IMPACT ASSESSMENT OF A BRIDGE ON SURMA RIVER IN BANGLADESH, A CASE STUDY

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Surma a very important river located in the North-East Bangladesh and flows through Sylhet town, a major commercial hub of the region. To enhance the communication facilities with major cities of Bangladesh and within other parts of the region, construction of a 366 m long bridge over the Surma at Kazirbazar, 850 m downstream from the existing Kaen Bridge was initiated. But before completion of the bridge severe morphological response was observed. The river experienced severe bank erosion at the upstream and downstream of the bridge location, which could not be stopped with usual protective measures. It became a major concern for safety of the bridge before completion of construction. To solve this problem historical data on water level and discharge was analyzed and a two dimensional model was developed and run to find best option. The model was simulated with existing bridge piers for different scenarios. The model boundary extends from 12.5 km upstream of the Bridge to 12.5 km downstream. The model was calibrated with real field condition. From the model velocity has been found higher than what the Surma shows within the last few years and causes scouring in the areas consisting with bridge piers. In case of extreme event more than 2.5 m/sec is observed at 2 km downstream from the under-construction bridge. Huge sedimentation was observed at immediate upstream of the bridge creating slack flow between Kaen bridge and Kazir Bazar Bridge. Along the right bank of the Surma, 40 to 50 m bank erosion was observed adjacent to the bridge and navigability was found to deteriorate due to the existence of the bridge. Bank protective structure within the extent was not only necessary for the safety of the infrastructure along the bank but also was intended to save the fish market, mosque and other important structures along river bank. The findings of this study provided useful design values for water level, velocities, scour depth, afflux and possible remedial measures to resolve the morphological impacts.

Keywords: Surma River, Bangladesh, morphological impacts, velocity, scour, afflux, bridge.

Introduction

The Surma originates in India as Barak river and flows into Bangladesh as Surma river and travels 215 km inside Bangladesh from the Indian boundary up to Sunamgang district. There are two closely spaced bridges, Kaen bridge and Shah Jalal bridge, that already exist on Surma river at Sylhet city but appears to be inadequate to serve the traffic load inside the city as well as the traffic coming from different parts of country. As Kaen bridge is going to be restricted for the heavy traffic and only available as walkway for pedestrians it might create additional load on the new Surma Bridge. Under these circumstances at 111th km of Surma river, construction of 366 m long bridge over the Surma at KazirBazar, 850 m downstream from the existing Kaen Bridge was initiated to enhance the communication facilities of Sylhet with major cities of Bangladesh.

Before the completion of the bridge an erosion occurred at immediate downstream of the bridge. During 2008 monsoon, 150 m reach eroded engulfing major part of fish market, rice mills and other important establishment. Immediate upstream area started to face sedimentation which might pose threat to smooth navigability. Apparently, water area of river at bridge site has been constricted severely (about 33 %) due to use of pier of great width compared to usual bridge pier. Since the river is characterized with the flash flood sudden increase of flow causes to spill over the bank. On the contrary, this river faces also abrupt reduction of flow during dry season.

For construction of Bridge we need to study the morphology, the river behavior, erosion deposition of the river. Study of the hydraulic issues have been carried out with the application of mathematical model which was being simulated under different hydrological conditions and also with extensive analysis of the past data and information. Assessment of the impact also allowed revisiting the design variables considered during design of the bridge. In this paper the study is related with the complex existing hydro Morphological state as well as the assessment of the impact of the under construction road bridge over the Surma on river bed erosion/deposition. Fig.1 shows the river system at and around the under construction road bridge over the Surma. Quite a few numbers of studies have been conducted on the river system of North East Bangladesh including Surma, Khowai and other. Mentionable studies are those of Biswas (2010), IWM (2010), FAP (1998), Hossain and Kamrunnessa (1996), Hossain (1997) and Hossain (1999).

