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SELECTION OF A BRIDGE LOCATION OVER THE RIVER LOHALIA: AN ASSESSMENT USING MIKE 21C MODEL

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Abstract

Choosing the ideal site for a bridge is as important as constructing the bridge itself appropriately. There is a range of location suitability criteria and models that assist in analyzing site suitability. This study is an attempt to determine the suitable location of a proposed bridge along with its alignment as well as approach road using MIKE 21C model over the Lohalia river in Patuakhali district. This study also provides hydraulic design parameters of the bridge as well as its approach roads. A field survey campaign has been conducted to collect field data necessary for model development and hydro-morphological study. The model was calibrated using field data and then applied for different scenario simulations in the base and with bridge conditions. It is revealed from the study that the bridge should be located at the inflection point between two consecutive meander bends near the Boga ferry terminal from hydro-morphological considerations. The suggested bridge length of 980m is much larger than that obtained from regime equation in order to fulfil specified navigational requirements. For the bridge pier and abutment, the design scour level is found as -16.46mPWD and -6.9 mPWD respectively. The study also comes up with design discharge, water level, girder bottom level and deck level of the bridge. Moreover, location and dimension of the approach road, slope protection works, river training works and design variables of the same have also been suggested from the study.

Keywords: *approach road, BIWTA, bridge, hydraulic design, MIKE 21C, thalweg.*

Introduction

River bridges play a fundamental role in road construction project. The choice of the right site is a crucial decision in the planning and design of a bridge. It may not be always possible to have a wide choice of sites for a bridge. For river bridges in rural areas, usually, a wider choice may be available. The location suitability of a river bridge consists of a comprehensive study of preliminary engineering, hydrology, and hydraulics, roadway alignment, along with environmental and geological surveys (Groenier and Gubernick, 2007). The characteristics of an ideal site for a bridge across a river are:

a) A straight reach of the river.
b) Steady river flow without cross-currents:
c) A narrow channel with firm banks
d) Suitable high banks above high flood level on each side.
e) Rock or other hard in erodible strata close to the river bed level.
f) An economical approaches, danger of floods; the approaches should be free from obstacles such as hills, frequent drainage crossings, sacred places, graveyards or built-up areas or troublesome land acquisition
g) Absence of sharp curves in the approaches;
h) The absence of expensive river training works;
i) Avoidance of excessive underwater construction.

Foregoing studies of site suitability have used a representation of static, dynamic, deterministic or stochastic mathematical programming models to determine the optimal site location. Groenier and Gubernick (2007) discusses a commonsense approach, combined with science, to help select the best locations for bridges. Ardeshir, *et al.* (2014) selected a bridge construction site using fuzzy analytical hierarchy process. Wimmer (2015) conducted another study to assess alternative proposed bridge crossing locations over the Merrimac river in the U.S using a GIS approach. Each method has its own criteria in finding the best alternatives.

In this study, MIKE 21C model is used to simulate the river processes. It is a special module of the MIKE 21 software package based on a curvilinear (boundary-fitted) grid, which makes it suitable for detailed simulation of rivers and channels, where an accurate description of bank lines is required. The MIKE 21C is particularly suited for river morphological studies and includes modules to

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describe flow hydrodynamics, helical flow, sediment transport, scour and deposition, bank erosion and planform changes (DHI, 2017)

In Bangladesh, the rural road network is essential for improving the health, education, and the livelihoods of about 66 percent of the county's people. As part of the strategy to expand transport and communication infrastructures in the country, Government has planned to construct a bridge over the river Lohalia in Patuakhali, the south-central region of Bangladesh.

The Lohalia river is tidally affected, meandering and dynamic in nature. It takes off from the Pandab-Paira river which is also a tidally affected river. The hydrological setting of the study area is very complex. Therefore, selection of a suitable bridge location requires investigation of the past and present erosion trend as well as likely future developments in the river planform under different hydrological scenarios. In case of the proposed bridge over the Lohalia river a number of issues have been identified first namely stability of the river at the bridge location, vertical and lateral stability the bridge, hydraulics of bridge opening, design discharge and flood level, navigational requirements and likely impacts of the bridge on river hydraulics and morphology particularly in terms of flooding potential in the upstream of the bridge. Selection of appropriate bridge length requires detailed analysis of hydraulics of bridge opening together with consideration of other relevant issues.

