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Application of narrow box steel girder with SCC deck slab and SPSP foundation in KMG Project

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ABSTRACT: Dhaka-Chittagong National Highway N1 is the economic lifeline of Bangladesh. But N1 is appraised to be inadequate to suffice the growing traffic demand. To accommodate the current and the future traffic demand, GOB is implementing 4-lane Kanchpur, Meghna and Gumti 2nd bridges construction through RHD. The superstructure of 2nd bridges is comprised of narrow box steel girders monolithic with Steel Concrete Composite (SCC) deck slab. The 2nd Meghna Bridge is 12-span continuous bridge of total length of 930m with 9 spans having 87m maximum span, whereas the 2nd Gumti Bridge is separated into two parts: 9-span continuous and 8-span continuous bridge with an expansion joint in between, having 17-spans with a total length of 1,410m and a maximum span of 87m. The foundations under severe scouring zone are of Steel Pipe Sheet Pile (SPSP) type. Therefore, application of these stated concepts in KMG Project will add a new dimension to the bridge construction industry in Bangladesh.

1 PROJECT BACKGROUND

Government of Bangladesh (GOB) has been implementing several major long bridges construction technology since 20~30 years back. Among them, the technology on Prestressed Concrete (PC) was introduced and added a dimension to bridge construction industry. As of their continuation, the existing Meghna and Gumti were designed with PC box girder type bridge and constructed in 1991 and 1995, respectively in order to connect the missing links between two particular sections on National Highway N1. On the other hand, Bangabandhu Bridge (Jamuna Multipurpose Bridge) was constructed in 1998 on National Highway N405, which is the longest PC box girder bridge among the bridge construction industry available in Bangladesh. Afterwards, several PC box girder type bridges were constructed on National Highways.

The traffic capacity on the highways connecting the major cities and metropolitan areas in Dhaka cannot keep up with the year-after-year increase of traffic volume, which necessitates on widening of National Highways and construction of new 2nd bridge parallel to the existing one. On the other hand, damage to roads and bridges is progressively increasing and has restrained traffic. In addition, Bangladesh National Building Code (BNBC) has been implemented in 1993 and the earthquake standards have been raised in 2006; therefore the existing bridges no longer meet the earthquake resistance standards. Accordingly, rehabilitation and retrofitting of the existing bridges have undoubtedly become a pressing issue.

With regard to the fact stated above, GOB is mainly concentrated on how to resolve two major issues through Kanchpur, Meghna and Gumti 2nd Bridges Construction and Existing Bridges Rehabilitation Project (referred hereinafter to as KMG Project). In KMG project, first issue includes the construction of three 2nd bridges (Fig.1) on National Highway N1, whereas the second issue covers the seismic-retrofitting of existing bridges. With regard to KMG implementation, a new concept of continuous narrow box steel girder type bridge is applied for 2nd bridge construction. In which, three narrow box steel girders monolithic with SCC deck slab will be used as superstructure, whereas SPSP closed to well shape is determined as the most suitable type foundation. Moreover, due to incorporation of the updated seismic specification along with severe riverbed scouring countermeasure, the foundations of existing bridge are appraised to necessitate adequate seismic-retrofitting. These foundations, subjected to severe scouring, are planned to retrofit by SPSP foundation which will be unified with those of 2nd bridge as well. Therefore, applying the concept of narrow box steel girder with SCC deck slab as superstructure and the SPSP as foundation in new bridges construction along with implementing the method of seismic retrofitting for existing bridges will add a new dimension to the bridge construction industry currently available in Bangladesh.

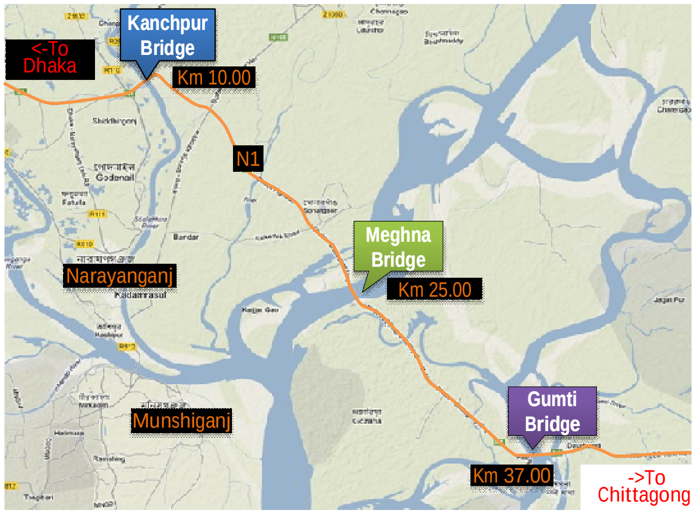

Figure 1. KMG Project Location

2 BRIDGE CONSTRUCTION HISTORY IN BANGLADESH

The number of bridges within the RHD road network has been increased dramatically since 1991. Accordingly, the growth in the number of bridges in the last 20 years is shown in Table 1. The numbers monitored and maintained by RHD administration are 18,356 currently which are around six (6) times that in 1991.

Table 1. Year wise no. of bridge structures under RHD management

	Year wise structure					
	1991		2006		2012	
Road classification	No. of culverts &bridges	Total length (m)	No. of culverts & bridges	Total length (m)	No. of culverts & bridges	Total length (m)
National Highway	1,012	55,393	3,617	64,837	3,649	65,013
Regional Highway	302	9,896	3,535	43,828	3,612	44,370
Zilla Road	1,843	26,383	7,560	75,933	11,095	109,920
Total	3,144	91,672	14, 712	184,598	18,356	219,303

Source: FS Report (2013)

In addition to the bridges listed in Table 1, the 1.8 km long Hardinge Rail Bridge which is steel truss type, was constructed in 1915 over the river Padma located at Paksey in western Bangladesh. At this stage, United Kingdom built mainly all rail bridges as steel bridge in principle. The exception is the construction of Jamuna Multi-purpose Bridge in 1998, which is PC box girder type road-cum-rail bridge with total of 4.8 km in length having 100m maximum span. It is exceptional in a sense that the Jamuna Bridge is completely new type road-cum-rail bridge with respect to other rail bridge construction history in Bangladesh since last 50 years. Therefore, these clearly make an evidence that Bangladesh has concrete bridge construction experience including long road bridge construction since last 20~30 years.

