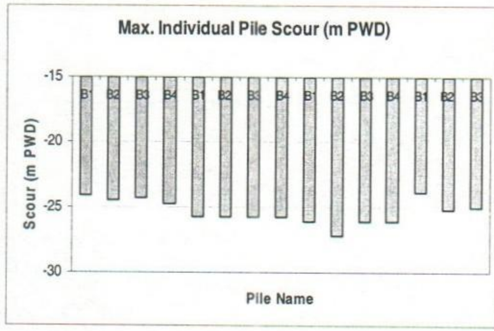

Fig. 5: Maximum Individual Pile Scour for Pier Group-B for Test Seties-2 (T7-T10).

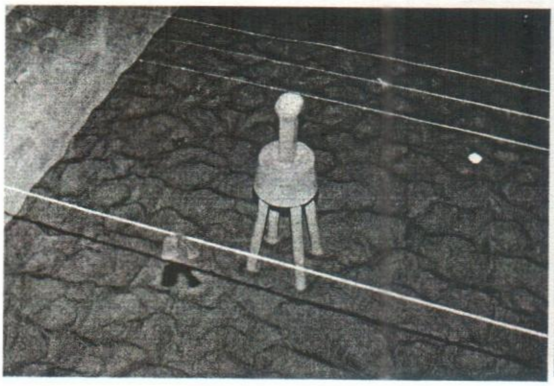

Fig.-6: Max. scour around Pier-A

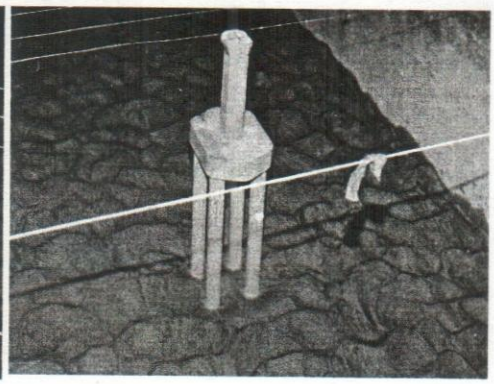

Fig.-7: Max. scour around Pier-B

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Determination of Design Parameters of the 3rd Karnaphuli Bridge Using Physical Modelling

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Abstract

An undistorted physical model study was carried out to determine the design parameters of the 3rd Karnaphuli Bridge placed upstream of the existing Shah Amanat Bridge over the Karnaphuli river. In this study, the bridge components, such as guide bunds and piers were reproduced in the model bed of the River Research Institute (RRI) using a scale of 1:100 with the objective to determine the design parameters: magnitude of scour and velocity at and around the bridge components mentioned above. The test results indicated that the guide bund is expected to function effectively for the sustainability of the bridge. The maximum value of scour was found as 9.2 m and 6.2 m around bridge piers and guide bunds respectively. The maximum velocity around bridge piers was found to be 2.6 m/s and 1.35 m/s for ebb and flood tides respectively and that in the vicinity of the guide bund was found to be 3.2 m/s and 1.66 m/s for ebb and flood tides respectively.

Introduction

After construction of the Shah Amanat Bridge, the area on the southern bank of the Karnaphuli river has developed rapidly. Consequently, the traffic from Chittagong to this newly developed area has increased quickly. Under these circumstances, the Roads and Highways Department (RHD) planned to construct another bridge, named as 3rd Karnaphuli Bridge at upstream of the Shah Amanat Bridge. RHD engaged RRI to conduct a physical model study with the objective to assess the morphological changes, i.e., erosion and deposition pattern likely to occur upstream and downstream of the 3rd Karnaphuli Bridge and also to determine the hydraulic design parameters of the bridge components. This paper presents the findings of the model study in terms of the effective functioning of the guide bunds which is essential for the sustainability of the bridge and the design parameters such as velocity and scour depth around the bridge piers and guide bunds. An undistorted physical model of the bridge along with the river reach that is expected to be affected by the bridge for checking the hydraulic design parameters of the bridge.

Objectives

- To optimize the design parameters of the Bridge components such as Bridge pier, Guide Bunds, bank protection works etc.
- To investigate the extent of maximum scour, its shape and locations.
- To investigate the extent of scour around the Bridge pier and river training works.
- To investigate the flow field around the structure.

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Methodology

The model is set-up using the existing facilities of RRI. An open-air model bed of RRI having dimension of 80mx40m has been used for setting up the model. The area reproduced in the model is about 4.0km river reach covering about 2km upstream and about 2km downstream of the existing Shah Amanat Bridge and full width of the Karnaphuli river.

The bathymetry of July 2005 surveyed by RRI has been used in the model. The bed material in the model is composed of fine sand (D_{50}=0.20mm) in the movable portion of model bed and some portion is fixed by cement-plastering the bed at the inflow and outflow section of the model. The prototype cross-sectional data of surveyed sections are converted to model to prepare the model bed.