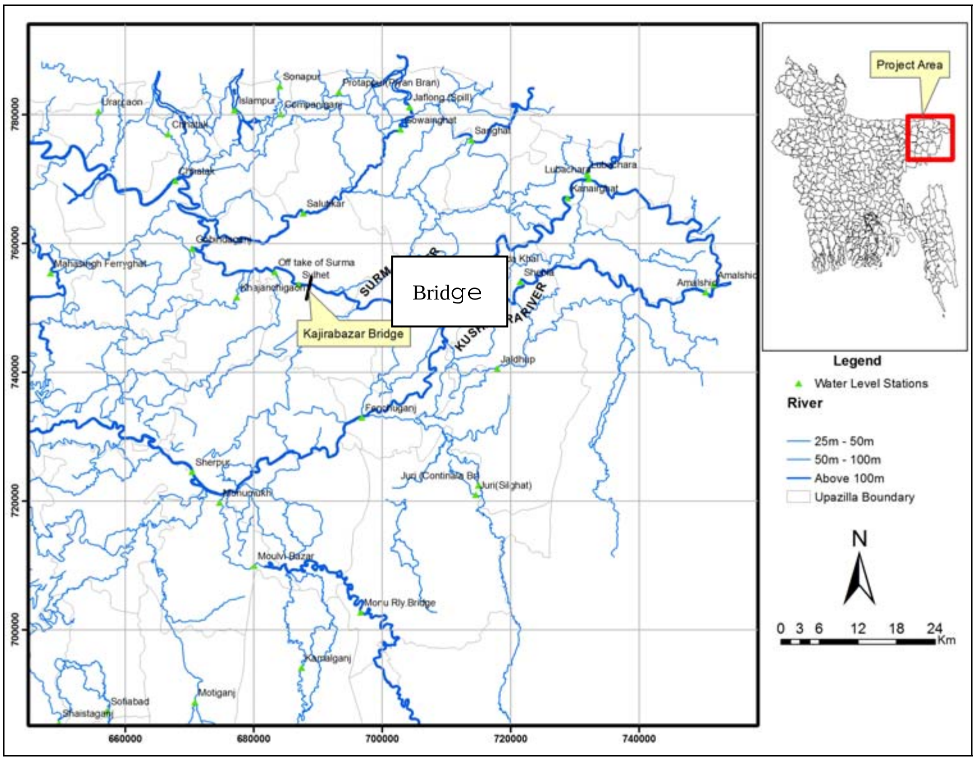


Figure 1: River system and the road bridge over the Surma

Data

In order to understand the fluvial process of the Surma and also to develop the mathematical model, hydraulic and morphological data have been collected and compiled. Processing of the data are made with a view to using it effectively in understanding the hydraulic and morphological process of the Surma in relation with the under construction of the bridge at Kazirbazar. Hydro graphic survey of the Surma near the bridge was conducted by IWM. Other sources of the hydraulic and morphological data are BWDB, IWM database, CEGIS and BIWTA.

Hydro-Morphological study

Hydraulic condition

Barak river bifurcates after entering Bangaldesh as Surma and Kushiyara. Discharge measurements at Surma rivers shows that at most stages the flow has remained stable over the last 20 years (FAP6, 1998). However, the distribution of flow changes seasonally, with the Surma river carrying about 40% maximum, even less most of the time of the Barak river flow during flood stages in June and July and around 10% of the flow in the dry season. The actual total flood discharge along the Surma river is difficult to estimate due to substantial spills that occur on both right and left bank of the river.

Annual maximum discharge and volume of the river had declined rapidly in the recent years. In 1997 the maximum discharge is of 1107 m^3/s whereas just two years back in 1995 it was 2060 m^3/s. On the other hand in 2001 the maximum discharge was 1818 m^3/s whereas in 2002 it was 1146 m^3/s. The reason could be upstream use. Fig. 2 shows the variation of maximum discharge of Surma at Sylhet station.

