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General arrangement, Design and innovative techniques of Construction in Padma Multipurpose Bridge Project

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I. Introduction

The Author's involvement in Padma Multipurpose Bridge Project was for two years and served as the Design Reviewer / Bridge Expert with the reviewers of PEC (Korea) in the consortium of the Companies engaged in Consultancy services for the Design Review and Construction Supervision of the project. The Companies are Korea Expressway Corp in association with SMEC (Australia), PEC, Sunjin (Korea), ACE & DevConsultants (Bangladesh).

Description of the Project

Padma Bridge – the longest in South Asia - connects the southwest part of Bangladesh to north region including Dhaka. The riverbanks of Padma are very unstable and the river width changes continuously due to high current flow. Sometime approaches of ferry crossing become seasonally inoperative due to high velocity of flow and tides. Maximum scour depths were estimated as roughly 50m below SHWL in 100 year flood level.

Figure 1: Isometric view of the Padma Multipurpose Bridge

The horizontal width and vertical height of navigation have been identified as:

- Horizontal = 76.2m and
- Vertical = 18.3 m above Standard high water level for three adjacent spans and 12.2m for all other spans within a total navigable river width of 4800m. The bridge composed of a highway 4 lane deck at the top level and a single railway track including gas and telecommunication services at the bottom level.

The bridge consists of about 6.15km long main bridge across the river, 1.67km long approach viaduct at Mawa, 10.58km long approach viaduct at Jajira and about 13.6 km of approach roads including bridge end facilities. It started to contribute substantially to the development of the National economic growth.

Figure 2: Isometric view of the Padma Main Bridge and West Viaducts

Geotechnical investigations

Geotechnical investigations were carried out by the Contractor and programmed to enable the information available in sufficient time that the final decision on pile length could be made and advised to the contractor before completion of the fabrication of the piles. It provided information to make the structure safe and durable as well as to make it economically viable. The results of detailed geotechnical investigation provided adequate information for the selection of the most suitable type of foundation for the proposed structure and indicated if special problems are likely to be encountered during excavation and filling. Information on the type of subsoil stratification, geotechnical parameters and its behaviour was obtained from comprehensive soil investigation programme which incorporated drilling of boreholes, collection of undisturbed and disturbed soil samples, performance of specific in situ tests and laboratory testing of soil samples. The results of laboratory tests and in situ tests needed carefully integrated in soil investigation. An engineering geological study of the project area was also an essential element of soil investigation to establish the physiographic setting and stratigraphic sequences of soil strata of the area. For the dynamic analyses of the foundation, the dynamic properties (such as shear modulus, G, damping ratio, h and liquefaction resistance) were determined from field tests (such as seismic down-hole test) and laboratory tests (such as cyclic triaxial test).

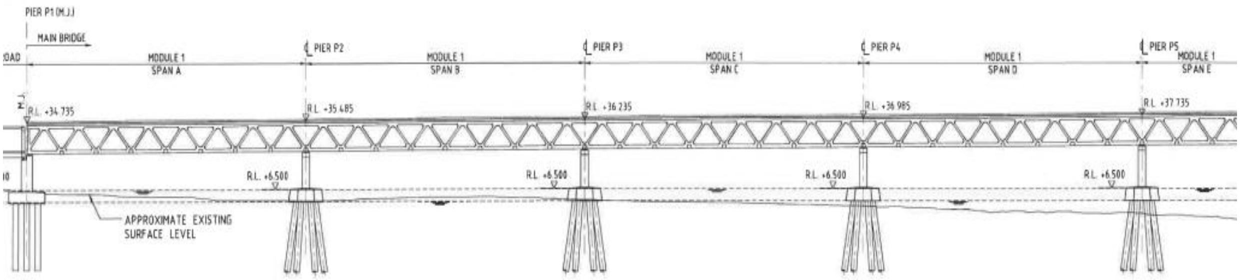


Figure 3: Typical Long Section of the Padma Multipurpose Bridge

Loadings considered in design

All the loadings considered in design of the Bridge Structures have been calculated based on the unit weights and specifications given in design criteria. The loadings considered in the design of structures are as follows:

1) Dead Loads: Dead load analysis of the deck was performed for the self weight of the trusses, steel girders, precast and insitu concrete slab, prestressed precast segment of prestressed beams, weight of parapets and barriers on deck slab, weight of gas pipe, railings, the haunches, and the asphalt wearing surface.

In substructure design, dead load includes weight of prestressed upper deck, trusses and reinforced concrete railway lower deck.

2) Highway loads: The Bridge is required to carry a dual two-lane carriageway road with a design traffic speed of 100km/hr. Each carriageway shall comprise two 3.5 meter wide traffic lanes plus a 2.5 meter wide hard shoulder and a 0.5m hard strip adjacent to median.