2.1 *Superstructure*

In accordance with RHD classified structures, total number of 18,356 structures categorizes 14-types of structures which are under RHD asset management. Among them, the bridges are of 11-types having RCC girder type bridges in maximum number (FS report, 2013). On the other hand, Bangladesh has good track record on the construction of major long road bridges since 1991. They are basically two types such as Prestressed Concrete (PC) box girder and PC girder type. Seven (7) PC box girder bridges (Table 2) have been constructed in Bangladesh and opened to road users, having total length within a range of 918m~4,800m with 79.5m~116.2m maximum span.

The existing Meghna is 13-span bridge with a total length of 930m having 87m maximum span. Its 11 spans from Dhaka side are PC box type having hinge and expansion joint at mid span. The end 2 spans at Chittagong side are PC-T girder type. Likely to Meghna, the existing Gumti is 17-span bridge with a total length of 1,410 m and its superstructure is continuous PC box girder type having hinge and expansion joint at center span.

Bangladesh entered into the era of PC Extradosed Box Girder Bridge through the design and construction of the 3rd Karnaphuli Bridge in 2010. The bridge is 950m long and 24.47m wide. The bridge is located on Chittagong-Cox's bazar Highway (N1) over the river Karnaphuli at the east side of Chittagong Port City of Bangladesh. The bridge has the curved span of 200m and it is the longest curved span in the world in the case of Prestressed Concrete Extradosed Box Girder Bridge until now.

Table 2. Major PC box girder bridges in Bangladesh

No	Bridge name	Length (m)	Max. Span (m)	Year of Completion	Foundation
1	Jamuna	4,800	100	1998	Steel pile(ϕ2.5&3.15m, 80m)
2	Paksey	1,786	109.5	2005	CIP RC pile(ϕ 3m, 75m)
3	Gumti	1,410	87	1995	CIP RC pile(ϕ 1.5m, 75m)
4	Rupsa	640	100	2005	CIP RC pile(ϕ 2.5m, 66m)
5	Bhairab	929	110	2002	CIP RC pile(ϕ 2m, 91m)
6	Meghna	930	87	1991	CIP RC pile(ϕ 1.5m, 91m)
7	Gabkhan	917.7	116.2	2001	CIP RC pile

Source: Japan-Bangladesh joint seminar (2005)

2.2 *Foundation*

Generally, whenever the bridge is planned to cross relatively wide river, the deep supporting layer at the beneath of foundation is necessary to confirm. Prior to determining the design depth of foundation, the local scouring depth around the pier is necessarily to be undertaken into calculation. For determination of foundation type, two typical forms, namely open caisson and cast-in-place (CIP) RC pile type foundation are taken into consideration. These two types are frequently used in Bangladesh. However, their selection depends on the depth of supporting layer available underneath the riverbed. If the supporting layer is confirmed at a shallow depth, 'Open Caisson method' can be used to construct bridge foundation. It is also to be confirmed that after the caisson is embedded to the desired depth, its bottom should be sealed with lean concrete. On the other hand, whenever the supporting layer is confirmed to a depth more or less equals to 90m, the CIP RC pile type foundation is the suitable candidate for selection. They have a good track record in Bangladesh. In addition to caisson and RC pile foundation history, Bangladesh experienced on the application of the inclined steel pile foundation having a large-diameter (maximum φ3.15m) in case of Jamuna Bridge construction, which deems an exceptional case and provides additional dimension to the era of bridge construction history.

3 APPLICATION OF NEW TECHNOLOGY IN KMG THREE BRIDGES PROJECT

3.1 *Superstructure*

3.1.1 *Narrow box steel girder*

1) Type of steel bridge having span length 90m

The span length of three 2nd bridges under KMG Project is determined within a range of 43.3m~97.8m for Kanchpur Bridge, 87.0m for Meghna and Gumti Bridges. With regard to the span arrangement determined above, several types of steel bridge, namely continuous box girder type with non-composite structure, box girder type with orthotropic steel deck, arch type, truss type and narrow box girder type can be suitable candidates for the superstructure of KMG three bridges. However, recently in Japan, the narrow box steel girder is frequently used as bridge superstructure due to its several advantages including economic efficiency, workability and ease of maintenance works. Due to the said advantages, the narrow box steel girder is selected as suitable type for the superstructure of KMG three bridges.

2) Salient features of narrow box steel girder

The narrow box girder bridge is a rationalized box girder bridge in which the structure inside the box is simplified by using a thicker flange and a narrower web distance of the box section than conventional box girders and rationalization is also sought by using a highly rigid steel-concrete composite deck. This type of bridge features excellent maintainability, improved aesthetic appearance and very good site constructability. Fig. 2 shows a comparison of narrow box steel girder with the conventional steel box girder structure.

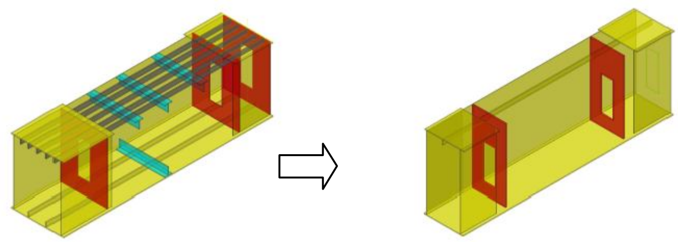

Figure 2. Comparison with conventional box steel girder

Longitudinal ribs must be placed at the necessary intervals on the compression flanges of a conventional box girder bridge to prevent buckling and ensure that the allowable stress is not exceeded. Cross ribs also need to be placed.