A prototype discharge of 10,270 m3/s and the corresponding average velocity 2.05 m/s were considered in the model study (Haskoning, 2001) at the bridge location.

The tides at Chittagong are predominantly semi-diurnal with a large variation in range between the seasons, the maximum tidal range occurring during the southwest monsoon. The strong diurnal influence on the tides results in the day-time tides being smaller than the night time tides during the wet season and vice-versa during the dry season. The following tide characteristics for Chittagong Port were obtained from The Admiralty Tide Tables (Haskoning, 2001).

Table-1: Tide characteristics at Chittagong Port Area

Mean Level	2.1 m
Lowest Astronomical Tide	-0.1 m
Mean low water Spring	+0.5 m
Mean low water Neaps	+1.2 m
Mean Sea Level	+2.2 m
Mean High Water Neaps	+2.9 m
Mean High Water Springs	+4.0 m
Highest Astronomical Tides	+5.0 m

From the hydrographic survey by Globe Survey Co, 2005, the water surface was found to be 12 cm/km for the study reach. Using this slope the water levels at Shah Amanat Bridge location was estimated with respect to that at the port area gauge.

Two peak discharges during the ebb and flood tides, which were mainly responsible for causing maximum scour around the bridge pier, were considered for the model. The effect of these flows were simulated in the model in two stages of tidal phenomenon i.e. the lowest and the highest astronomical tides by controlling the upstream and downstream measurement devices and tail gates with a view to get an idea about the changes in river morphology and velocity due to the construction of the proposed bridge.

Data Collection

Prototype data is required to simulate the existing hydro-morphological processes of the river in the physical model. The bathymetric data is obtained by surveying the cross-sections of the Karnaphuli river@100m interval throughout the surveyed reach (5km upstream and 8km downstream of the Shah Amanat Bridge). The topographic data is obtained by surveying the ground level with important installations within the study area required for model study. The water level, discharge and depth averaged velocities are measured at the upstream and downstream boundaries of the surveyed area. These data were analyzed and used for design of the model. Several nos. of bed and bank material samples are collected from different location of the study area and have been analyzed in the Sediment Laboratory of RRI. These data have been used in the model study. Detail design and drawings of the existing Shah Amanat Bridge and proposed 3rd Karnaphuli Bridge with Guide Bund are collected from Roads and Highways Department (RHD).

Model Design

An undistorted model was constructed considering both horizontal and vertical scale of 1:100. The model was designed fulfilling the Froude's model law. The scour velocity in the model was such that sufficient sediment transport was ensured in the model and the model was expected to reach the dynamic equilibrium condition after running about 16-20 hours. Reynolds number was ensured to be high enough to produce rough turbulent flow in the model.

The basic design parameters for the model study along with some derived parameters and the corresponding scales are shown in **Table-2**.

Table-2: Hydro-morphological parameter for the model study

Description	Unit	Prototype	Model	Scale
Length, L	m	4000	40	100
Width, W (CS92)	m	994	9.94	100
Water depth, h	m	5.25	0.052	100
Water surface slope, i	-	0.00012	0.00012	1
Average ebb velocity, v	m/s	2.00	0.20000	10
Cross-sectional area, A	m^2	5124	0.512	10000
Critical velocity, v_{cr}	m/s	0.377	0.221	1.71
Ebb discharge, Q	m^3/s	8870	0.089	100000
Median particle diameter, D_{50}	m	0.000065	0.00020	0.325
Tidal discharge	m^3/s	8236	0.082	100000
Width, W (CS7), (Sikolbaha Khal)	m	143.89	1.44	100
Water depth, h (Sikolbaha Khal)	m	4.90	0.049	100
Cross-sectional area, A (Sikolbaha Khal)	m^2	712	0.071	10000
Discharge, Q (Sikolbaha Khal)	m^3/s	1424	0.014	100000
Dimensionless particle diameter, D_*	-	1.456	4.480	0.325
Shields parameter, Theta	-	5.873	0.019	307.7
Critical Shields parameter, θ_{cr}	-	0.165	0.054	3.1
Froude number, Fr	-	0.279	0.279	1
Shear velocity, v_*	m/s	0.079	0.008	10
Critical shear velocity, v_{*cr}	m/s	0.01317	0.01317	1
Particle Reynolds number, Re_*	-	0.713	2.196	0.325
Reynolds number, Re	-	8748154	8748	1000

Model Calibration

In principle calibration is the actual reproduction of the prototype hydrodynamic and morphological condition in the model. All the features of the study area was reproduced in the model after reducing the dimensions linearly with certain scale. Here horizontal and vertical dimensions were reduced in the same scale. The hydrodynamic condition was reproduced by adjusting the point velocities of the model with the prototype point velocities along a specified section at the upstream boundary of the model, called the calibration section. After repeated trails the calibration was performed matching velicities in the model along calibration section with the prototype velocities. The water level at the downstream end of the model was also adjusted with the prototype water level.

