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Bridges that sustains the deltaic Bangladesh

M.A. Sobhan
Design Planning & Management Consultants Ltd., Dhaka 1205, Bangladesh

ABSTRACT: Bangladesh has been formed, geologically, by the alluvium and silt deposits of the Ganges, the Brahmaputra, and the Meghna river system; the delta-building process of this land is still incomplete. While building bridges, dams, barrages, embankments, etc. in this active delta, adequate care for sustainability of its sensitive river system, flood plains and coastal estuaries is needed. The paper reviews the effect of the existing above infrastructures, and thereafter arrives at the new design paradigm of river bridges for global sustainability. Two case studies are presented; one, the effect of the multiple span Hardinge railway bridge, Paksey, on the river regime of the Ganges (Padma); and, the other, the effect of the Bangabandhu Jamuna bridge on the Jamuna river. Another case study is presented on the concept of the new bridges sustaining the ecosystem of the Halda River, Chittagong Hill Tracts. Thereafter, bridges for sustaining the coastal estuaries of Bangladesh are discussed. In conclusion, important recommendations for the designers of bridges are given.

1 INTRODUCTION

Bangladesh possesses a few natural endowments, namely, the fertile agricultural lands; the mighty river system comprising the Ganges, the Brahmaputra, and the Meghna with their many tributaries & distributaries; the strategically located Bay of Bengal with two existing ports, namely, Chittagong and Mongla, the ongoing Payra seaport, and the potential for developing several other deep-sea ports; and the vast stretches of coastal estuaries and islands, inhabited by the very resilient and outward-looking entrepreneurial people; the scenically beautiful hilly areas of Chittagong and Chittagong hill tracts, inhabited by mostly minority nationalities and tribal people with varied and rich cultural heritages. Besides, it has the tropical monsoon climate, with six beautiful seasons. In 1703, the British Hydrographer John Thornton on his “Mapp of the Greate River Ganges As it Emptieth itself into the Bay of Bengala” wrote across the map in large letters, “The Rich Kingdom of Bengala” (Tappin, Jones & Khan, 2015). This gives a clear reference to the fertility of the alluvial plains of Bangladesh.

The primary rivers of Bangladesh, the Ganges, the Jamuna, and the Meghna, under the natural conditions, are perennial rivers. Currently the southerly distributaries of the Ganges, namely, the Mathabhanga, the Gorai, and the Arial Khan are dying, as their Ganges off-takes become silted up and remain almost dry during the winter and summer months, due to natural and manmade reasons. Similar situation prevails for the eastern and central region distributaries of the Jamuna, namely, the Old Brahmaputra, the Dhaleswari, the Bangshi, and the Sitalkhya, as their Jamuna off-takes become choked up during the winter and summer months, due to the same reasons as above. The catchment of the Meghna being mostly in the hilly areas, their tributaries, the Surma, the Kushiyara, etc. remain perennial with low flows during winter and summer months.

Bangladesh contains, in total, more than 230 rivers, out of which 57 are trans-boundary rivers; 54 are common with India, and 3 are common with Myanmar. The upper riparian countries are mainly Nepal, Bhutan, India, and China. Obviously with modernization, water demand in all the riparian countries including Bangladesh has become high. The country wise breakup of the total 1.72 million square kilometers catchment areas of these rivers are given in Table 1(TA Khan (2007).

The flood plains of the Ganges, the Brahmaputra, and the Meghna cover approximately 40% of the total geopolitical area of Bangladesh (Sobhan & Amin, 2010). Bangladesh, being located in the lowest riparian of these trans-boundary rivers, has no control over their flows entering the country, through the international boundary. Challenges for Bangladesh, by virtue of its location, is to drain out more than 90% of the monsoon flood discharges through its land, and also to address the effect of droughts during winter months. The challenges of addressing climate change have been added with it.

Table 1. Country wise break up of catchment areas (%).

Sl No.	1	2	3	4	5
Name of country	Bangladesh	India	Nepal	Bhutan	China
Catchment areas	7.0	64	8.5	2.7	17.80

2 BRIEF HISTORY OF THE RIVER BRIDGES IN BANGLADESH

Mustafiz & Pathan (2010), based on their recent archaeological excavation at Wari-Boteswar, located in the Belabo Upazila of Narsinghdi Zila, shows the evidence of wide asphaltic concrete pavement there; carbon dating shows it dates back to about 500 BC. Shahnawaj & Imran (2011) referring to the Ashoka's inscriptions inscribed in stones, obtained at Mohasthangarh, shows in map that the rule of the Maurya emperor Ashoka (269-232 BC) extended up to the Northern Bangladesh. During the Mughal period between 1608 and 1717 AD, Dhaka was the capital of the then Mughal Suba Bangla; but during earlier period also, Bangladesh region contained a well-organized road network with small span bridges. These were constructed of brick masonry in plane land and stone masonry near the hilly region. Aroad existed long before the reign of the Afghan ruler Sher Shah Suri (d. 1545 AD). This road started from Langal Band of Narayanganj Zila, ran along the western bank of the Brahmaputra river, touched Wari-Bateswar of Narshingdi Zila, and ended at the Pataliputra (present Patna) of Bihar. Also the Afghan ruler Sher Shah Suri built the Grand Trunk Road, which starts from Agra, runs via Bangladesh, and ends at Arakan of Myanmar. Nuruzzaman and Sabbir (2015), based on the sketches of Sir Charles D'oily (1781-1845),gives the list of some of the Mughal bridges (Table 2).