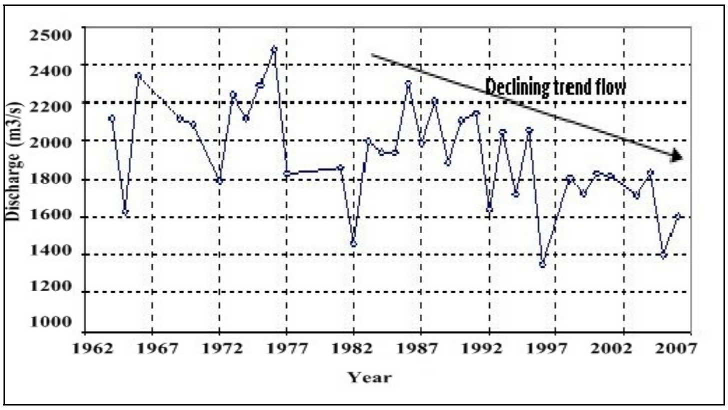


Figure 2: Annual maximum Discharge of the Surma at Sylhet Station

Similar graphical representation is made for water level variation and it may be seen in Fig.3 that maximum water surface elevation varies from 10.5 to 12.4 mPWD. The rising trend of the water level could be due to reason that due to reduction of discharge the flow velocity is decreasing and bed is being silted up giving a trend of rising bed and water level.

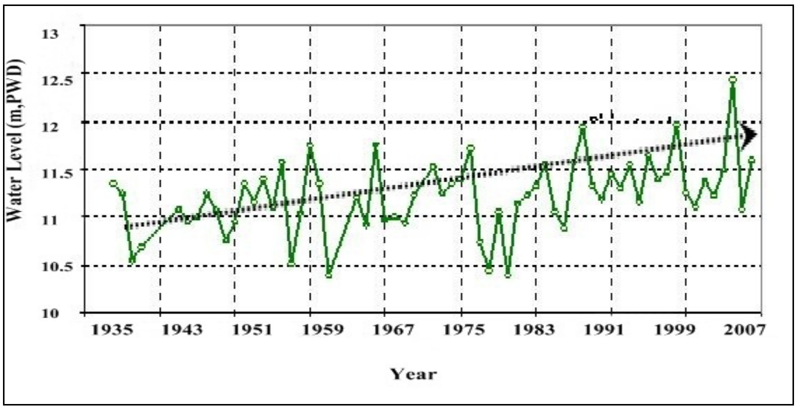


Figure 3: Annual maximum water level of the Surma at Sylhet Station

Slope analysis was done on the basis of available data of Surma River for the period 1988 to 2007. Observation of the water surface slopes for the Surma River from Fig.4 shows that the range of the slope is from 1 cm/km to 7cm/km (from Kanairghat to Sylhet) and 1 cm/km to 8.5 cm/km from Sylhet to Chattak. On average, the slope is in the order of 4 cm/km during monsoon. In winter slope is flatter and in the order of 1 to 2 cm/km.

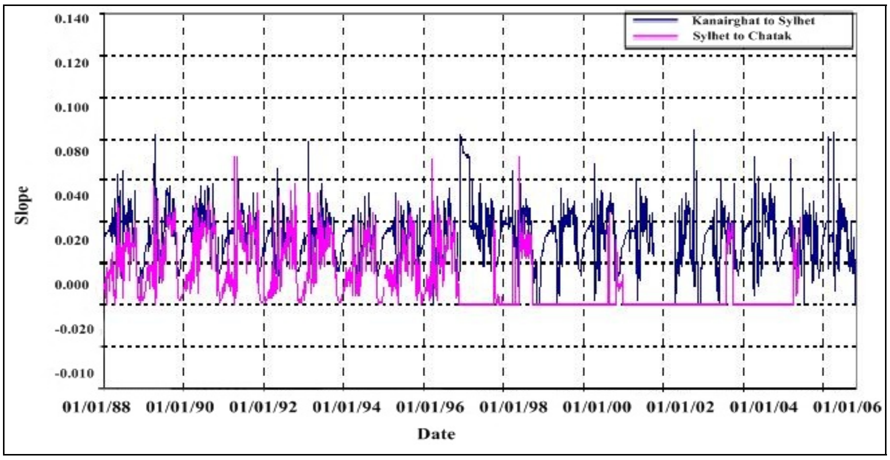


Figure 4: Historical observed water surface slope of the Surma

Water Depth and velocity of the Surma

Water depth of the Surma river varies from 2.0 to 10 m where the velocity of flow ranges from 0.2 m/sec to 1.4 m/sec. Such variation depends on the intensity of the flow within the Surma. Table 1 shows the variation of the water depth and the velocity as a function of the flow. It may be noted that during construction of the bridge the velocity was intensified due to reduction of flow area to about 2.5 m/s and even higher at some point at downstream of the bridge creating huge erosion.