The velocities at the calibration sections (CS-92 for Karnaphuli river and CS-7 for Sikolbaha Khal) were measured during ebb flow and compared with the prototype values. is shown in **Figure-1.** From this figure it can be seen that the model velocities are in good agreement with the prototype velocities.

Water level of 0.34 m (PWD) and 5.2 m (PWD) were maintained at the downstream end of the model (CS-61) during ebb and during flood flow respectively.

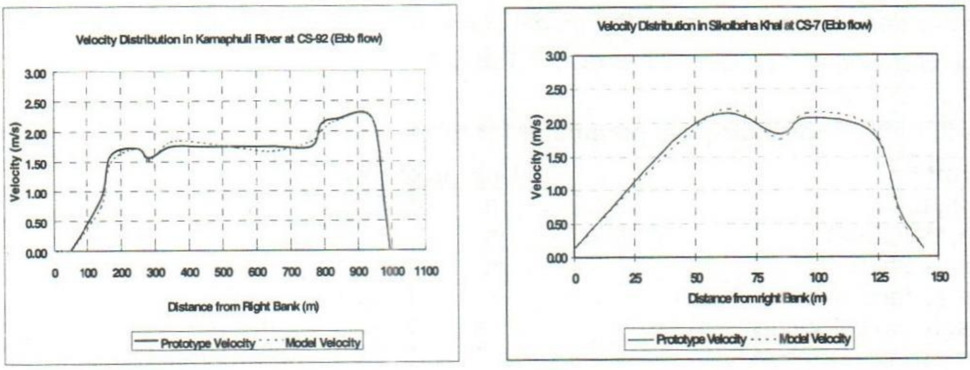

Figure-1: Comparison between prototype and model velocity at the calibration sections (CS-92 and CS-7) during ebb flow

Test Runs

After calibration, three application tests were conducted. Each test was conducted with ebb as well as flood condition. Test T0 stands for the calibration of the model with existing condition. The application tests T1 through T3 were carried out with a view to observe the performance of the guide bund of the under construction bridge representing different test scenarios. Each application test was run with Froude's discharge to determine flow velocity, flow field by float tracking, and scour discharge to determine the scour depth. In Table-3, the objectives and test conditions of various tests are presented.

Table-3: Objectives and test conditions of the model study

Test	Objectives	Test Conditions
T0	Calibration of the model	July 2005 bathymetry with existing Shah Amanat Bridge and other existing structures.
T1	To observe the effectiveness of the Guide Bund of the 3rd Karnaphuli Bridge and to finalize the design parameters.	Same as T0 plus 3rd Karnaphuli Bridge plus its Guide Bund.
T2	To observe the effectiveness of the Guide Bund of the 3rd Karnaphuli Bridge under channel dredging condition and sheet pile constructed on the dredged bathymetry proposed by Chittagong Port authority (CPA) and to finalize the design parameters.	Same as T0 excluding Shah Amanat Bridge plus 3rd Karnaphuli Bridge plus its Guide Bund plus dredged channel plus 2.75km sheet pile constructed upstream and downstream of Bridge along the right bank of the river.
T3	To observe the effectiveness of the Guide Bund of the 3rd Karnaphuli Bridge and to finalize the design parameters.	Same as T0 excluding Shah Amanat Bridge plus 3rd Karnaphuli Bridge plus its Guide Bund.

Analysis and Interpretation of the Test Results

Calibration Test (T0)

In this test, velocity during ebb and flood flow, and the scour depth around the existing Shah Amanat Bridge piers were simulated in the model as shown in **Table-5**. The table shows that the maximum velocity occurs around pier #2 of the existing Shah Amanat Bridge and its value is 3.34 m/s and 1.52 m/s for ebb flow and flood flow, respectively. The maximum scour is found as 9.0 m around pier #2 of the same bridge.

Table-4: Velocity and the corresponding scour depth around the existing Bridge piers in Test T0

Pier No from LB	Velocity around the existing Bridge piers in m/s		Scour depth (m)
	During ebb flow	During flood flow	
P1*	0.00	0.00	-
P2	**3.34**	**1.52**	**-9.00**
P3	1.22	0.94	-2.20
P4	1.15	0.84	-2.50
P5	0.70	0.85	-1.30
P6	0.00	0.29	-0.70

* On the flood plain

The flow field recorded by float tracking has been plotted and shown in **Figure 2(a)** and **2(b)** for ebb flow and flood flow respectively. From the flow field, it is observed that the flow lines are concentrated near the left bank during ebb flow. The flow lines are less concentrated near the left bank and some flow also enters the Sikolbaha Khal during flood flow.