3) Railway loads: Two locomotives of 32.5t axle loads and vertical wagon loads with different combinations of Railway Loads (as specified in RDSO) will operate at a maximum permissible speed of 125 km/hour.

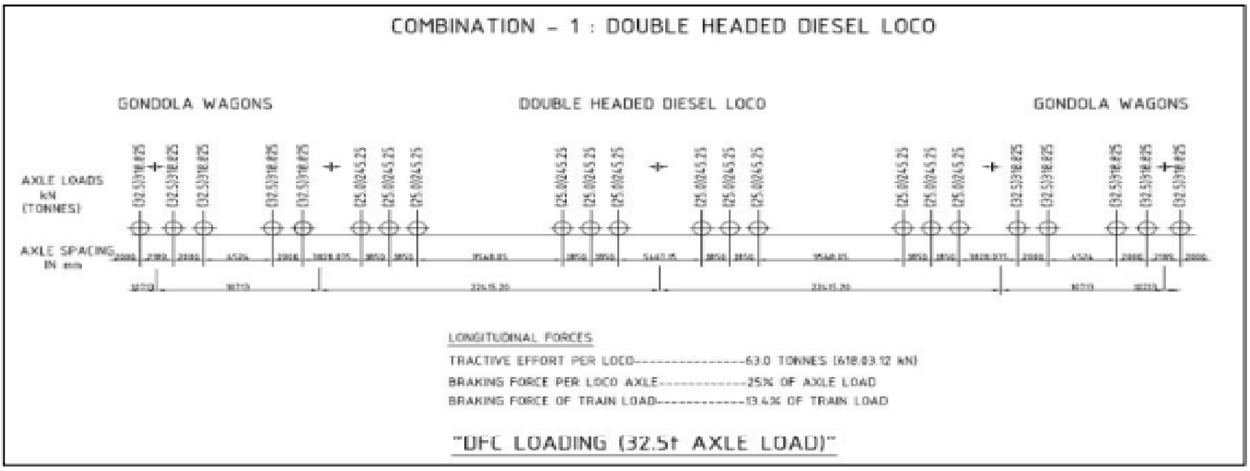


Figure 4: One of the Loading Combination of DFC Loadings and Wagon Loads

According to design criteria, the DFC loadings are wagon loads combined with different locomotives.

4) Differential settlement has also been considered as a dead load. The impact of permanent differential settlement of the foundations on the structure due to dead and superimposed dead loads have been considered.

5) The impacts of shrinkage and creep have been evaluated for the following:

- Calculation of differential shrinkage and creep stresses in composite construction.
- Calculation of pre-stressing losses in pre-stressed concrete construction.
- Superimposed dead Loads: Superimposed dead loads checked in accordance with the AASHTO Bridge Design Specification. Loads include the effects of utilities, waterproof membrane, road surfacing and non-composite barriers. Deck surfacing used as 70mm asphaltic concrete but allowance for 100mm thickness taken in the design.

6) Vehicular loading on the Viaducts and Bridges, designated HL-93, consists of a combination of the:

- Design truck or design tandem and design lane loading. The design truck or tandem loads are assumed to occupy a width of 3.60 m transversely within a design lane. The design lane load consists of a load of 9.3 kN/m uniformly distributed in the longitudinal direction. Transversely the design lane load is assumed to be uniformly distributed over a 3.0 m width.

The bridge decks have been designed for live loads:

- to resist the traffic loads specified above which approximate the effects induced by moving traffic, stationary lanes of traffic and pedestrian traffic where available;
- For the most adverse effects induced by the following loadings, combinations of these loadings and their corresponding load factors:
- Design truck load, Design lane load without impact, Dynamic load allowance (IM),Number and position of traffic lanes, Multiple presence factors (m), Centrifugal forces (CE), Vehicular collision force, Tractive / Braking forces (BR)

7) Locomotives and wagon loads with impact

The live load force effect has been determined by considering each possible combination of number of loaded lanes multiplied by a corresponding multiple presence factor to account for the probability of simultaneous lane occupation by the design live load. The number of standard design lanes loaded and the load pattern (standard design lane numbering) has been selected to produce the most adverse effects.

8) Centrifugal Force : Structures on curves designed for a horizontal radial force equal to the following percentage of the live load, without impact, in all traffic lanes:

$$C = 0.00117S^2D = \frac{6.68S^2}{R}$$

where, C - the centrifugal force in percent of the live load, without impact; S - the design speed in miles per hour; D - the degree of curve; R - the radius of the curve in feet.