Table 2. Mughal bridges.

Location of bridges	Description of bridges
Mir kadim Bridge, Munshiganj	3-span 4-centered brick masonry arch bridge
Sarail Bridge on Comilla-Sylhet highway	1-span 4-centered brick masonry arch bridge
Tongi bridge (ornamental)	3-stilted 4-centered arch spans in the middle, plus 2x1 arch spans at both ends
Paugla bridge, Narayanganj	3-stilted 4-centered arch spans in the middle, plus 2x1 arch spans at both ends

Since the British period, the reinforced concrete (RCC), and steel composite, and steel truss bridges have been built in Bangladesh.

3 EFFECT OF MULTIPLE SPAN BRIDGES ON THE PRIMARY RIVERS OF BANGLADESH

Long span bridges are generally designed as multiple span bridges; but in spite of providing strong river training works, severe erosion of river banks occur, even threatening outflanking of the bridge also. Again, multiple piers in the primary rivers of the country invite new char and shoal formations, beside aggravating the existing ones. Two case studies are presented below; one, on the Hardinge Railway Bridge over the Ganges at Paksey, and the other, on the Bangabandhu Jamuna Bridge at Sirajganj.

3.1 *Case Study 1: Hardinge Bridge on River Regime*

The Hardinge railway bridge over the river Ganges had been built by the British engineers and was opened to traffic on 04 March 1915 (Figure 1). Some pertinent bridge and hydrological data of the river are given below (Table 3). Sir Alexander Robert Gales, a partner of Rendel Palmer and Tritton (RPT) was the Chief Engineer of the bridge project. Historically the Ganges shifted courses around the bridge location frequently. Comparing the courses, the river occupied during 1780, 1868, 1917,and 1933, shows the river shifted courses within a band of about 12 km (Figure 2). Gales stated, while the design was ongoing, at that time also, the river course near the bridge site, had been moving eastward at the rate of 61m (200 ft) per year. Considering the dynamic nature of rivers in alluvial plains, from the time of completion of the bridge, watchmen were posted at each of the protection bank locations, to patrol and report any unusual occurrence in them (ref. Tippin, Jones & Khan, 2015).

Figure 1. Hardinge railway bridge at Paksey, North Bengal.

Table 3. Span arrangement of Hardinge Bridge and hydrological data of the river.

Total length, m (ft)	Span arrangement	Measured Q_{max} (1910), cumec (cusec)	HWL MSL m (ft)	Design Discharge, $Q_{max,}$ cumec (cusec)	During construction	
					$V_{max,}$ m/sec (ft/sec)	V_{mean} m/sec (ft/sec)
1,713 (5,328)	15 main spans @ 105 m (345 ft/sec) + 3 land spans @23 m (75 ft)	54,542 (1,926,080)	14.47 (47.47)	70,795 (2,500,000)	3.90 (12.80)	2.55 (9.34)

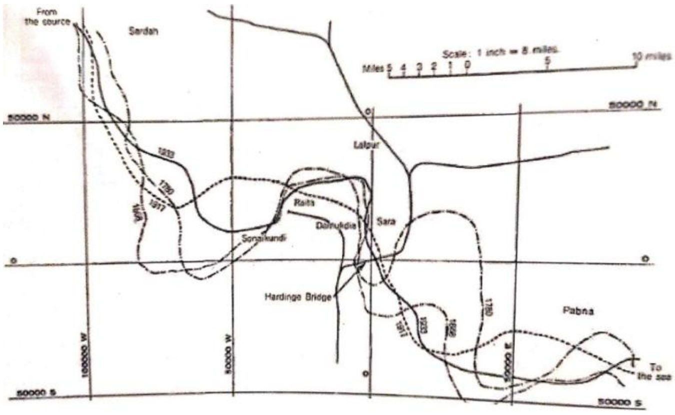

Figure 2. Course of the Ganges between 1780 and 1933.

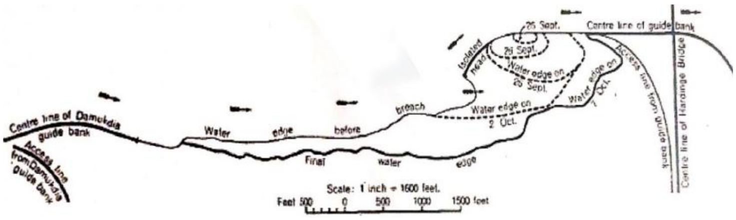

Figure 3. Failure of right guide bund during September-October 1933.