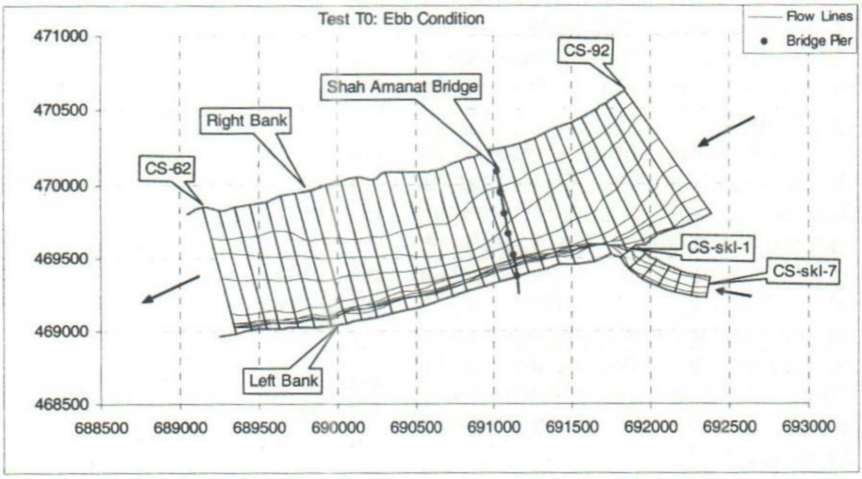

Figure 2(a): Flow lines in Test T0 (Ebb)

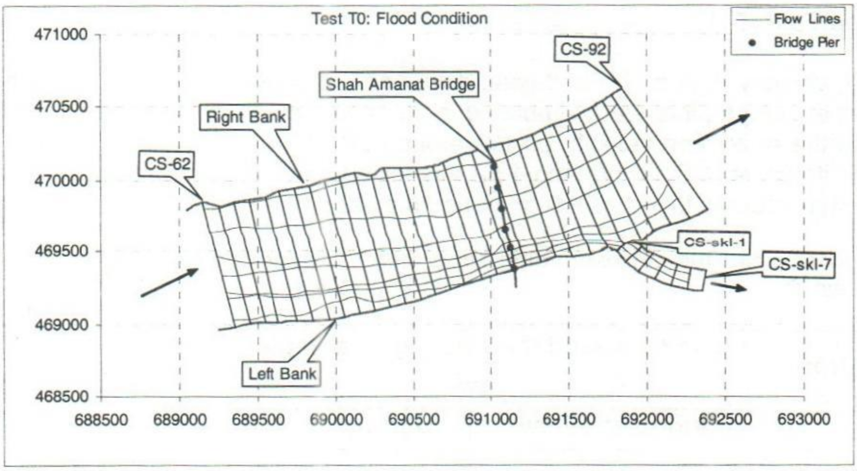

Figure 2(b): Flow lines in Test T0 (Flood)

Application Test (T1)

In Test T1, velocity during ebb flow and flood flow, and scour depth around the existing Shah Amanat Bridge piers have been measured in the model as shown in **Table-5**.

Table-5: Velocity and the corresponding scour depth around the existing Bridge piers in Test T1

Pier No from LB	Velocity around the existing Bridge piers in m/s		Scour depth (m)
	During ebb flow	During flood flow	
P1	1.37	1.02	-0.50
P2	2.17	1.60	**-7.20**
P3	1.27	0.97	-1.40
P4	1.07	0.87	-3.00
P5	0.87	0.65	-0.80
P6	0.00	0.28	-0.40

From **Table-5**, the maximum velocity is found around pier #2 of the existing Shah Amanat Bridge and its value is 2.17m/s and 1.60m/s for ebb flow and flood flow respectively. From this table, the maximum scour is found 7.2m around pier #2 of the existing Bridge.

The velocity during ebb flow and flood flow, and scour depth around the 3rd Karnaphuli Bridge piers have been measured in the model as shown in **Table-6**.

Table-6: Velocity and the corresponding scour depth around the 3rd Bridge piers in Test T1

Pier No. from RB	Velocity around the 3rd Bridge piers in m/s		Scour depth (m)
	During ebb flow	During flood flow	
P1	0.00	0.36	-0.28
P2	0.00	0.47	-0.75
P3	1.06	0.97	-2.50
P4	1.27	0.97	-3.00
P5	1.17	0.97	-3.20
P6	2.58	1.35	**-9.20**
P7	1.25	1.07	-0.70

From **Table-6**, the maximum velocity is found around pier #6 of the 3rd Karnaphuli Bridge and its value is 2.58m/s and 1.35m/s for ebb flow and flood flow respectively. From this table, the maximum scour is found 9.2m around pier #6 of the **3rd** Bridge.