On the other hand, due to tidal influence, the total scour at a bridge crossing can be evaluated using the scour equations recommended for inland rivers and the hydraulic characteristics can be determined using flow modelling and coastal engineering methods. However, it should be emphasized that the scour equations and subsequent results need to be carefully evaluated considering other information from the existing site, other bridge crossings, or comparable tidal waterways or tidally affected rivers in the area. The hydrology of the study area is very complicated as four types of climatic factors influence its hydrology. These climatic factors are cyclonic surge, tidal flow, monsoon flow and sea level rise due to global warming (BUET and IWM, 2008). Thus to investigate the combined effect of these four factors are very important to determine the vertical and horizontal clearances of the bridge. Implementation of the proposed bridge may cause an adverse impact on tide, sedimentation, and erosion. Therefore, these issues should be addressed carefully. The objective of this study is to find out a suitable bridge location together with its appropriate length and alignment taking all the relevant issues in view and to suggest measures for protecting the bridge and approach roads from being outflanked by the river.

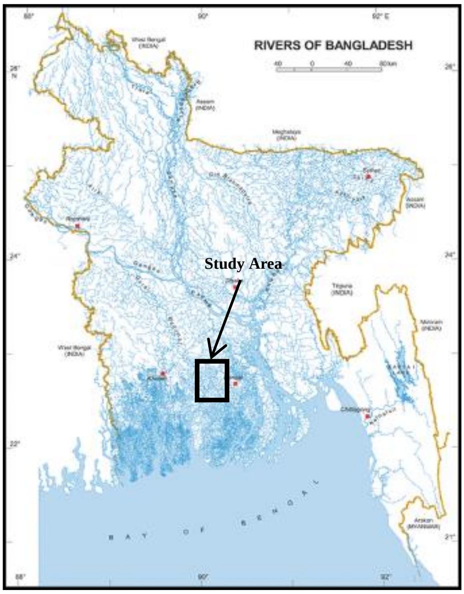

Fig. 1. Location of study area

Methodology

Study site

The study area is in the district of Patuakhali which is situated in the south-central region of Bangladesh. The Zilla (district) road Lebukhali to Amragachia starts from Lebukhali on Dhaka-Barisal-Patuakhali National Highway and headed to the Amragachia through Dumki, Bauphal, Dasmina, Galachipa and Amtali Upzillas (units that form a district).

This thoroughfare is the only way of road communication for the people of the area with Patuakhali, Barisal, and Dhaka. The proposed Boga Bridge over the Lohalia river is located at 14th K.M. of Lebukhali-Amragachia road (Fig. 1). At present, ferry service has been provided by the Roads and Highways Department (RHD) to cross the river. The Lebukhali-Amragachia Road plays a very important role in road communication network of this area. A good number of villages, bazaars, and trade centres are connected to this road through LGED (Local Government Engineering Department) and other village roads. A large number of light and heavy vehicles move on this road and also the traffic volume is increasing day by day. The river at the likely bridge location is a boundary between Dumki and Bauphal upzillas. The west part of the proposed bridge is situated at Muradia union (on the right bank of the river) of Dumki upzilla. On the other hand, east part of the same is situated at Boga union (on the left bank of the river) of Bauphal upzilla (RRI, 2014). The distance of the off-take from the proposed Boga Bridge is about 3.5 km (along the river). The total length of the river from off-take to outfall is about 85 km (along the river).

Data collection and model development

In order to conduct the study, necessary historical hydrological data of the river, time series and satellite imageries of the study area were collected from the Water Resources Planning Organisation, Dhaka (WARPO) and The Centre for Environmental and Geographic Information Services (CEGIS), Dhaka. A field survey campaign was conducted to collect the recent bathymetric and bankline data of the river, nearby existing road alignment data, water level, discharge and sediment data etc. The collected data was processed and analysed to the extent of gaining an understanding of the present physical conditions of the river at the bridge location and also deriving information to use as model inputs. A two-dimensional model covering an extent of about 20km of the river was developed using modelling software MIKE 21C (DHI, 2017). The initial bathymetry (Fig. 2) of the model was formed using recently surveyed bathymetric data.