Table 1: Hydraulic properties of the Surma calculated from the flow of 1969-1992

Different Flow Q (m^3/sec)	Water width (m)	Water Depth (m)	Flow Velocity (m/sec)	Water surface slope
562	180	5.02	0.61	0.00003
757	183	5.60	0.71	0.000035
1458	191	7.49	1.02	0.00004
2040	195	8.59	1.22	0.00004
2480	200	9.32	1.37	0.00004

Morphological condition

It is to be noted that the total width of the four constructed bridge piers over the river are 64m, width of each pier in transverse direction is 16m whereas the width of the river along bridge section is 200m. Such big and flow obstructing piers might cause local scour around the pier which may generate disturbance in the river bed and thus ultimately can produce overall imbalance in the equilibrium of the river. Small scale disturbance if continues might generate large scale morphological changes if not managed intelligently and may lead to disastrous consequences. Apart from the river disturbance, continuation of scour may threat the stability of the bridge itself.

Siltation

As Surma has slightly higher water surface profile and the velocities at the off-take are also slightly higher than those of the Kushyara, the khals of Surma is not associated with huge sedimentation in comparison with that of the Kushiyara regardless of Surma itself is getting silted from year to year. The sediments carried with the flows from the Surma are deposited in the beels and in lower reaches of the river basin. The eroded and deposited area may be seen in Fig. 5. It appears from the figure that immediate upstream of the bridge experienced siltation. Though the siltation is very obvious but in this present case it took place very quickly within short period from construction to date which might push the channel to flow in different direction.

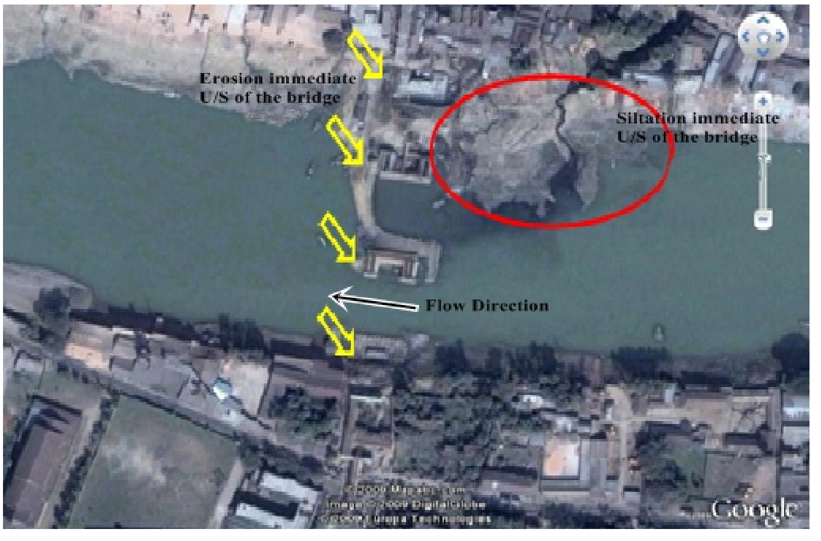


Figure 5: View of the bridge site showing erosion and siltation

Huge bed scour is also observed at the left bank of the Surma at immediate downstream of the under construction bridge. It is seen that at downstream of the bridge, bed scouring ranges from 1 to 5 meter associated with the thalweg movement from middle to left bank. Such changes i.e. bed scouring along the left bank extends approximately 1 km downstream from the bridge. The study reveals that at immediate upstream along the right bank, scouring is more severe than that at downstream. Bed level undergoes from 10 to 16 m from its initial i.e. surveyed bed. Exactly at bridge location, bed scouring is not so substantial and remains within 8 to 12 m. Spatial extent of bed scouring along the right bank is from 1 km upstream to 500 m downstream of the bridge.

River erosion

Analysis of available maps, data indicated that erosion occurs due to progressive migration of the river's meander pattern. This process is driven by secondary currents in the channel that deposit sediment on the convex side of the meander bend and scour material from the outer (concave) side of the bend. As a result, local sloughing and slow bank retreat are occurring at virtually each of the sharp bends in the rivers. Unlike other major rivers of Bangladesh erosion rates on the Surma River are limited by the cohesive nature of the banks and comparatively the low velocities of the river. According to available historic maps, the location of the bifurcation appears to have shifted considerably over the last 40 years. This shifting has produced erosion rates of 15 m/year on the Surma and Kushiyara Rivers.