The velocity and scour at some points (10 points) around the Guide Bund of the 3rd Karnaphuli Bridge has been measured in the model. The location of these points also can be seen in **Figure-3.**

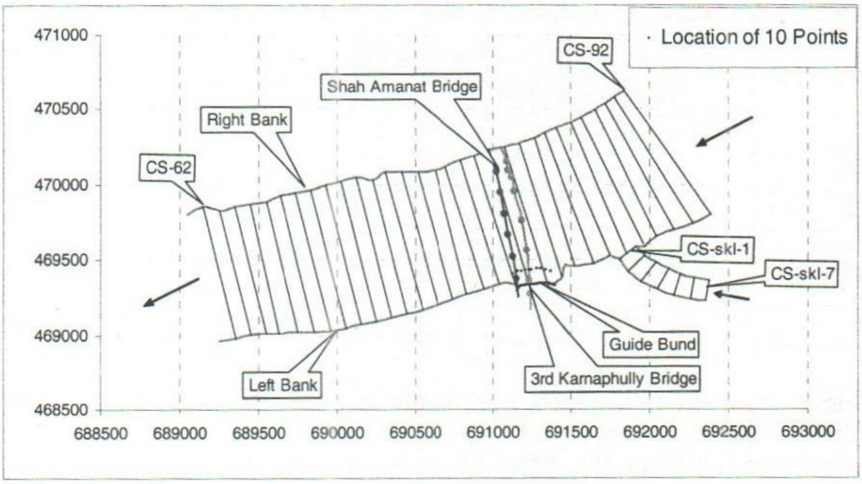

Figure-3: Location of 10 points around the Guide Bund of the 3rd Bridge for velocity and scour measurement

The velocity during ebb flow and flood flow, and scour depth at 10 points around the Guide Bund of the 3rd Karnaphuli Bridge have been measured in the model as shown in **Table-7**.

Table-7: Velocity and the corresponding scour depth around the Guide Bund of the 3rd Bridge in Test T1

Point No.	Location of the Point		Velocity around the Guide Bund of the 3rd Bridge in m/s		Scour depth (m)
	mEasting	mNorthing	During ebb flow	During flood flow	
1	691131.71	469411.28	2.58	1.60	**-6.10**
2	691157.88	469423.57	**3.20**	**1.66**	-2.90
3	691183.75	469428.20	3.09	1.60	-2.50
4	691208.03	469432.67	2.79	1.58	-3.30
5	691231.00	469434.00	2.79	1.58	-3.30
6	691251.58	469436.42	2.89	1.37	-2.70
7	691281.60	469438.36	2.69	1.68	-2.30
8	691307.18	469438.89	2.69	1.58	-2.00
9	691340.00	469436.43	2.79	1.58	-2.40
10	691369.00	469427.00	2.69	1.47	-5.40

From Table-7, the maximum velocity around the Guide Bund is found 3.2m/s and 1.66m/s for ebb flow and flood flow respectively. The maximum scour is around the Guide Bund is found 6.1m.

The flow field recorded by float tracking has been plotted and shown in Figure-(a) and Figure-4(b) for ebb flow and flood flow respectively. From the flow field, it is observed that the flow lines are concentrated near the left bank and also around the launching apron of Guide Bund of 3rd Karnaphuli Bridge during ebb flow. The flow lines are less concentrated near the left bank but concentrated around the launching apron of Guide Bund and some flow has also been entered in to the Sikolbaha Khal during flood flow.

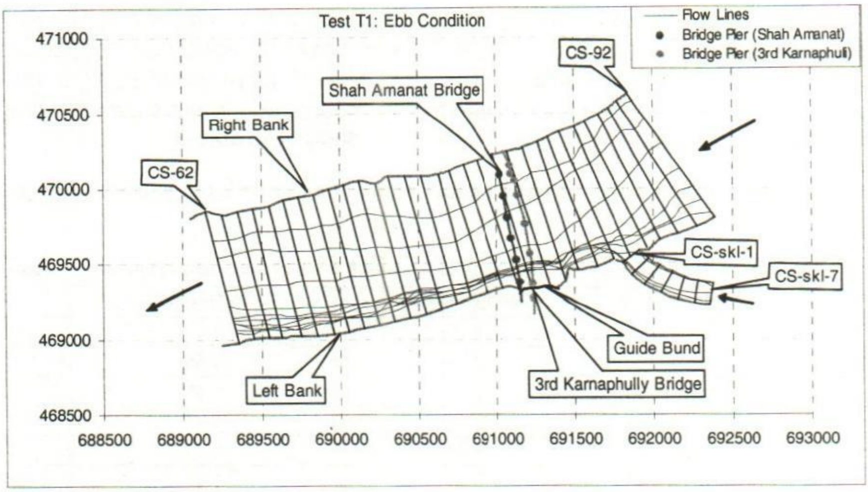

Figure-4(a): Flow lines in Test T1 (Ebb)