9) Tractive Effort or Braking forces: Braking effects of traffic will be considered as a longitudinal force. The restraint system will be designed to resist the most adverse co-existing effects induced by the braking force and the vertical traffic load.

The braking force per lane is the greater of:

(a) 25% of the axle weights of the design truck or tandem;

(b) 5% of the axle weights of the design tandem plus lane load;

It is assumed that the bridge is likely to become one directional in the future, Therefore, all design lanes may be used to compute the governing braking force, Also braking forces are not increased for dynamic load allowance.

For single traffic lane:

(a) 25% of design truck – 0.25 (32 +32 +8) 18 kips. 25% of design tandem = 0.25 (25+25) = 12.50 kips;

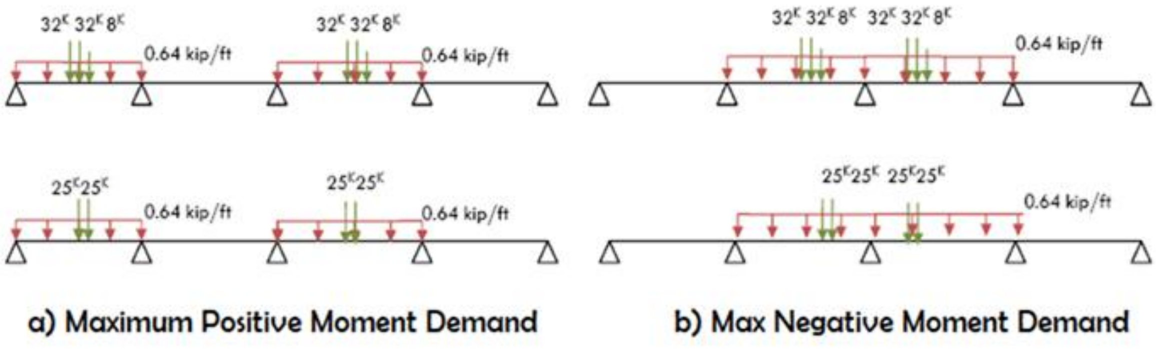
(b) 5% of axle weights of the design truck plus lane load = 0.05[(32 + 32 +8) + (0.64 x 115)] i.e. for 35m (115 ft) span = 0.05 (72 + 73.6) = 7.28 kips

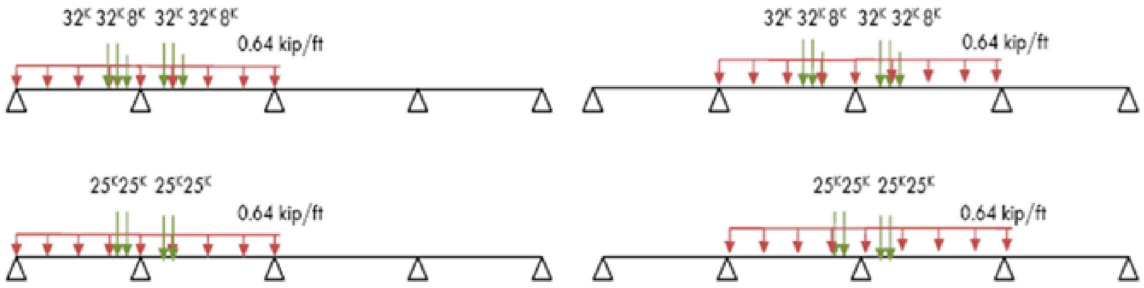
(c) 5% of axle weights of the design tandem plus lane load = 0.05 [(25+25) + (0.64 x 115) = 6.18 kips

Let us use max 18 kips which is applied at a distance of 6 ft above the roadway. However, since the bearings are assumed incapable of transmitting longitudinal moment the braking force will be applied at the bearing level.

10) Longitudinal load: According to Indian railway standard, no addition for dynamic effects shall be made to the longitudinal loads. Structures and elements carrying single tracks shall be designed to carry the larger of the two loads produced by traction and braking in either direction parallel to the track.

The AASHTO LRFD Bridge Design Specifications HL-93 load model is used for live load analysis of the girder. The maximum moment (not for trusses) and shear demand for the continuous girders under live loads computed considering different load placement schemes. The following Figures present the critical live load placement on alternate spans of the flyovers to determine the maximum moment and maximum shear demand.





c) Maximum Shear Demand

Figure 5: Critical Load Placement of HL-93 Vehicular Live Load over Continuous Span for Maximum Moment and d) Shear Demand

11) Frictional Resistance: In load combination where fr included frictional resistance of bearings due to expansion or contraction of superstructure are to be considered. Frictional force be determined by using LFR = f. RDL

where f – Coefficient of friction of bearing; RDL - dead load reaction of girder on bearing;

12) Fatigue: All new bridges are designed to comply with Code requirements (AASHTO LRFD Bridge Design Specifications). This requirement applied particularly to all truss components for considerations of structural fatigue.