Images of 2000 and 2008 have been examined to observe the nature of bank line migration. Analysis of the images showed that almost no changes have taken place within last eight years. But analyses of the survey data conducted by IWM showed that around 200 m area along the right bank at immediate downstream of the bridge experienced bank erosion and it is still continuing. This may be possible due to coarse resolution of the satellite image where such small erosion could not be dtedcted. Bank erosion at this stretch can be considered as the impact of the constriction scour produced by the under construction bridge. More eddies along both the banks formed as flow was constricted by the bridge piers and then released suddenly within short reach. Since the left bank is protected with embankment right bank is easily eroded by these eddies even though the thalweg remains along the left bank.

Sinuosity

The sinuosity near the bridge site is found to be 1.25. The total stretch of a river or a part can be called meandering if sinuosity value exceeds 1.50. So, at the bridge site the river is not highly sinuous.

Model Development

In order to analyze the baseline and predicted hydrodynamic and morphological conditions at and around the bridge, a 2D morphological model has been developed using MIKE21C modelling system. The developed two-dimensional morphological model of the Surma River is simulated for different scenarios to understand the short term changes of the river. This model extends from 12.5 km upstream of the Bridge to 12.5 km downstream covering total 25 km in length.

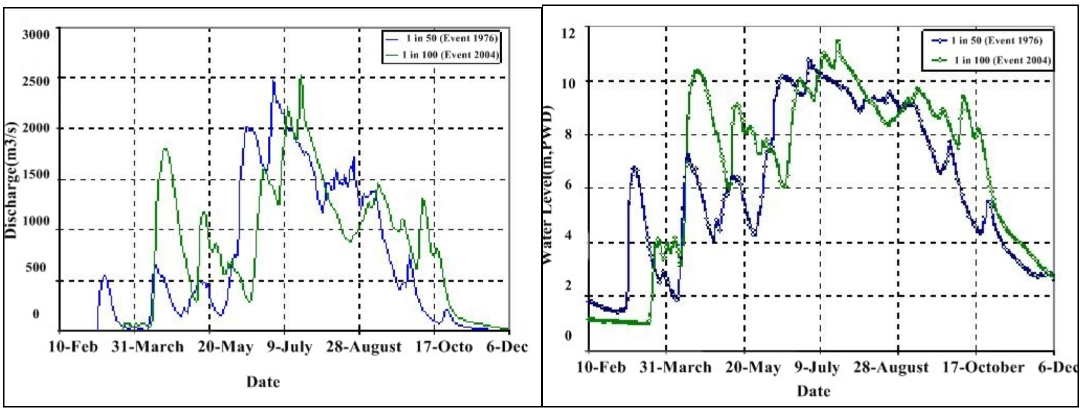
Model generation

Model covers 25 km river reach representing the bed level of pre monsoon (March-April) 2009. Observation from the models being subject to different flood conditions and analyzed in relation with the hydraulic and morphological characteristics of the Surma due to existing under construction kazirbazar bridge. The comparison have been made with existing field condition, impact of the bridge in bank erosion, in flow velocity, bed erosion/deposition, back water etc has been determined. To compare the river hydraulic and morphological characteristics between "with" and "without bridge" condition an attempt has been made. With the intention of doing so "without bridge" condition has been generated in the model considering non existence of kazir bazaar bridge. Model development actually covers the following steps sequentially

- Generation of computational grid or cell where each of the cell would contain the input and outputs
- Preparation of model initial bathymetry (recently surveyed cross section @ 50m interval) which represents the river bed
- Determination of initial and boundary conditions and
- Calibration of the model for evaluating the performance of the model.