During the high flood of 1933, the right bank guide bund of the bridge had been almost failing (Figure 3). On 25 September 1933, a breach of right guide bund completely cut off portion of portion of it from the main land, forming it an island. On 07 October a rapid fall in the river caused the breach to extend to 488m (1600 ft). The total scheme for protection of the bridge adopted by Gales is shown in Figure 4. Sir Claude Inglis of Poona Hydraulics Laboratory, who developed the concept of falling apron for river training works used it first time for the Hardinge bridge. He pointed out that the major cause of the above failure was the construction of the Damukdia guide bank. This was against the common-sense logic that opposing the direct force of flow caused relatively harmless kinetic energy to be changed to highly destructive turbulent eddy-flow of an unstable kind, accompanied by surging; whereas the way to control flow should have been by coaxing the river to swing in a large natural curve, around a fixed guide bund. The outflanking was saved by several years of continuous surveillance, and dumping of stone ballast during monsoon period. Gales opined that from the stability point of view, Sara "hard" point would have been the ideal location of the Hardinge bridge, but this couldn't be done due to urgency and unavoidable other reasons on behalf of the Client. The observed subsequent severe char formation in the river includes effect of the multiple piers of the bridge also.

It's evident from the above that even though the Hardinge Bridge had been under a very close monitoring after its commissioning in 1915, a very critical condition threatening the safety of the bridge was created. The situation suggests the cost of maintenance of the bridge during its life time may exceed cost of the bridge.

3.2 *Case Study 2: Effect of The Bangabandhu Jamuna Bridge on River Morphology*

The Bangabandhu Jamuna Bridge is 4.80 km long, comprising 47 main spans @100.00 m per span, plus 2 equal end spans (Figure 5). The bridge has been opened to traffic during 1998.

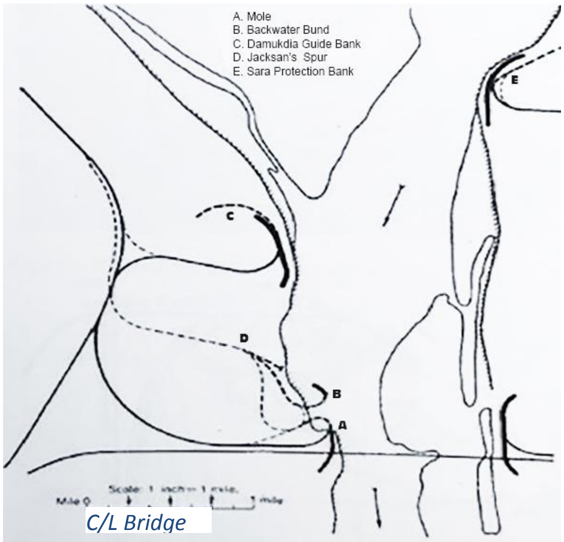

Figure 4. Total scheme of protection of the bridge.

Figure 5. Bangabandhu Jamuna Bridge.

Figure 6. Braided Jamuna River.

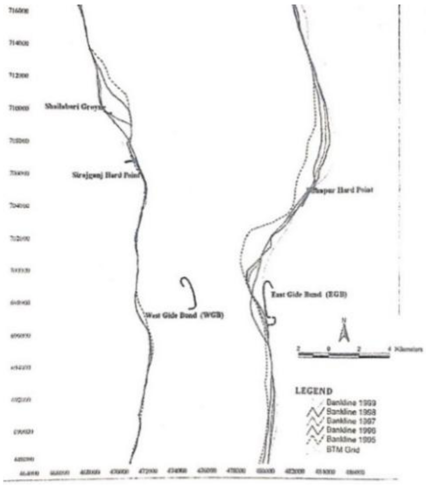

Figure 7. Guide bunds and bank line shift of Jamuna River (1995-99).

A few pertinent data of the Jamuna river at Sirajganj bridge site are: the recorded maximum discharge during high flood,100,000 cumec, which is higher than that of the Hardinge bridge; the river bed material is silty micaceous type, up to about 70.00 m depth; the sediment concentration, combining both suspended and bed material, measured on 01 & 02 October 2000, maximum 11,097 mg/l and minimum 132 mg/l (SWMC, 2001). For the high flows of the Jamuna river, this silty micaceous type bed material contributes to the excessive scour depth of about 40.00 to 45.00 m below river bed; besides, it contains high liquefaction potential; and lastly, this gives much reduced horizontal shaft resistance by deep pile foundations, requiring excessively large lengths of piles.

The satellite image of the Jamuna river at Sirajganj bridge site shows the braid belt of the river along with the west an east side guide bunds (Figure 6). The approximately 10.00 km wide river at bridge site has been guided to 4.80 km bridge length (Figure 7). This also shows this reduction of the river width has been done mainly on the west bank side of the river. Both side river banks of the river have been stabilized by the guide bunds, and several hard points, connected with the bridge by embankments (SWMC, 2001). TY Lin International, on behalf of the contractor uyundai, designed the bridge. The plan of the bridge and its west and east bank guide bunds is shown (Figure 8).

The satellite images taken during January & November 1999, and February 2002, show the eastward migration of the river, due to construction of the bridge and the guide bunds. The pattern of the char migrations observed during 1998 and 1999 are shown in Figure 9 (ref. SWMC, 2001). It's presumed this includes effect of the multiple bridge piers also.

A conservative design for the slope protection works of the west and east guide bunds of the bridge have been followed. The riprap has been extended from the top of the river bank up to the maximum scour depth below the river bed. The excavation along the slope has been done by dredging. Such dredging in micaceous silt has the risk of collapse of the excavated slope. The slope protection has been designed as launching apron, following Spring's guidelines, as noted in case of Hardinge bridge earlier; that means additional quantities of stones have been kept as reserve in the toe to compensate the potential additional scour that may occur.