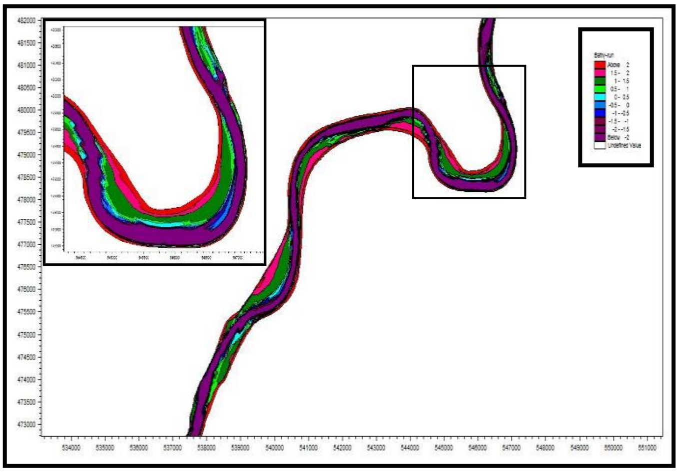

Fig. 2. Initial bathymetry of the model using MIKE 21C

Calibration of the model

The model was calibrated for measured discharge and water level under the framework of the study since there was no historical discharge data available on the Lohalia river. The calibrated model was then applied for different scenario simulations in the base and with bridge conditions. Since the measured discharges at the proposed bridge location was insufficient for deciding about design discharge, indirect method was adopted for computation of design discharge. In this case, slope area method was used for calculating discharges corresponding to different return period water levels because the river has a defined channel. Standard manuals on hydraulic and hydrologic design of bridge and BIWTA guidelines for navigational clearances was consulted for deciding about design flood level and discharges, standard high and low water levels, bridge height, bridge span length, approach road formation level etc. (BUET and IWM, 2008).

Results and Discussion

Suitable Bridge location and approach road alignment

It appears from the analysis of collected bathymetric data of the river and time series satellite images of the study area and also from the model simulation results that the crossing between two consecutive meander bends at the Boga ferry terminal is almost stable in terms of lateral migration and bed degradation. At present, the thalweg is almost in the middle of the river at this location and the maximum velocity also occurs almost in the middle of the river. The suitable river stretch for siting of the bridge is shown in Fig. 3.

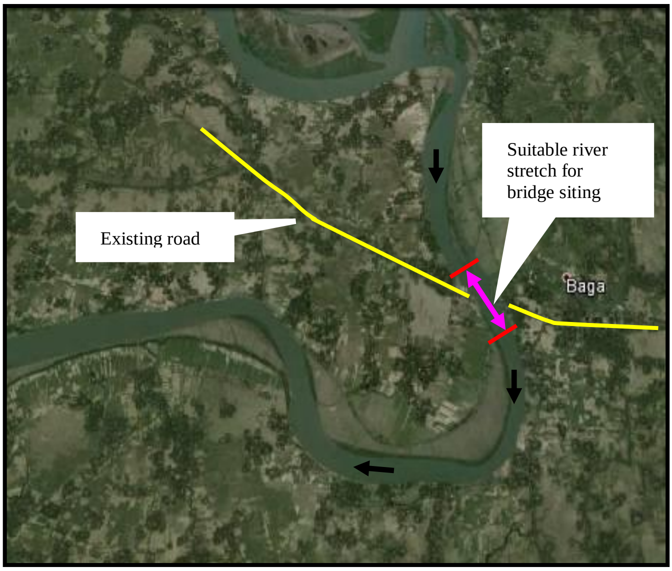

Fig. 3. Suitable river stretch for siting of the bridge

It is observed from the study that a longer bridge compared to that needed from the hydrological and morphological point of view has to be adopted to fulfil the BIWTA requirements for navigational clearance and to restrict the abutment height within a reasonable limit. Considering the issues related to the selection of suitable bridge location and approach road alignment namely proximity to and alignment of the existing RHD Zilla road, river approach to the bridge, skew in the bridge, proportion of displaced households etc. only one option is found for bridge and left link road (approach and access road). The appropriate bridge location is at somewhat downstream of the meander crossing. However, for the right link road, four options have been identified. Considering all relevant issues namely, length of the link road (approach and access road), curve of the approach road etc.,option-3 has been selected (Fig. 4).