With the purpose of resolving the consequence of the bridge, mathematical model of the Surma within the bridge has been applied for average and extreme flood events. Assortment of these flood events is based on frequently occurrence of average flood and worst scenario. Frequency analysis has been done to determine the design event to be used as the boundary condition of the numerical model after collecting all the historical data of flow and water level. Discharge data measured at Sylhet gauge station from 1962 to 2007 has been used to carry out the statistical analysis of the probable discharge of the Surma,

As per rule, upstream boundary is defined as a single discharge boundary or a discharge time series and downstream boundary is defined as corresponding single water level or water level time series. Available discharge data of Sylhet station is used as upstream boundary of the 2D model. Water level boundary is determined from the slope analysis using as a reference of Sylhet water level station. It is worth mentioning there that downstream boundary of the model is located at 12.5km from Sylhet water level station. In this case no inflow and outflow have been included since within the study area, there is no such inflow and outflow. The model was simulated for extreme event of 100 years return period as in 2004 and average flow (2.33 years return period which means flow of 1985) as shown in Fig.6



Extreme flood event Average flood event

Figure 6: Discharge and water level boundary for different return period flood

Results and Discussion

In general the model results show that velocity is higher than what the Surma shows within the last few years and causes scouring in the areas consisting with bridge piers. In case of extreme event more than 2.5 m/sec is observed at 2 km downstream from the under construction bridge. Due to the bridge Surface water level for extreme event is 12.41 mPWD. Afflux due to the bridge is not significant but the slope of water surface is very less (1cm/km) in comparison with the observed (4 cm/km). Owing to such slope, huge sedimentation is observed at immediate upstream of the bridge creating ponding of water between Kaen bridge and Kazir Bazar Bridge. Navigability is found very poor due to the existence of the bridge. Even prior to the construction of the bridge, this river is categorized under class four by BIWTA. Due to sedimentation at immediate upstream of the bridge, thalweg shifts towards the banks. Within these deeper parts of the channel, only navigable route is available during dry period. At immediate upstream of the bridge the bed-scour in the range of 10 to 15 m is found which is prominent along the right bank. Bed erosion at immediate downstream is not as severe as observed along right bank at upstream. Along the right bank of the Surma near the bridge 40 to 50 m bank erosion is observed. Affected reach covers 1000 m starting from immediate upstream to downstream of the bridge. Bank protective structure within this extent is not only necessary for the safety of the infrastructure along this bank but also is intended to save the fish market, mosque and other important structures along this bank. So, protection work is recommended and the estimated cost of 1000m long revetment is Tk. 913 Lakh (Tk. 91,300 per m of protection). Hardly 20 m bank erosion may take place just at the bridge line along the left bank where protective revetment work is nonexistent. Design scour of 12.77 m may be considered as computed by using FHWA method. Adding general and constriction scour of 12.00 m and considering minimum bed level of river of 0.90m PWD the anticipated total scour and design scour level are -24.77 m and -23.87 mPWD respectively.

Conclusion

Flow velocity was found to increase due to placement of very wide piers on the flow path of Surma river and velocity more than 2.5 m/s was observed. Due to very low slope, deposition was noticed at upstream and erosion was noticed at downstream. Poor navigability existed and bed scour of the order of 10-15 m was observed. Immediate implementation of the protective works is recommended for sustainability of the river river.

Acknowledgement

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References

Biswas, S.K. (2010). Effect of bridge pier on waterways constriction: a case study using 2-D mathematical modelling, Proceedings;IABSE-JSCE Joint Conference on Advances in Bridge Engineering-II, August 8-10, 2010, Dhaka, Bangladesh.

FAP6. (1998). Northeast Regional Water Management Project, Kalni-Kushiyara River Management Project, Feasibility Study, Final Report, March, 1998

Hossain,M.M.(1997) "Assessment of sediment load in the large alluvial rivers of Bangladesh", Acta Hydrotechnica, 15/18, 203, p.159-162, September.

Hossain, M.M. and Kamrunnessa.(1996) "On the geometry and sediment transport aspects of Surma river in Bangladesh, Proc., 10th. APD-IAHR Congress, Hydraulics Research and Engineering Towards and Beyond 2000, Vol. II, pp.242-249, Langkawi Island, Malaysia, August 26-29.

Hossain, M. M. (1999)Aggradation and degradation of Kowhai river in Bangladesh" Proc. International Conference on River sedimentation, Ed. Jayawardena, Lee & Wang, Balkema, Rotterdam, ISBN 90 5809 0345, pp. 267-272.

IWM.(2010).Hydrological and Morphological Impact Assessment for under construction Road Bridge on Surma River at Kazir Bazar in Sylhet Town using Mathematical Modelling, IWM, DOHS, Dhaka