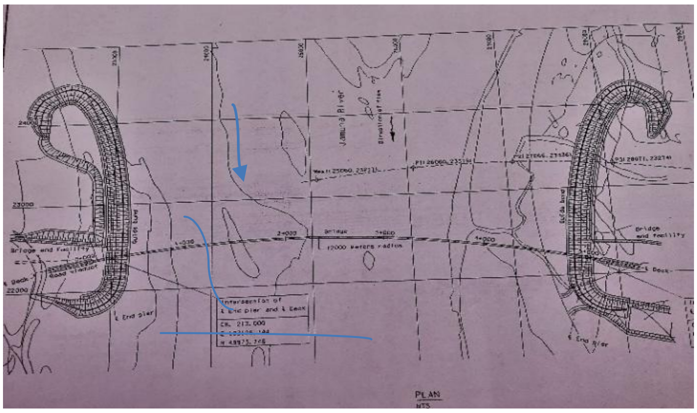

Figure 8. Plan of Jamuna Bridge.

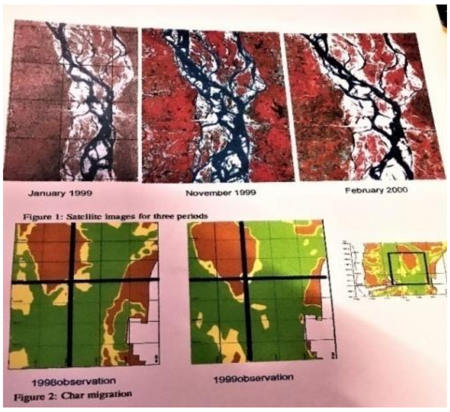

Figure 9. River and char migrations of the Jamuna (1998-2000).

In spite of all the above strong protection, the risk of outflanking the bridge by the river is not eliminated. Continuous monitoring of the guide bunds and the "hard" points are being done. In sum up, due to reducing the width of the Jamuna river by more than 5.00 km, the guide bunds and the "hard" points are needed to be monitored and maintained during the whole life time of the bridge.

The mathematical model studies done, apparently (based on Figure 7 & 9) gives it included the guide bunds only, but not the bridge piers (SWMC & DHI, 2001). The interpretation of 1995-1999 bank lines (Figure 7), shows the bank line shifting is predominantly due to reduction of the river width by the guide bunds, and the effect of "hard" points combined. The careful examination of observed and satellite map of the bridge location (Figure 9) indicates additional char and shoal formations and the changes in the pattern of the existing ones, are due to the effect of the multiple river piers in the braided river.

4 BRIDGES IN DELTAIC FLOOD PLAINS AND COASTAL ESTUARIES

4.1 *Bridges in Deltaic Flood Plains*

Sobhan and Amin (2010) showed that for maintaining stable river regime in the deltaic region, the maximum and minimum discharge ratio (Q_{max}/ Q_{min} ratio) plays an important part; this should preferably be 10, but not exceeding the upper limit of 20. Currently almost all the rivers in the deltaic flood plains of Bangladesh, become almost dry during the winter and summer months, that means this ratio far exceeds the sustainability limit. The Old Brahmaputra River bridge, located in the Belabo Upazila of the Narsingdi district is cited as an example (Figure 10, ref. The RHD Setu Album, 2008-2016). The photograph shows the people cultivate paddy crops in the almost dry river bed; and it also shows thick vegetative cover in the slope and in river bank.

Figure 10. Old Brahmaputra River Bridge in Belabo UZ, Narsingdi Zila. (Ref. RHD Bridge Album).

In natural river, the high flows during monsoon, normally deepens the river bed by occurring bed scour, and the enlarged cross-sections, achieved thereby, enable transmission of the normal flood discharges up to bankfull level without adversely affecting the river regime. In case of excessive floods, the excess water over-spills the bank and spreads in the flood plains with slow speed. This release of the excess pressure on the main river course, doesn't endanger the lives and properties of the people, rather shallow depth flooding of the flood plains enhances the fertility of the agricultural land, by depositing silt in it. People welcome this sort of normal flooding.

In case of the above Old Brahmaputra river bridge (Figure 10), the paddy cultivation in the river bed hinders the normal scouring of the river bed during monsoon flood; and the excessively thick vegetative cover of the river bank enhances its roughness coefficient and thereby retard the flood flows. As a result, the HWL exceeds the danger level, causing damage to lives and properties. Most of the Local Government Engineering Department (LGED) bridges in rural areas fall into this category.

From this, the inference may be drawn that, to sustain the stable river regime by the rural bridges in the flood plains, have two options; either augmenting the natural flow regime of the rivers by any means, so that the Q_{max}/ Q_{min} ratio is reduced to allowable limit, as the situation our forefathers enjoyed. Alternatively, designing the bridges avoiding multiple river piers is the other good choice. In the latter case, by eliminating river piers, the causes of affecting river regime by bridges are eliminated.