On a narrow box steel girder bridge, the narrow web distance resulted in a small flange width, so the flange thickness needs to be increased. This allowed the number of longitudinal ribs to be reduced. Fig.3 shows the required number of longitudinal rib with respect to relation between web distance and flange cross section area. On a conventional box girder bridge with flange thickness 25mm, the web distance of 3.0m or so and four (4) longitudinal ribs are needed, while on narrow box steel girder bridge with flange thickness 45mm and a web distance of 1.8m, the number of longitudinal rib can be reduced to 1.

Fig.4 shows the relation of the required stiffness (height) of longitudinal ribs and transverse rib spacing as parameters of web distance and the number of longitudinal ribs in case of flange with 40mm thickness of SM490. In case the web distance is less than 1.8, transverse ribs spacing can be expanded without increasing stiffness (height) of longitudinal ribs. That means that the required stiffness of a longitudinal rib on a compression flange is constant regardless of transverse rib spacing, so diaphragms only can be applied without transverse ribs.

In fabrication of the narrow box steel girder, the welding work can be eased by reduction of number of small plate materials such as ribs. And it is also possible to decrease overall surface area that leads to the reduction of paint quantity.

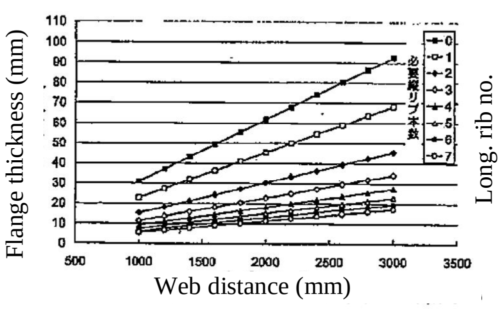

Figure 3. Necessary no. of longitudinal ribs to web distance and flange thickness (SM490Y)

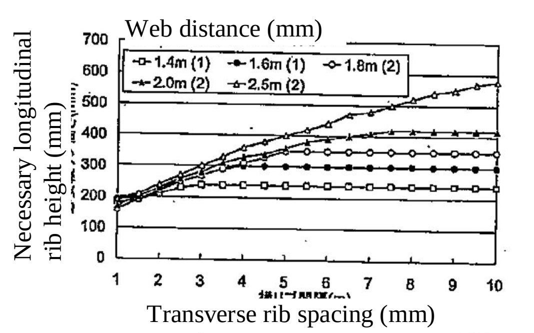

Figure 4. Transverse rib spacing and necessary longitudinal rib height to web distance

3.1.2 *Steel concrete composite (SCC) deck slab*

1) RC slab damage case in Japan

In 1980s, several cases of RC slab damage were observed in Japan, which is due to the increasing movement of large size traffic volume resulted from economic growth. The initial cracks in a reticular pattern were formed and damages in RC slab were generated from slab underneath. Then the progress in damage was accelerated and ultimately covered the entire area. The reason behind it is the frequent movement of heavy size vehicle. It caused concrete spalling prior to embedded rebar fracture and progressed in damage as well (Fig. 5). Taking this fact into background, Japan Road Association (JRA) developed highway bridge specifications on how to strengthen the floor slab in 1972 and followingly updated in 1996. Moreover, in parallel, several extensive research programs on durable floor deck were carried out by universities and private companies in Japan.

a) Reticular crack in concrete

b) Concrete spalling

Figure 5. RC slab damage in Japan

2) RC slab damage restage study

To make enhancement on RC slab function, it is necessary to grasp accurately the damage mechanisms in RC slab by conducting lab test.

(i) One point loading test on RC slab

At first in Japan, the point loading test was conducted on RC slab where load was applied repeatedly at one point (Fig. 6) to understand the fatigue resistance. It was observed that radial cracks below the loading point spread through the underneath of RC slab. However, it was impossible to restage the damage mechanism in RC slab.

(ii) Moving wheel loading test on RC slab

A moving wheel loading lest was conducted in Public Works Research Institute in Japan. The laboratory test overview is shown in Fig. 7. In the test, the wheel load moved on RC slab with the control of ground contact pressure. It was observed that the vertical stress was possible to be obtained while well maintaining the continuous wheel movement on the slab. The reticular crack pattern was overserved underneath of RC slab. The concrete damaged surface was turned into quadrangular pyramid shape at the end, which resembles to the punching shear failure. The embedded rebar was not fractured until the final stage, which deemed to be real phenomenon to the RC slab damage under this loading condition.

Figure 6. Point loading test on RC slab

Figure 7. Wheel loading test on RC slab

3) Confirmation of deck slab durability

(i) Constant wheel loading test (16 ton)

Public Works Research Institute in Japan (former Ministry of Construction) carried out wheel loading test on deck slab which was designed according to the specification (1964 version) of highway bridges by JRA. The obtained result represents that initially the deck deflection at the center increases rapidly and later increases gradually. This leads to the damage by constant load intensity. Fig.8 shows the relation between failure load and loading frequency.

However, the wheel loading test (with intensity of 16 ton) on deck slab designed based on the specification (1996 version) takes very long time to attain the failure. So, a new incremental (step by step) loading test was proposed to evaluate fatigue durability in deck slab. Details are explained in the following section.

(ii) Step-wise increased moving wheel loading test

Instead of constant wheel loading test (16 ton), the loading program was changed to step loading, in which 2 ton incremental load from 16 ton was applied by 40,000 loading frequency and maximum load attains to 40 ton. Total of 520,000 loading frequency was programmed to apply 40 ton load finally. Fig. 9 compares the performance of RC slab (39 means 1964 version) under constant intensity of 16 ton loading test and RC slab (8n means 1996 version) under incremental moving wheel loading test with maximum intensity of 40 ton. The slab design was compliant with the specifications of road and highway bridges by JRA in 1964 version and 1996, respectively. It exhibits that the fatigue resistance of deck slab designed based on 1996 version specification is significantly improved compared to that of 1964 version. Even though step-wise incremental moving wheel loading test can't be used to evaluate the slab fatigue durability quantitatively because test loading intensity is greater than standard wheel load, the result by the step-wise incremental moving wheel loading test can be a key indicator to evaluate fatigue resistance (durability) for highway deck slab.