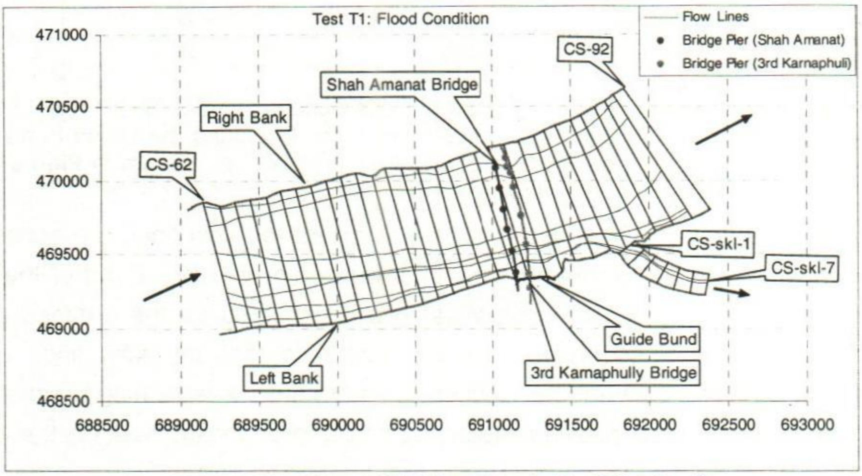

Figure-4(b): Flow lines in Test T1 (Flood)

Application Test (T2)

In this test, velocity during ebb flow and flood flow, and scour depth around the 3rd Karnaphuli Bridge piers have been measured in the model as shown in Table-8.

Table-8: Velocity and the corresponding scour depth around the 3rd Bridge piers in Test T2

Pier No. from RB	Velocity around the3rd Bridge piers in m/s		Scour depth (m)
	During ebb flow	During flood flow	
P1	1.07	0.70	-0.25
P2	0.87	0.97	-0.50
P3	1.07	0.97	-2.00
P4	1.17	0.87	-2.75
P5	1.47	0.97	-3.50
P6	**2.20**	**1.15**	**-7.50**
P7	1.20	0.97	-0.55

From **Table-8,** the maximum velocity is found around pier #6 of the 3rd Karnaphuli Bridge and its value is 2.2m/s and 1.15m/s for ebb flow and flood flow respectively. The maximum scour is found 7.5m around pier #6 of the 3rd Karnaphuli Bridge. The velocity during ebb flow and flood flow, and scour depth at 10 points around the Guide Bund of the 3rd Karnaphuli Bridge have been measured in the model as shown in **Table-9**.

Table-9: Velocity and the corresponding scour depth around the Guide Bund of the 3rd Bridge in Test T2

Point No.	Location of the Point		Velocity around the Guide Bund of the 3rd Bridge in m/s		Scour depth (m)
	mEasting	mNorthing	During ebb flow	During flood flow	
1	691131.71	469411.28	2.50	1.07	**-5.20**
2	691157.88	469423.57	**3.09**	**1.55**	-2.90
3	691183.75	469428.20	2.58	1.55	-2.40
4	691208.03	469432.67	2.48	1.47	-3.20
5	691231.00	469434.00	2.69	1.37	-3.20
6	691251.58	469436.42	2.58	1.07	-2.60
7	691281.60	469438.36	2.69	1.27	-2.10
8	691307.18	469438.89	2.50	1.37	-1.90
9	691340.00	469436.43	2.69	1.47	-2.40
10	691369.00	469427.00	2.69	1.50	-4.90

From **Table-9,** the maximum velocity around the Guide Bund is found 3.09 m/s and 1.55 m/s for ebb flow and flood flow respectively. The maximum scour is around the Guide Bund is found 5.2m. The flow field recorded by float tracking has been plotted and shown in **Figure-5(a)** and **Figure-5(b)** for ebb flow and flood flow respectively.

During ebb flow from the flow field it is observed that the flow lines are concentrated near the left bank and also around the launching apron of Guide Bund of the Bridge. Some flow is also passing along the sheet pile constructed on the dredged channel. During flood flow it is observed from the flow field that the flow lines are less concentrated near the left bank but concentrated around the launching apron of Guide Bund. Some flow is also passing along the sheet pile constructed on the dredged channel and some flow has been entered in to the Sikolbaha Khal.