4.2 *Case Study 3: Halda River, Chittagong Hill Tracts*

4.2.1 *About the river*

Halda is a 81 km long tributary of the Karnaphuli river. It originates in Badnatali hill of Ramgarh Upazila in the Chittagong Hill tracts and flows through Fatikchari, Hathazari, & Raozan Upazilas, and thereafter joins the Karnaphuli river in Chandgaon Thana of Chittagong Metropolitan city. At about 48 km downstream from the source, Dhurung river joins with Haldaat Purba Dhalai. The river is navigable, by big boats up to Nazirhat, located at about 29 km upstream of the Karnaphuli offtake, and by small boats up to Narayanhat, 6-24 km further upstream. The depth of Halda varies between 6.40m and 9.10m. Islam (2018) stated in an interview with Inqilab that in Bangladesh, Haldais the largest natural breeding place for Indian carps. During 2017 & 2018, the mother fishes brood eggs1,680 kg and22,680 kg respectively. Total earning from this would be about several thousand crores taka, which shows the high economic potential of this river from aquaculture alone. Several other species of mother fish migrate to the spawning ground of Halda from the Karnaphuli, Matamuhuri and Sangu. The oxbow bend locations, where the speed of the flush flood of the river reduces are considered as the ideal location for fish spawning. Fishermen collect the eggs after spawning ends. At present, the carp fish territory is under risk of extinction because of the several polluting agents e.g., rubber dams, embankments, sluice gates, loop cutting in meanders, waste discharge from paper industries & power plant, oil spill and noise pollution by ships in the Chittagong port, etc.

4.2.2 *Bridges for sustainability of Halda*

As shown earlier for the Padma and the Jamuna rivers that the multiple bridge piers affect the morphology of the sensitive rivers, the same is true for the Halda river also for ecological reasons. It's advisable to restore the favorable environment for deriving economic benefit from this river, as explained earlier. The lash green hill setting also suggests an aesthetically beautiful single span bridge will be more appropriate for this river. The Roads & Highways Department (RHD) constructed an aesthetically beautiful 51.20 m long elevated tied concrete arch type bridge on the Dhum-Ramgarh highway (Z1602) in the same Chittagong Hill tracts. Accordingly, the Author chooses an arch bridge for this location also. Out of the many types of arches, his preliminary selection is in favor of either Nielsen type arch or the Network type arch, considering ease of building with local materials and local technology. One 40.00 m long Nielsen type arch bridge over the Modhumati river in Gopalganj, and another 56.50 m long Network Arch bridge at Rayerbazar Graveyard, Dhaka, have been designed and also supervised their construction by the Author's company. One photogenic steel Nielsen type arch bridge has been constructed reportedly by an expatriate company for the fish market in Chittagong, near the 2nd Karnaphuli extra dozed type bridge. The concept of the Network arch bridge has been developed by the Norwegian Professor Per Tveit. The Author improvised the design further enabling the Bangladeshi contractors to build it (ref. Sobhan, 2015). Several longer span network arch bridges, designed by the Author's company have been constructed in Nepal, and also one in Bhutan. The Author, based on those experiences, considers the latter option will be more appropriate for Halda, considering ease of construction and cost. The sample bridge for the case study is located on Chittagong-Rangamati national highway N106 (Figure 11).

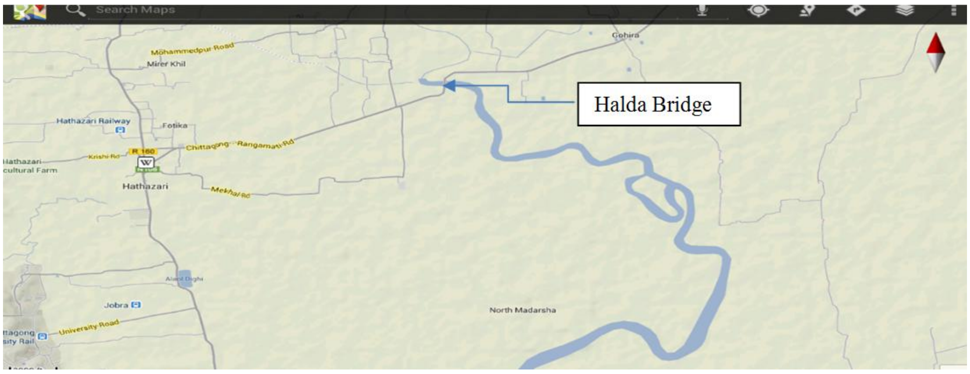

Figure 11. Location map of Halda Bridge on N106.

In this location, one existing dilapidated 5-span bridge needed replacement. RHD first designed the replacement bridge using the identical 5spans as of the original bridge (Figure 12). During the construction stage, the design was further modified to equal 3 spans, and constructed accordingly.

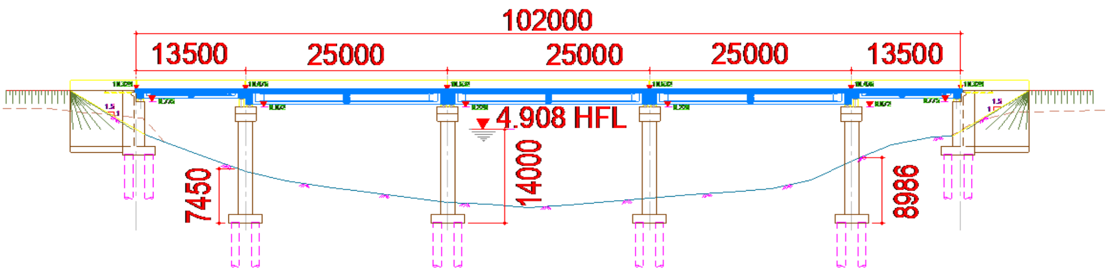

Figure 12. Typical design of a 5-span bridge for Halda River.