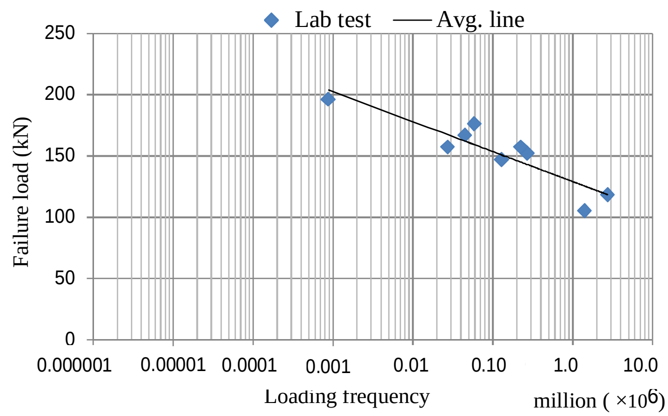

Figure 8. Results from point loading test on RC slab

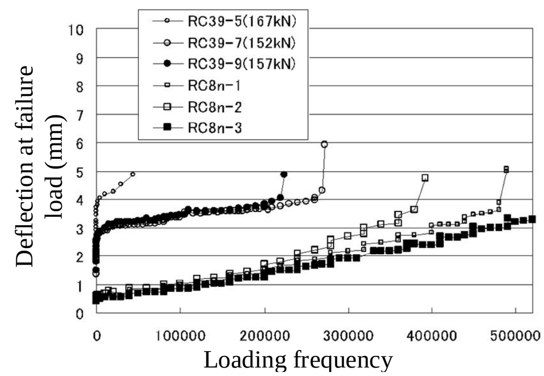

Figure 9. Performance of RC slab under moving wheel load

4) Durable deck slab type

Steel Concrete Composite (SCC) deck slab comprises RC core, re-bars and bottom steel plate connected and composited by shear connectors to form a composite unit. During the past few decades, there have been many researches and developments in SCC deck slab. The structural performance of SCC deck slab system has proven advantageous over other structural forms in application requiring high strength, ductility and energy absorbing capability. The most important component of SCC deck slab system is the shear connector, which transfers forces between steel and concrete. Also, the bottom steel plate can take significant roles in formation of formwork of the deck slab concrete after casting. Several types of SCC deck slab are introduced by many fabricators recently in Japan. Fig. 10 shows three typical examples of SCC deck slab used in Japan. Fig. 11 shows moving wheel load test results for SCC deck slab designed based on 1996's specification by JRA. Even though in some cases, the step-wise increased moving wheel load test applied through 520,000 loading frequency with load intensity of 16 ton to 40 ton leads to the failure in RC deck slab designed based on 1996 version (Fig.9), however, this loading test with same condition does not lead to failure in SCC deck slab. Taking this fact into consideration, it is decided to apply SCC deck slab in KMG three 2nd bridges due to their excellent fatigue resistance and workability.

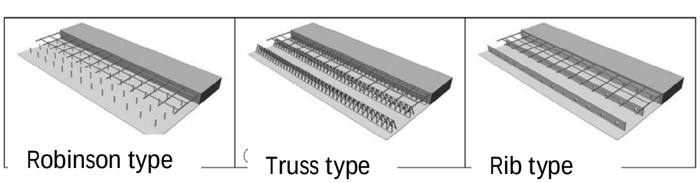

Figure 10. Typical example of SCC deck slab

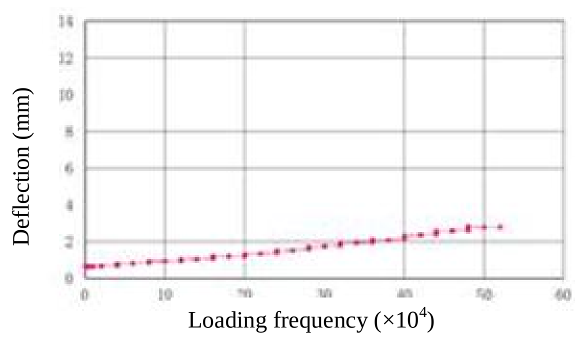

Figure 11. Result of Fatigue Test on SCC slab

3.2 *Steel Pipe Sheet Pile (SPSP) foundation*

3.2.1 *Components of SPSP foundation*

A perspective image of SPSP foundation after construction is shown in Fig. 12, which may be a form of rectangular, circular or oval closed to well shape. It should be embedded into supporting layer underneath the riverbed. Two steel piles should be rigidly connected by a typical joint filled with mortar so that SPSP can easily resist slippage due to earthquake shaking. In Japan, SPSP technology was adopted first for Ishikari Kako (Ishikari river mouth) Bridge in 1969 and then, more than 2,000 bridge foundations have already been constructed using this technology.