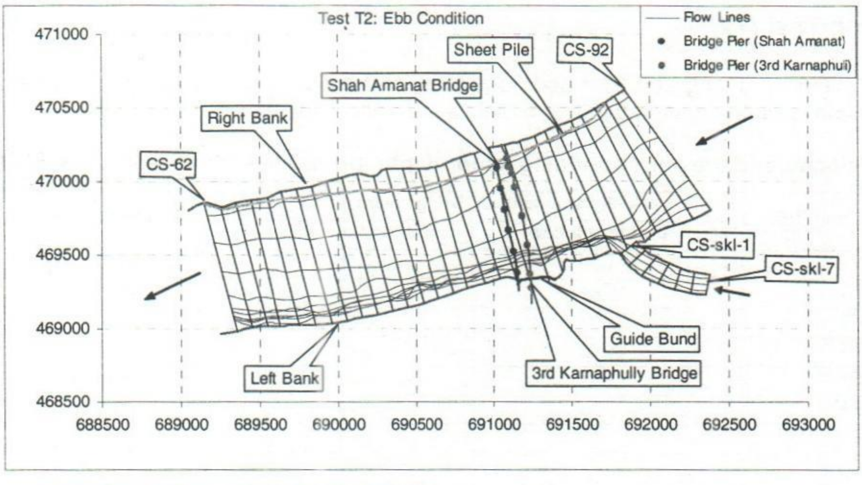

Figure-5(a): Flow lines in Test T2 (Ebb)

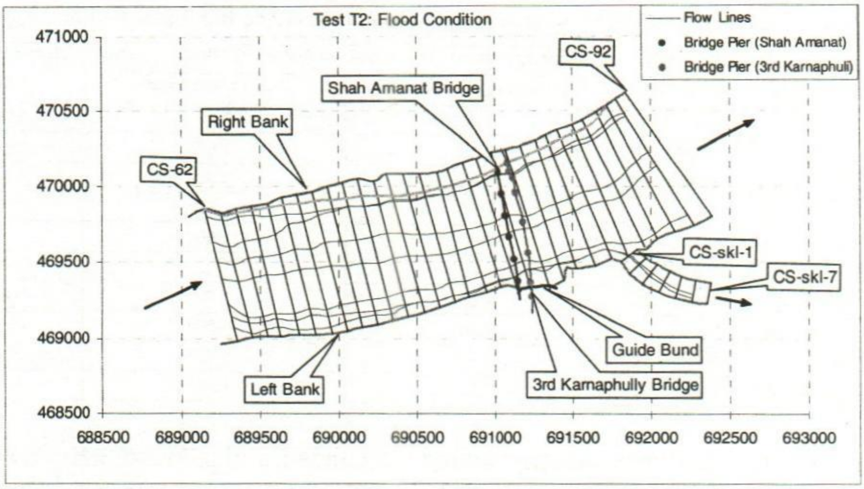

Figure-5(b): Flow lines in Test T2 (Flood)

Application Test (T3)

In this test, velocity during ebb flow and flood flow, and scour depth around the 3rd Karnaphuli Bridge piers have been measured in the model as shown in **Table-10**.

Table-10: Velocity and the corresponding scour depth around the 3rd Bridge piers in Test T3

Pier No. from RB	Velocity around the 3rd Bridge piers in m/s		Scour depth (m)
	During ebb flow	During flood flow	
P1	0.00	0.40	-0.30
P2	0.00	0.53	-0.80
P3	1.00	1.02	-3.00
P4	1.20	1.00	-2.90
P5	0.97	0.96	-3.10
P6	**2.60**	**1.30**	**-9.00**
P7	1.30	0.95	-0.60

From **Table-10,** the maximum velocity is found around pier #6 of the 3rd Bridge and its value is 2.6m/s and 1.3m/s for ebb flow and flood flow respectively. The maximum scour is found 9.0m around pier# 6 of the Bridge.

The velocity during ebb flow and flood flow, and scour depth at 10 points around the Guide Bund of the 3rd Bridge has been measured in the model as shown in **Table-11**.

Table-11: Velocity and the corresponding scour depth around the Guide Bund of the Bridge in Test T3

Point No.	Location of the Point		Velocity around the Guide Bund of the 3rd Bridge in m/s		Scour depth (m)
	mEasting	mNorthing	During ebb flow	During flood flow	
1	691131.71	469411.28	2.50	1.47	**-6.20**
2	691157.88	469423.57	**3.10**	**1.60**	-0.40
3	691183.75	469428.20	3.00	1.50	-0.50
4	691208.03	469432.67	2.90	1.55	-1.50
5	691231.00	469434.00	2.85	1.50	-1.30
6	691251.58	469436.42	2.80	1.37	-1.40
7	691281.60	469438.36	2.60	1.70	-0.80
8	691307.18	469438.89	2.60	1.70	-0.40
9	691340.00	469436.43	2.70	1.60	0.20
10	691369.00	469427.00	2.65	1.50	-5.00

From **Table-11,** the maximum velocity around the Guide Bund is found 3.1 m/s and 1.6 m/s for ebb flow and flood flow respectively. The maximum scour is around the Guide Bund is found 6.2m.

The flow field is shown in **Figure-6(a)** and **Figure-6(b)** for ebb flow and flood flow respectively. During ebb flow from the flow field it is observed that the flow lines are concentrated near the left bank and also around the launching apron of Guide Bund of recently constructed Bridge. So bank protection is to be required around bridge corridor. During flood flow it is observed from the flow field that the flow lines are less concentrated near the left bank but concentrated around the launching apron of Guide Bund. Some flow has also been entered in to the Sikolbaha Khal.