The Author now shows the possible re-design of the bridge as single span network arch bridgefor the same 102.00 m long single span network arch bridge (Figure 13).

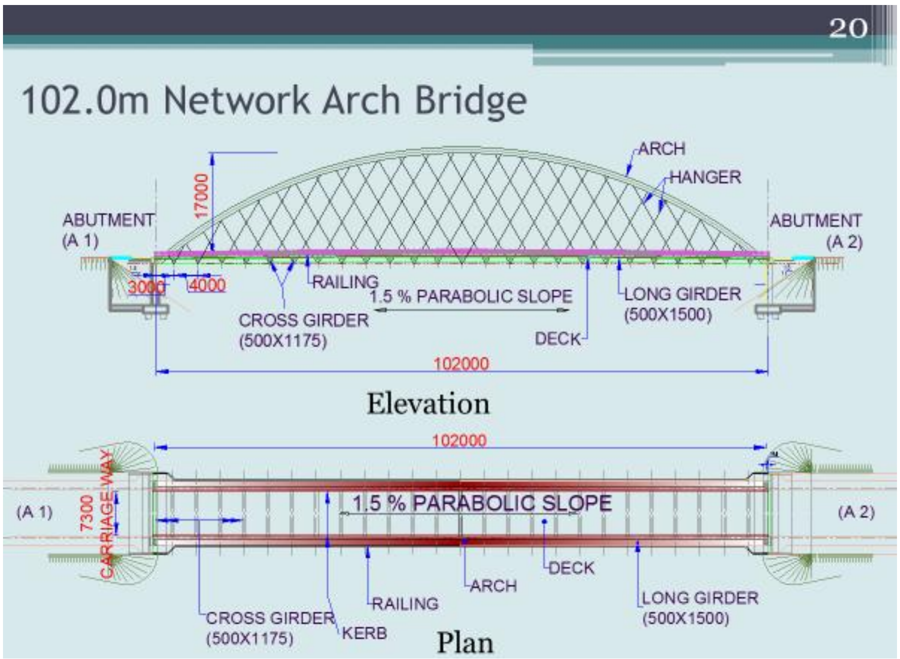

Figure 13. Typical plan and elevation of the bridge.

This design possesses flexibility in providing adequate navigational clearance, both horizontal and vertical, as required by Bangladesh Inland Water Transport Authority (BIWTA). It saves considerable material compared to the conventional other types. Because of elimination of river piers, saving in foundation cost is obtained. Thereby, it's relatively cost-effective, and local contractors have already gained experiences in constructing such bridge.

4.3 *Bridges for Sustaining Coastal Estuaries*

The tidal estuary are defined as that part of the rivers, channels and creeks, through which the diurnal flow and ebb tides originated in the sea, propagates landward by their potential and kinetic energy, and after exhaustion of the same, recedes back to the sea as ebb tide. Thus, all the southerly rivers from the upland become tidal rivers near their mouths at the sea. The past and the present scenario of development in the coastal belt is discussed now.

4.3.1 *The past scenario of development*

In the decade of 1960s up to 1980s, 92 number polders had been constructed all along the coastal estuaries, mainly for agricultural and aquaculture development; simultaneously, these were intended to provide some minimum protection to the people and the livestock against cyclonic surges also. The polders of the Khulna and Chittagong zones are shown (Figure 14 & 15).

4.3.2 *The current scenario of development*

Currently with globalization, re-use of these polders for port and power plant development, etc. have already started. For example, construction of Payra sea port near Kalapara in Polder 43/1 (Figures 16a & b). This shows how the past use of the polder is being shifted from agricultural to industrial or port development purposes, satisfying the current economic demand.

Under this scenario of industrial and port development, etc. in this coastal belt, many new bridges will be needed for crossing the tidal rivers and estuaries. One example is the under-construction Lebukhali Bridge near Patuakhali (Figure 15). The cable-stayed type bridge has been designed for this location, instead of the multiple span bridge containing multiple piers in the heavily sediment-laden tidal river. This has been the right decision in consideration of maintaining the stable regime of the tidal estuaries. Alternative could be tunnel, as of the under-construction Karnaphuli tunnel or equivalent.