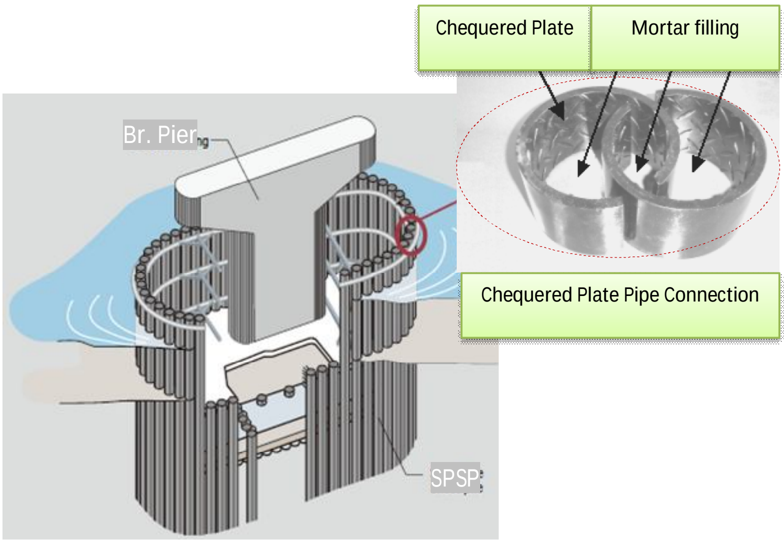

Figure 12. Structural components of SPSP

3.2.2 *Salient features of SPSP foundation*

The distinct features of SPSP foundation with regard to design and construction are outlined as follows;

(i) Strong shear resistance in pipe joint and behaves an intermediate structure between steel pile and caisson foundation

(ii) Act itself as a cofferdam during construction as well as main body of the structure. This leads in reduction of construction time and construction work volume

(iii) Proven structural advantages of higher earthquake resistance and riverbed scouring countermeasure.

4 DESIGN SUMMARY OF KMG THREE BRIDGES

4.1 *Design of Superstructure*

4.1.1 *Design standards*

Bridge design standard (2004) recommended by RHD is prevailed in the detailed design, however, where the specifications are not covered for carrying out the detailed design, the standards and specifications from latest version of AASHTO LRFD (2012) and JRA (2012) are applied. In particular, the detailed design of deck slab is carried out according to the higher live loading specifications recommended by JRA (2012).

4.1.2 *Design results*

The superstructure of 2nd bridge is designed with continuous narrow box steel girder type monolithic with Steel Concrete Composite (SCC) deck slab (Fig. 13). The steel girder is composed of three narrow box girders connected transversely by I-shaped cross beams. Each girder is supported by an elastomeric bearing at the box center.

In order to obtain the section forces and displacement, the entire structure is analyzed based on the grid model shown in Fig.14 for 2nd Meghna. The same modeling concept is also applied for 2nd Kanchpur and 2nd Gumti Bridges. The girder analysis is carried out considering the rigidity of main girders and cross beams. Since the girders are designed as non-composite beams, the rigidity of deck slab is ignored. For analysis, the commercial FEM based package program STAAD is used.

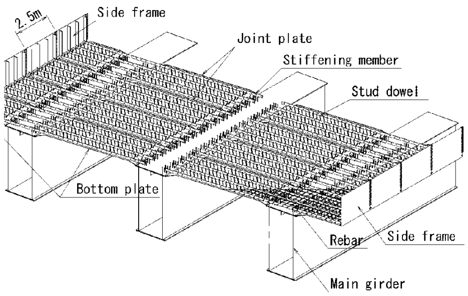

Figure 13. Steel Concrete Composite (SCC) deck slab

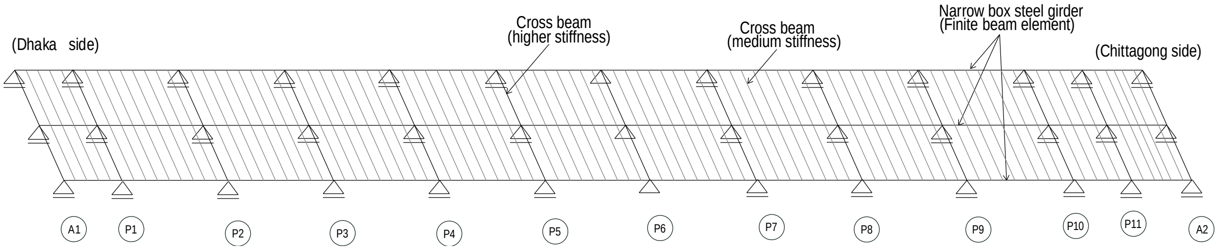

Figure 14. Grid model for girder analysis (2nd Meghna Bridge)

The bending moment diagram with respect to girder length, obtained from the global analysis, is shown in Fig.15 as a typical example. It is also found that the difference in bending moment of three girders is small as less than 10%. Therefore, the section size, determined from maximum results, is also used for the remaining two girders.

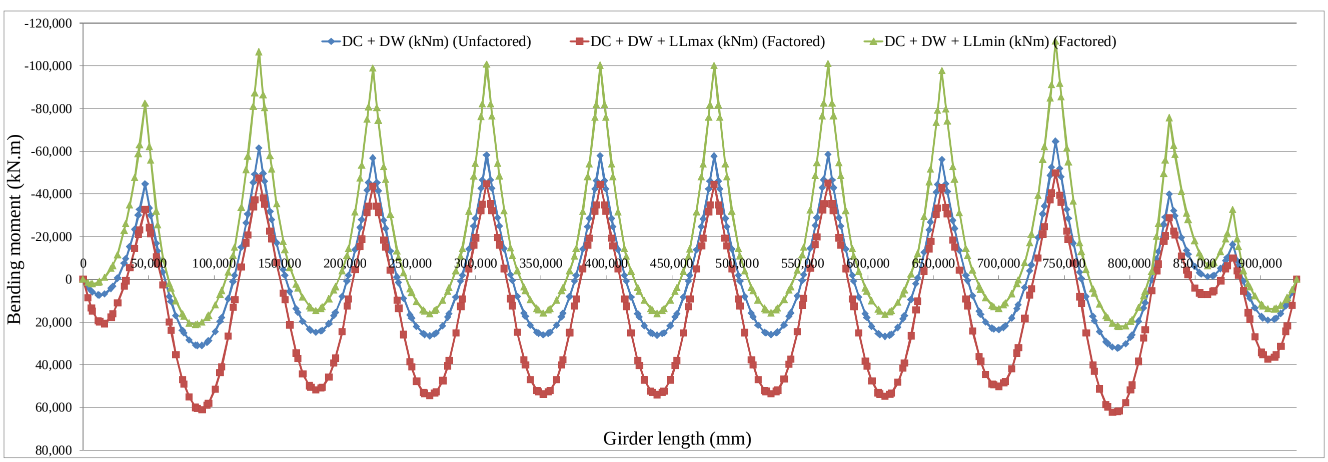

Figure 15. Bending Moment Diagram (2nd Meghna bridge)