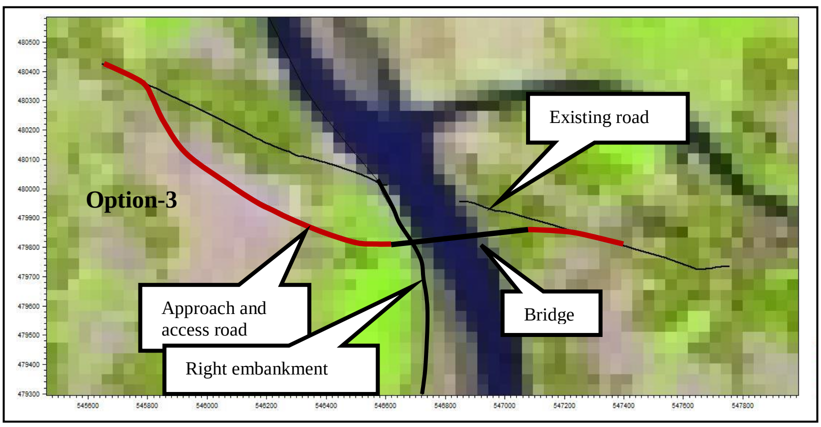

Fig. 4. Proposed alignment of the bridge and approach road over Lohalia river at Boga ferry terminal

Suitable Bridge length

The bend in the upstream of the selected bridge location is still in the process of development, however, the rate of bank erosion is rather low. The right bank of the river in the downstream of the bridge location is part of a compound bend and is experiencing erosion. The hydrodynamic simulations of different return period discharges show similar velocity distribution pattern along the cross-sections at and in the immediate upstream and downstream of the proposed bridge location. The design discharge for the bridge has been estimated as 1972 m^3s^{-1} and based on the design discharge and other relevant issues in view appropriate length for the bridge has been determined as 980m.

The model simulations with different return period discharges have been conducted with the bridge in place to see the effects of bridge constriction caused by bridge piers on existing hydraulics at and around the bridge. It is found from the simulation results that the bridge causes a local increase in flow velocity around the bridge piers and some extent upstream and downstream of the same but has negligible effects on the water level upstream compared to the base condition. It means with the selected bridge opening the free passage of flood flow will not be hampered. The velocity field in the vicinity of the bridge for 50-year and 100-year discharges and with the bridge in place is shown in Fig. 5. The bridge is introduced in the model as accurately as possible as per decision as to the number of spans, pier width etc.

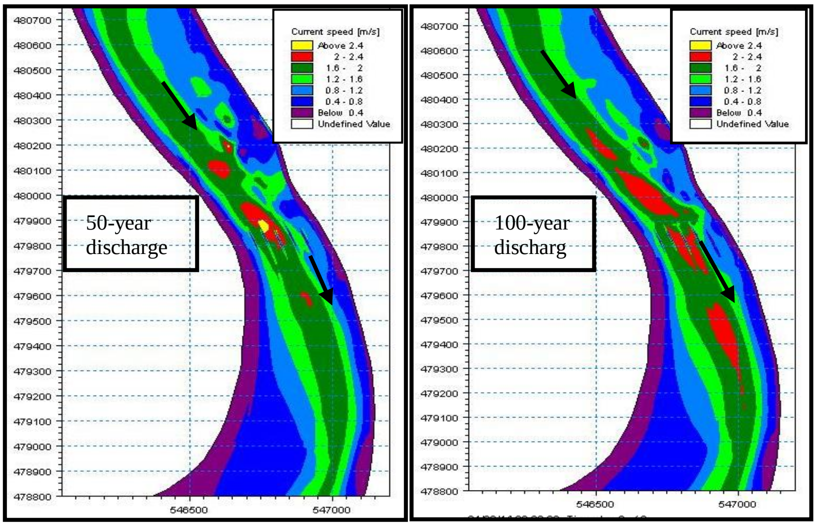

Fig. 5. Velocity field at and around the bridge for 50-year and 100-year return period

Hydrological and hydraulic design parameters

Table 1. The hydrological and hydraulic design parameters of the bridge and approach road obtained from the study.