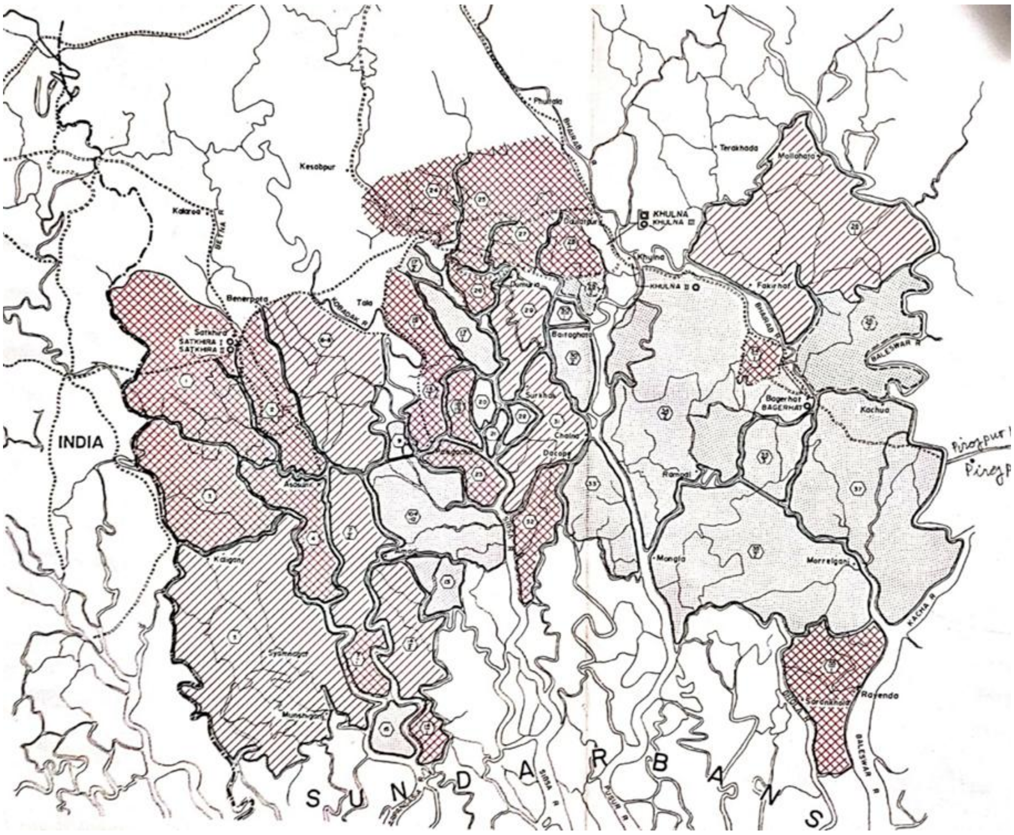

Figure 14. Khulna circle CEP polders (Ref. LDL polder maps, 1968).

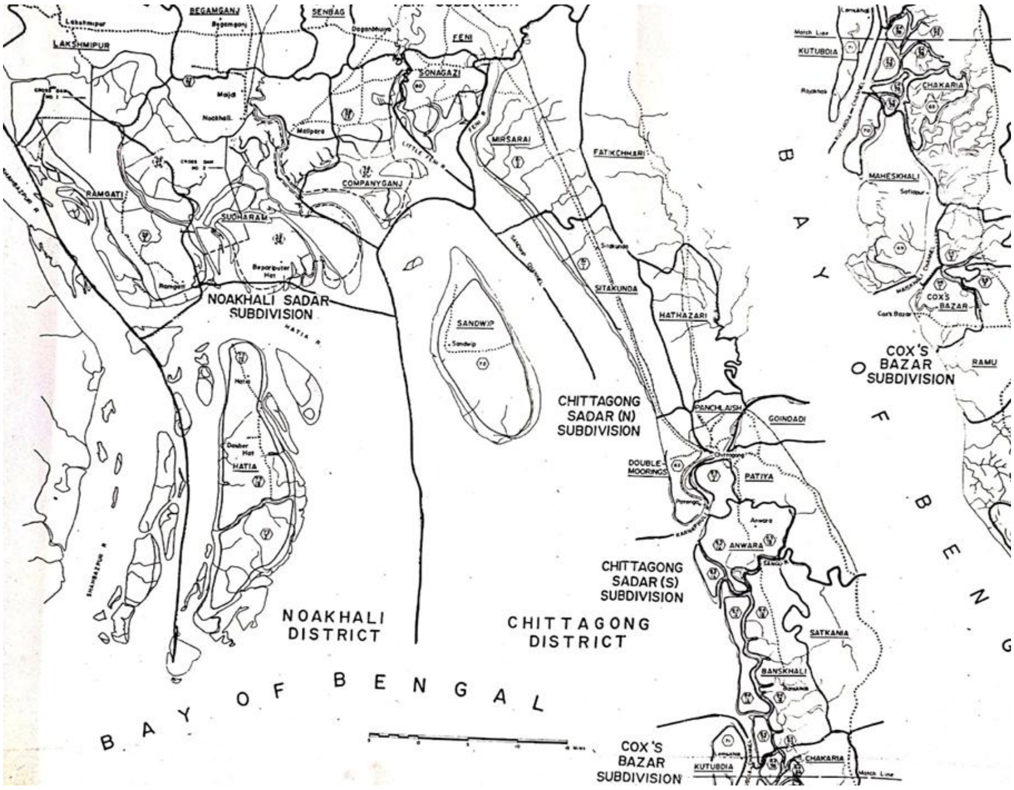

Figure 15. Chittagong circle CEP polders (Ref. LDL polder maps, 1968).