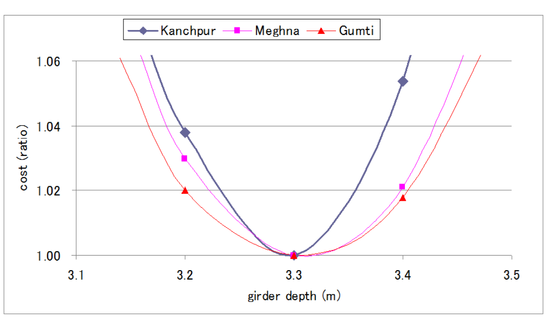

Figure 16. Optimization of girder depth

Under this bending action, placing of High Tension Bolts (HTB) within 8 rows is designed to fit with the flange. Moreover, based on a comparative study and considering economic aspects, the optimum depth of girder of KMG three bridges is designed at 3.3m (Fig.16). The girder width of KMG three bridges is set at 1.8m, 1.5m and 1.6m respectively. A typical cross-sectional view of Meghna Bridge is shown in Fig. 17. The steel girder material is specified at SM490 grade; however the flange thickness 50mm along with SM570 grade material is also specified at some locations where relatively larger amount of negative moment occurs at the support.

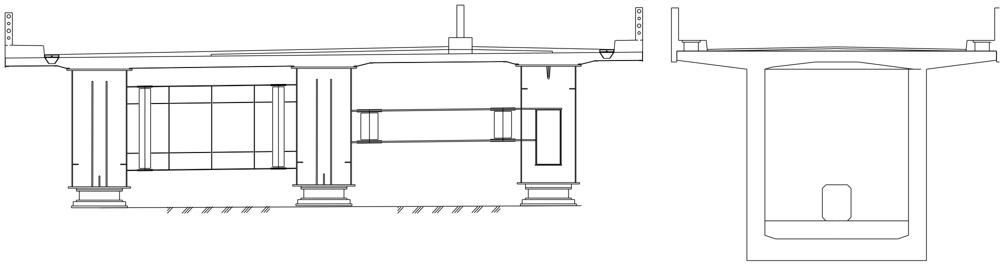

Figure 17.Cross section: Meghna Bridge

The thickness of SCC slab is designed at 230mm for entire sections. In Japan, the bottom plate is usually used with 6.0mm in thickness. However for KMG three bridges, the thickness is set at 8.0mm in order to enhance the durability. The final structure of SCC slab will be determined by the contractor based on moving wheel loading test results and the Contractor shall be instructed to get approval from RHD and the Consultant.

4.2 *Design of Foundation*

4.2.1 *Design scouring level for foundation design*

According to the bathymetric survey conducted and considering the previous results, the current riverbed conditions are studied and confirmed its changes from the past. Moreover, based on the study of river hydraulics, the water level, design discharge and design scouring depth (Table 3) are determined for respective pier foundation. These are used as input parameter for foundation analysis. Based on this analysis, the design maximum scouring level is determined for Kanchpur K-P5~P6 at -17 m.MSL, for Meghna M-P6~P9 at -24 m.MSL and for Gumti G-P2~P7 at -18 m.MSL (DD Report, 2014).

In addition, the necessity of river training works is appraised for Meghna River only. The riverbed near bridge Piers M-P3~P10 is being planned to protect by installation geo-bags, whereas the abutment A2 will be protected by revetment works including CC block, riprap and geo-bags.

Table 3. River hydrology

Bridge / Items	Kanchpur	Meghna	Gumti
Standard High Water Level (m.MSL)	5.46	5.37	5.57
Design Discharge (100-yr), m3/s	3,480	21,910	12,400
Scour Depth (m. MSL)	Pier 2-3=-1.5 Pier 4=-11.0 Pier 5-6=-17.0	Pier 2=-5.0 ; Pier 3-5=-15.0 Pier 6-9=-24.0 ; Pier 10=-15.0	Pier 1=-1.0 ; Pier 2-7=-18.0 Pier 8-12=-1.0 ; Pier 13-16=-3.0
River Training	Not recommended	-Riverbed protection around Piers 3-10 by Geo-bag -Revetment work at A2 (CC block, riprap, geo-bag)	Not recommended

4.2.2 *Foundation design results*

Piers are designed with form of wall shape in order to ensure least disturbance to river water flow. The design scouring level, earthquake force and form of existing foundations are taken as governing factors for the selection of foundation type. Each steel pile diameter is designed at 1.0m with 14.0mm thickness and its material is specified at SKY490.

a) Kanchpur Bridge

Based on numerical calculation, it is obtained that the SPSP foundation can be terminated at shallower depth rather than that of existing foundation. The foundation of existing bridge is open caisson type but their design details are not currently available. Therefore, due to the consideration of safety margin, the supporting layer is considered to be set at additional 2m deeper into clayey layer or sandy layer from the bottom of existing foundation (Fig. 18).