Design parameters		Specifications
Design discharge for bridge substructure	:	2165 m^3s^{-1}
Discharge for bridge	:	1972 m^3 s^{-1}
Design flood level for bridge substructure	:	3.35 mPWD
Design flood level for bridge	:	3.22 mPWD
Standard Low Water Level	:	-0.45 mPWD
Standard High Water Level	:	2.44 mPWD
d_m of soil material	:	0.18 mm
Formation level of the approach road	:	3.95 mPWD
The bottom level of the bridge girder	:	21.0 mPWD
Deck level at centreline of the bridge	:	23.5 mPWD
Length of the bridge	:	980 m
Number of bridge spans (main bridge)	:	4
Number of bridge spans (viaduct)	:	24
Design scour level for abutment	:	-6.90 mPWD
Design scour level for pier	:	-16.46 mPWD
Length of the approach road	:	302.5 m

[Note: Bangladesh Water Development Board and other government departments refer water levels to the Public Works Datum (PWD). PWD is a horizontal datum believed originally to have zero at a determined Mean Sea Level (MSL) at Calcutta. PWD is located approx. 1.5 ft below the MSL established in India under the British Rule and brought to Bangladesh during the Great Trigonometric Survey (FFWC, 2017).]

Velocity information at and in the Vicinity of the Bridge

Velocity information at and in the vicinity of the bridge location in base and with bridge conditions are shown respectively in Table 2 and Table 3 below.

Table 2. Velocity information at the bridge location in base condition

Return Period (year)	Discharge (m^3s^{-1})	Maximum velocity (ms^{-1})	Cross-sectional mean velocity (ms^{-1})
50	1972	2.04	1.36
100	2165	2.13	1.40

Table 3. Velocity information with bridge in place and for 100-year discharge

Location	Maximum velocity (ms^{-1})	Near bank velocity (ms^{-1})
Along right bank upstream of Dumki ferry terminal	-	1.80 to 2.15
Near left abutment (over left floodplain)	Not applicable	-
Near right abutment	Not applicable	-
Along left bank in the immediate downstream of the bridge	-	1.70 to 2.10
At the left pier of the middle span	2.70	-
At the right pier of the middle span	2.38	-
Along right bank in the immediate downstream of the bridge	-	1.10 to 1.40

Bridge height and span arrangements

According to BIWTA navigation route classification, the Lohalia river in the study area falls under the Class I navigation route(BUET and IWM, 2008). It means minimum vertical clearance should 18.3m with reference to Standard High Water Level (SHWL). The SHWL determined by BIWTA at Kaitpara which is about 3.5km upstream of the Boga ferry terminal is 2.45mPWD. On the other hand, the same at Patuakhali (16.5km downstream of Boga ferry terminal) is 2.40 mPWD. The bottom level of the bridge girder, in this case, is the summation of Standard High Water Level, minimum vertical clearance as specified by BIWTA and anticipated sea level rise due to global warming. The bottom level of the girder is thus 21.5 mPWD. The minimum horizontal clearance for Class I navigation route is 76.22m (BIWTA, 2018). The entire length of the bridge (980m) is divided into main bridge and viaducts. The main bridge length is divided into 4(four) spans. An 80m long span is considered in the middle of the dry flow channel to meet the BIWTA navigational requirements. The other three spans of the main bridge are of the length of 60m each. For the remaining length, 24 (twenty-four) viaducts of an equal span length of 30m are considered (11 in the right side and 13 in the left side).

Need for river training works

The proposed bridge is located at the crossing of two consecutive meander bends. Examination of satellite images of the study area and consultations with the local people point to the fact that substantial right bank erosion did occur in the upstream of the Dumki ferry terminal and at present, the rate of erosion is rather low. The left bank in the immediate downstream of the bridge is still being eroded and there is potential for future bank erosion. The Lohalia river originates from the southern branch of the Paira river and its off-take is only about 3.5km upstream of the proposed bridge location. Based on the planform analysis of the Lohalia and its parent river it can be concluded that there is a degree of uncertainty as to future morphological developments at and around the proposed bridge location. In consideration of the long-term safety of the bridge, bank protection works in the form of bank revetment has been proposed in the upstream of the Dumki ferry terminal (along the right bank) and in the downstream of the bridge (along the left bank). The suggested length of bank revetment is 300m in the upstream of the Dumki ferry terminal and 200m in the downstream of the bridge (RRI, 2014a). The location and placement of the bank protection works are shown in Fig. 6.