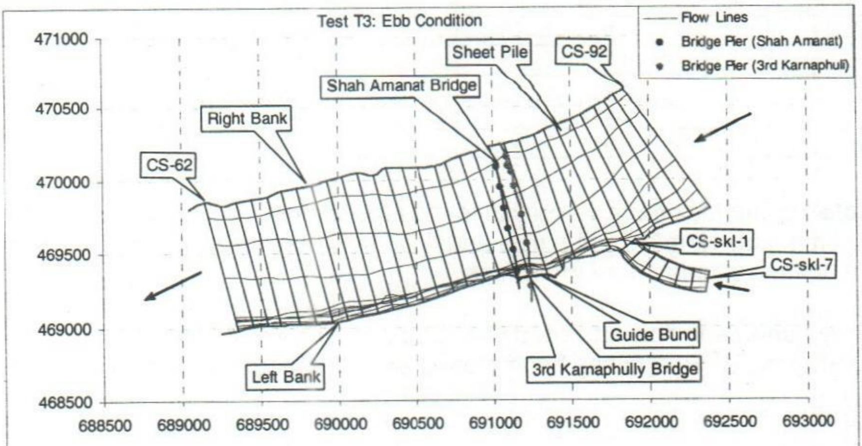

Figure-6(a): Flow lines in Test T3 (Ebb)

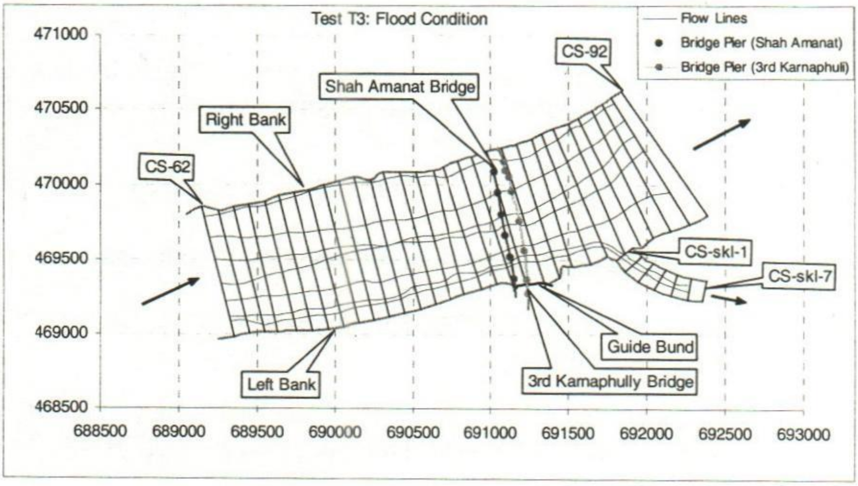

Figure-6(b): The flow lines in Test T3 (Flood)

Conclusions

The following conclusions are drawn from the study:

- The maximum velocity as determined around pier # 2 of the existing Shah Amanat Bridge is 3.34 m/s and 1.6m/s for ebb flow and flood flow respectively. The maximum velocity is found 2.6 m/s and 1.35 m/s around pier # 6 of the 3rd Karnaphuli Bridge for ebb flow and flood flow respectively.
- The maximum scour is found as 9.0 m around pier # 2 of the existing Shah Amanat Bridge and as 9.2m around pier # 6 of the under construction 3rd Karnaphuli Bridge.
- In the Guide Bund, the maximum velocity as observed 3.20 m/s and 1.66 m/s which appears at the downstream of guide bund for ebb flow and flood flow respectively, the maximum scour around the Guide Bund is observed 6.20 m
- From the model investigation, it is found that the guide bund is expected to function effectively.

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References

Globe Survey Company (2005): Report on Bathymetric and Topographic survey in the vicinity of Karnaphuli River, Chittagong, [better to insert name of the organization for which it was done]

River Survey Project (1996a): FAP24, Final Report, Main Vol, No.1.

River Survey Project (1996b): FAP24, Special Report No.3, Bathymetric Surveys.

River Survey Project (1996c): FAP24, Special Report No.7, Geomorphology and Channel Dimensions.

Royal Hasconing (2001): Third Karnaphuli Bridge, Feasibility Study Report, Reference number K2768.21/R003/GTS/Nijm, Roads Highways Department, Dhaka.

RRI (2006): Physical model study of 3rd Karnaphuli Bridge Project, Final Report, Roads Highways Department, Dhaka.

Sir Willium Halcrow and Partners (1985): Chittagong and Chalna Study Report, Overview Report, UNDP/WB.

Van Rijn C. (1984): Bed Forms and Alluvial Roughness, Sediment Transport, Part-III, ASCE Journal of Hydraulic Engineering, vol. 110, No. 12.

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