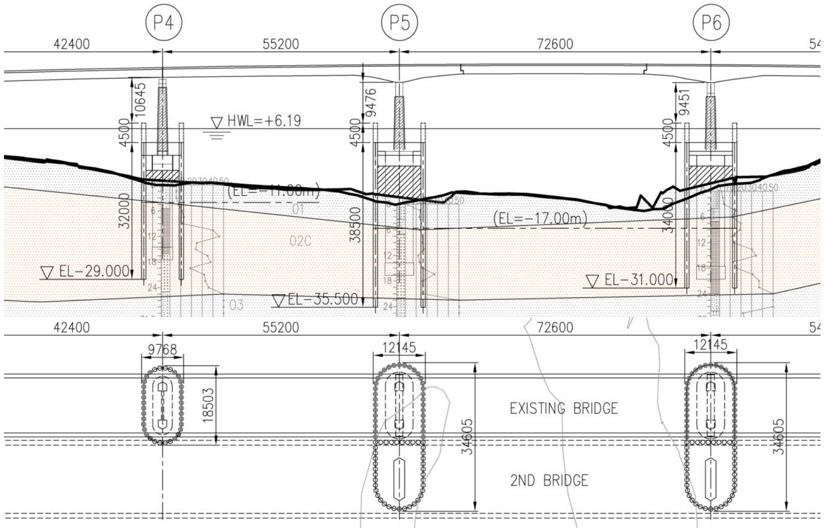

Figure 18. Kanchpur Bridge foundation

b) Meghna Bridge

The SPSP foundation well (M-P6~P8) is embedded up to a level of -47.46 m.MSL, whereas M-P9 is embedded to relatively shallow level of -39.46 m.MSL. The bottom of SPSP well is terminated at the horizon containing very dense brownie sandy layer, which is beyond thin clayey layer (Fig. 19).

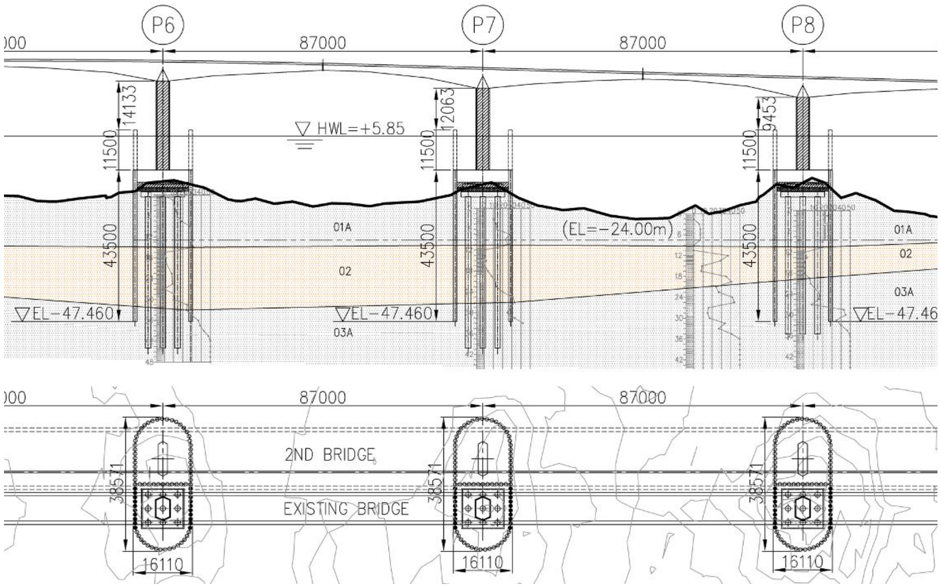

Figure 19. Meghna Bridge foundation

c) Gumti Bridge

The subsoil investigation results make evidence that the geological structure underneath of the Gumti riverbed is the formation of hard and thick clayey layer. Therefore, the bottom of SPSP is possible to terminate at this supporting layer. In addition, it is predicted from soil characteristics (DD Report, 2014) that no significant settlement will occur due to the consolidation. However, for the sake of safety only, one (1) SPSP with leg is provided at the rate of one of three.

On the other hand, the navigation clearance under existing Gumti Bridge is very small compared to the Meghna. During construction, the vertical clearance of only 2.4m~5.8m underneath of existing bridge can be secured for the installation of SPSP, which is expected to lengthen the construction period. Therefore, under a limited vertical clearance, potentiality of no installation of total six (3+3) SPSPs with leg are planned symmetrically at both side along transverse direction underneath of the existing bridge so as not to interrupting the overall construction schedule.

In order to confirm the above possibility, a 3D frame model is developed (Fig. 21) for carrying out FEM analysis using the most severe scouring case at G-P2. In this analysis, the conditions of existing bridge foundation are not taken into consideration in order to keep additional safety margin in the results. The obtained numerical results confirm that inclusion of SPSP with leg is not mandatorily required.

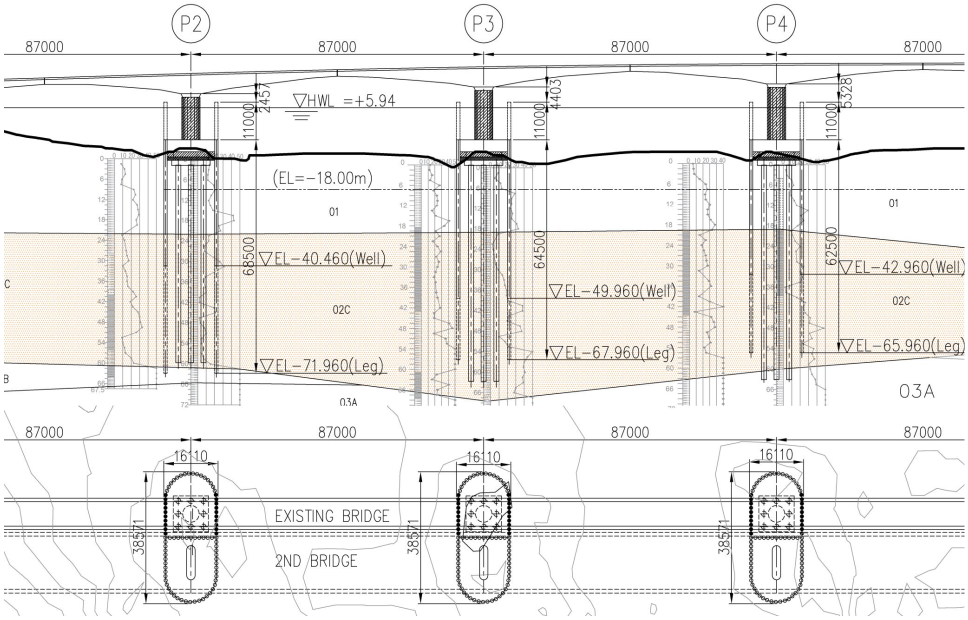

Figure 20. Gumti Bridge foundation

Direction	Vertical reaction (kN)	Horizontal reaction (kN)	Moment (kN m)
Longitudinal	90,972	33,261	509,232
Transverse	90,972	8,626	350,695