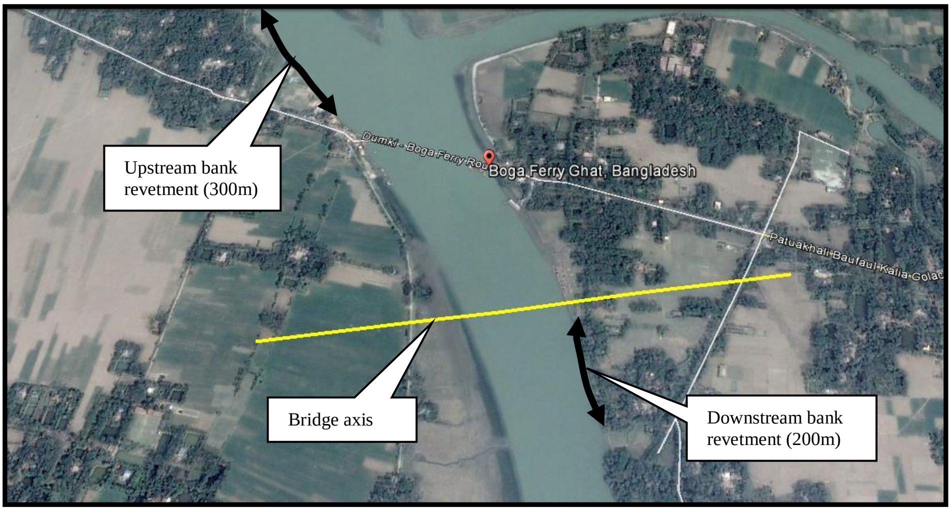

Fig. 6. Placement and length of suggested bank revetments upstream and downstream of the bridge

Conclusions

The length of the bridge is selected as 980 m which is aligned at an angle of about 10° with the river. The design discharge for the bridge and bridge substructure is 1972 m^3s^{-1} and 2165 $m^3\ s^{-1}$ respectively. The design water level for the bridge and bridge substructure is 3.22 mPWD and 3.35 mPWD respectively. The Standard High Water Level (SHWL) and Standard Low Water Level (SLWL) is 2.44 Mpwd and -0.45 mPWD respectively.

Besides, the approach road formation level at access road and at abutment is 3.95 mPWD and 10.0 mPWD respectively. The length of the approach road is 302.5 m on both sides of the bridge. The bottom level of the bridge girder at the centre of the bridge should be kept at 21.0mPWD. The bridge deck level at centreline of the bridge is 23.5 mPWD.

The main bridge consists of one 80m long span in the middle and three 60m long spans (two in the right side and one in the left side). There will be 24 (twenty-four) viaducts (eleven in the right side and thirteen in the left side) of 30m length each.
The design scour level at the abutment is -6.9 mPWD. The bottom level of the pile foundation for the abutment should be placed well below this level. The design scour level for the bridge pier is suggested to be -16.46 mPWD. The bottom level of the pile foundation should be set well below this level.

Furthermore, suggested length of the bank revetment along the right bank is 300 m in the upstream of the Dumki ferry terminal and 200 m along the left bank in the downstream of the bridge. The required length of the link roads on right and left side of the bridge is 1952 m and 300m respectively.

The results of this study can encourage public participation in the decision-making process and assist various planners and authorities to formulate a suitable plan for sustained transportation development of the region. Economic, social, political and public support, as well as environmental concerns, will all be challenges that will need to be addressed and overcome. While the conclusions formulated here may be more helpful in ascertaining a more suitable bridge location across the Lohalia, it also demonstrates that continued analysis and up-to-date data as well as developing new criteria for site selection can benefit the analysis process and overall result.

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