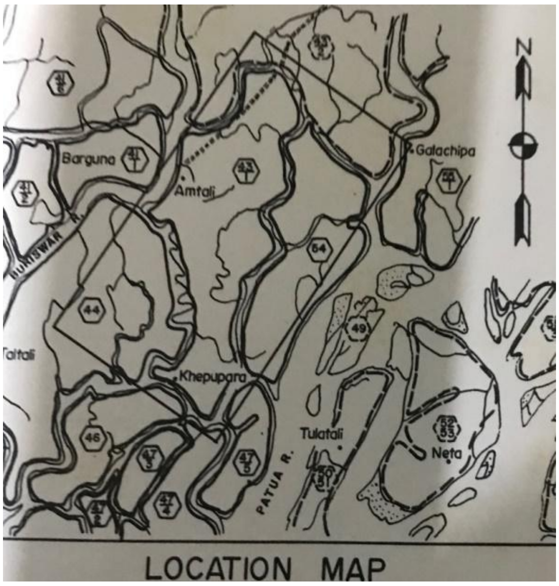

Figure 16a. Payra sea port in Polder 43/1

Figure 16b. Paya sea port in Google map.

Figure 17. Lebukhali Bridge (under-construction).

5 CONCLUSIONS

Bangladesh, being formed as delta, by the silt deposits of the Ganges, the Brahmaputra, and the Meghna river system, its flood plains are very fertile, under natural condition. The country's people genuinely consider their river system as their life blood. In the recent decades, the characteristics of this precious river system are being destroyed due to both the natural and manmade causes. Amin & Okui (2015) shows when the Britishraj thought of constructing railways in India during the decade of 1860s, they deeply felt the importance of studying the river morphology of the different rivers of India, including those of Bangladesh. The paper presented case studies how seriously the British engineers considered the effect of the Hardinge bridge at Paksey would affect the bank line migration and river morphology of the Ganges (Padma), and accordingly designed the guide bunds and river training works. Similarly for the Jamuna river, in spite of their competent design, occasional threats of outflanking of the bridges by the rivers, could not be eliminated for these two sensitive rivers.

The current scenario of the above two bridges suggests, continuous monitoring and restoration of either partial or sometimes total failure of the part of the river training works will be needed for the whole life of the project. Thereby the whole life cost of the maintenance works of the bridges may exceed the original capital cost of the project. Besides, the aggravation of the rivers by char and shoal formations due to effect of the multiple river piers of the bridges, may hinder navigations of the ferries and other vessels all the year round. Due to it, intensive recurrent dredging to keep the channels navigable all the year round might be needed. Frequent accidents are thereby caused by the vessels, hitting these chars and shoals.

It's recommended that, in these two sensitive rivers, in future, either long span cable-stayed bridge, or tunnels underneath the river bed, should be given a serious thought. This may reduce the whole life cost of the river crossing projects considerably.

Currently for bridges in the flood plains, threats on the river regime and excessive flood inundations prevails. The ongoing 2020 flood has proved the correctness of this apprehension. The paper explained the reasons for it in details by an example of the Old Brahmaputra river bridge at Belabo in the Narsingdi Zila. The rivers in the flood plains remain almost dry during the winter and summer months. Currently, due to it, the maximum and minimum discharge ratio of most of the rivers in the country's flood plains exceeds, many times the sustainable upper limit of 20. The local people cultivate crops in the river bed; the unusually thick vegetation grows in the river bank and slope lines. Because of these obstructions, the maximum flood discharge is unable to cause normal scour below the river bed. As its effect, the river swells raising flood heights excessively. The multiple piers of the bridges, under this condition, aggravates the flood situation further. Two probable solutions have been discussed, one is flow augmentation by creating reservoirs upstream, or by designing bridges eliminating river piers. The execution of the latter solution is possible with the available technology, and capabilities of the local professionals, and contractors, and at an economical cost also. This has been discussed in the case study of the Halda river bridge.

For the coastal estuaries, BWDB constructed 92 polders during the decades of 1960s to 1980s; their objectives had been defined the agricultural &aquaculture development, and providing minimum protection of people and their livestock against damage by cyclones and normal tidal bores. The paper while discussing the role of bridges in these estuaries, observed alternative use of some of these polders for industrial, power, and sea port development. For example, in Polder 43/1 in Khepupara under Patuakhali Zila. Payra sea port and other ancillary structures are under construction in this area, using embankments as roads. Apparently, this trend of alternative industrial use simultaneously with the agricultural and aquaculture may be the future trend. All these developments necessitate different kind of bridges for crossing the tidal rivers. At present excessive sediment load carried by the flow tides being deposited in the bed of the river chokes the river mouth affecting flood discharge capacities during ebb tide. Now, near Patuakhali, Lebukhali bridge is under construction. The client has rightly selected the long span cable-stayed type bridge for it. This will help in sustaining the stabile regime of the estuaries. If the current trend of industrial development progresses, then for selected large tidal rivers, alternative tunnel options may also be found justified economically.

James Meadows Rendel, founder of Rendel, the latter RPT, who designed the Hardinge bridge, was the President of the Institution of Civil Engineers, UK. At that time he made an important remark in his presidential address on 13 January, 1852, "History of the civil engineer shows that mere technical knowledge of the details of a work, however critical and correct, will not of themselves lead to distinction. All undertakings must be examined with comprehensive views of their ultimate effects, not only as regards immediate projectors and the present time, but on society generally and on the future."

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