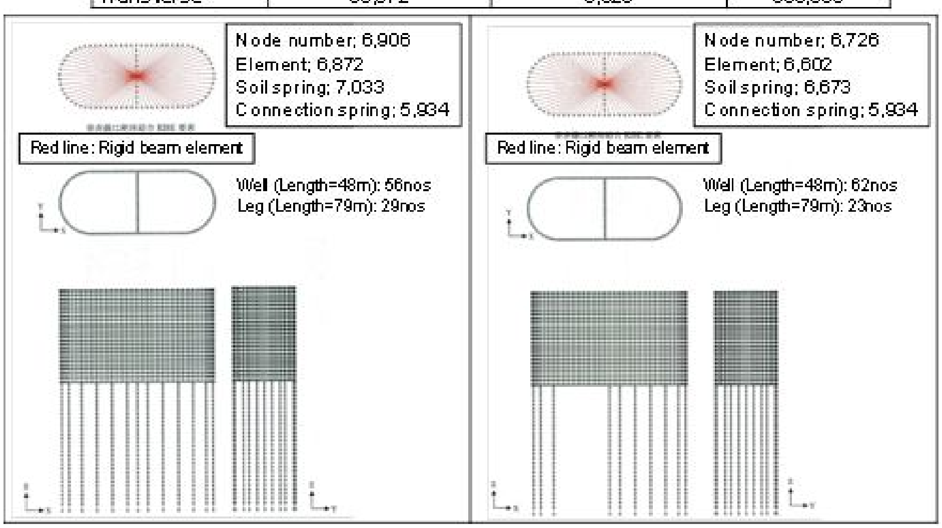

Figure 21. 3D frame model for foundation analysis

4.3 *Summary of Technical Details Designed for 2nd Bridge Design*

Addressing to the set of design criteria (DD Report, 2014) and following AASHTO LRFD (2007, 2012) and Japanese design standard (JRA, 2012), the detailed design has been carried out for the proposed three 2nd bridges. The 2nd bridges are designed with a provision of 4-lane in width, keeping alignment next and parallel to the existing bridge. A summary of the technical details of the 2nd bridges is provided in Table 4.

Table 4. Technical details of 2nd bridge

		Kanchpur	Meghna	Gumti
2nd bridge perspective view				
Length(m)		397.3	930.0	1410.0
Width(m)		18.0	17.45	17.45
No. of lanes		4	4	4
Superstructure		Continuous narrow box steel girder with Steel Concrete Composite (SCC) slab		
Pier foundation	Abutment	Inverted T-type		
	(No.)	2	2	2
	Pier	wall type		
	(No.)	5	11	16
	Foundation (No.)	Cast-in-place RC bored piles		
		3(A1, A2, P7)	4 (A1,A2, P1, P11)	12 (A1, A2, P1, P8-P16)
		Steel Pipe Sheet Pile (SPSP)		
		4 (P1,P3,P5,P6)	9 (P2-P10)	6 (P2-P7)

5 CONCLUSIONS

The proposed three 2nd bridges under KMG project are designed with 4-lane. Type of superstructure is determined as continuous steel narrow box girder monolithic with Steel Concrete Composite (SCC) deck slab which endures against relatively heavier traffic loading. The foundation is designed with Steel Pipe Sheet Pile (SPSP) closed to well in order to resist strong earthquake shaking and sustain against severe riverbed scouring. Moreover, the SPSP foundation of 2nd bridge is planned to unify with that of existing bridge. Therefore, application of narrow box steel girder monolithic with SCC deck slab as superstructure as well as unified SPSP foundation in KMG three bridges will undoubtedly add a new dimension to the bridge construction industry in Bangladesh.

After four years from now, the 2nd bridge will be opened to road users. The commencement of civil works is expected to schedule at the end of this year 2015.

REFERENCES

AASHTO LRFD, 2012. Bridge Design Specifications (6th edition), *American Association of State Highway and Transportation Officials*. America.

AASHTO LRFD, 2007. Bridge Design Specifications (4th edition SI Unit), *American Association of State Highway and Transportation Officials*. America.

BNBC, 1993 [Gadget 2006]. Bangladesh National Building Codes, *Housing and Building Research Institute*, Dhaka.

Bridge Design Standard, 2004. Bridge Design Standards by RHD, *Roads and Highways Department*, Dhaka.

DD Report, 2014. The Kanchpur, Meghna, Gumti 2nd Bridges Construction and Existing Bridges Rehabilitation Project, *Roads and Highways Department*, Dhaka.

Feasibility Study Report, 2013. Preparatory Survey for Dhaka-Chittagong National Highway No.1Bridge construction and Rehabilitation project, *JICA*, Japan.

Japan-Bangladesh Joint Seminar, 2005. Some Remarkable Bridges of Bangladesh; Japan-Bangladesh Joint Seminar on Advance in Bridge Engineering, *Japan Society of Civil Engineer*, *Japan & Institution of Engineers, Bangladesh.*

JBA, 2004. Concept of Narrow Box Steel Girder Bridge, *Japan Bridge Association*, Japan.

JRA, 2012. Specifications for Highway-Bridges, Part IV Substructures, *Japan Road Association*, Japan.

Technical Note, 2008. Research on Fatigue Durability Evaluation for Highway Bridge Slabs, No.472. *National Institute for Land and Infrastructure Management*, Japan.