Fatigue Stress Limits: The range between a maximum tensile stress and minimum stress in straight reinforcement caused by live load plus impact at service load shall not exceed:

$$f_f = 21 - 0.33 f_{min} + 8(r/h)$$

where: Ff - stress range in kips per square inch;

Fmin - algebraic minimum stress level, tension

13) Ship impact: Following a survey of current shipping patterns in the river a vessel of 4000DWT has been used for determining the ship collision load to be applied to the bridge. Based on the above vessel and adopting the provisions in AASHTO LRFD an impact load of 23.3 MN shall be considered to apply for head-on impact and half of this value, 11.7MN applies to sideways impact.

14) Wind Force: a) Calculation of Design Wind Pressure (As per BNBC): The project location lying on isotech of 200km/hour, which is the basic wind speeds. Yhe sustained wind pressure qz on a flyover structure at a height of about 9m to 19m above ground shall be calculated by using

$$q_z = C_c . C_1 . C_z V_B^2$$

where, qz – Sustained wind pressure at height (meter) h, kN/m2;

Cc - Velocity to pressure conversion coefficient = 47.2 x 10-6

C1 - Structure importance coefficient;

Cz – Combined height and exposure coefficient;

VB - Basic wind speed in km/hour;

Then, for height h=9m, C1 = 1.0, Cc - 47.2 x 10-6 ; Cz = 1.371 (Exposure C) and VB = 200 km / hour; Sustained wind pressure at height h = 9m,

qz = 47.2 x 10-6 x 1.0 x 1.371 x (200)2 = 2.59 kN/m2;

Similarly, sustained wind pressure at height h = 18m,

qz = 47.2 x 10-6 x 1.0 x 1.575 x (200)2 = 2.97 kN/m2

i.e. 15% higher than that at h=9m. Therefore, the design wind pressure in kN/m2

$$P_z = C_g C_p q_z$$

where, Cg – Gust coefficient; Cp - Pressure coefficient

qz – Sustained wind pressure at height h, kN/m2;

For W/L = 0.9 and h/L= 0.3, Cp= 1.314

Then, Pz = 1.102 x 1.314 x 2.59 = 3.75 kN/m2 (79 lb/ft2) at height h=9m;

Similarly, Pz = 1.102 x 1.314 x 2.97 = 4.30 kN/m2 (90 lb/ft2) at height h=18m;

For the usual girder and slab bridges having maximum span lengths of 38m (125 feet), the following wind loading may be used in lieu of the more precise loading specified above. WS (wind load on structure) 50 pounds per square foot, transverse 12 pounds per square foot longitudinal. Both forces shall be applied simultaneously.
WL (wind load on live load) 100 pounds per linear foot, transverse 40 pounds per linear foot, longitudinal. Both forces shall be applied simultaneously.
Then, WS i.e. Lateral load for girders = 50x 1.563 = 78 ib/ft2;
Longitudinal load = 12 x 1.563 = 19 lb/ft2;
WL in transverse direction = 100 x 1.563 = 156 lb/ft;

Steel Tubular piles for the Main Bridge
The main bridge Steel piles have been designed and constructed as per guidelines of working stress design as recommended by API 2000 (American Petrolium Institute). Tubular steel piles were manufactured from steel to BS with grade S355 including stiffening plates, jetting manifolds or shear keys.
Grout for steel piles to increase shaft friction and base resistance were the cement and water mix having the minimum cementitious content of grout of 600kg/m3.
For skin grouting, grout was injected around the outer periphery of the steel tubular pile to strengthen the adjacent soil and to increase the pile –soil interface skin friction.
Grout for strengthening of base soil was injected under pressure at an appropriate injection rate beneath the concrete plug of the steel tubular pile and at the base of the steel pile to uniformly and suitably strengthen and consolidate the soil underneath the pile base.

Figure 6: One Segment of steel tubular pile manufactured in Piling Yard

For sand filling, a steel tubular pipe of 200 mm dia closed at the lower end by a steel plate and slotted along its length shall first lowered down the water-filed pile. Sand then dumped or sluiced into place up to the design level.The tube then withdrawn while simultaneously applying vibration. During withdrawal the tube raised and lowered alternately to compact the sand. After complete withdrawal of the tube further sand was added as necessary to make up to the required level.

Piling works complied with the Code of Practice for Foundations BS 8004, API 2000 and ASTM D4945.

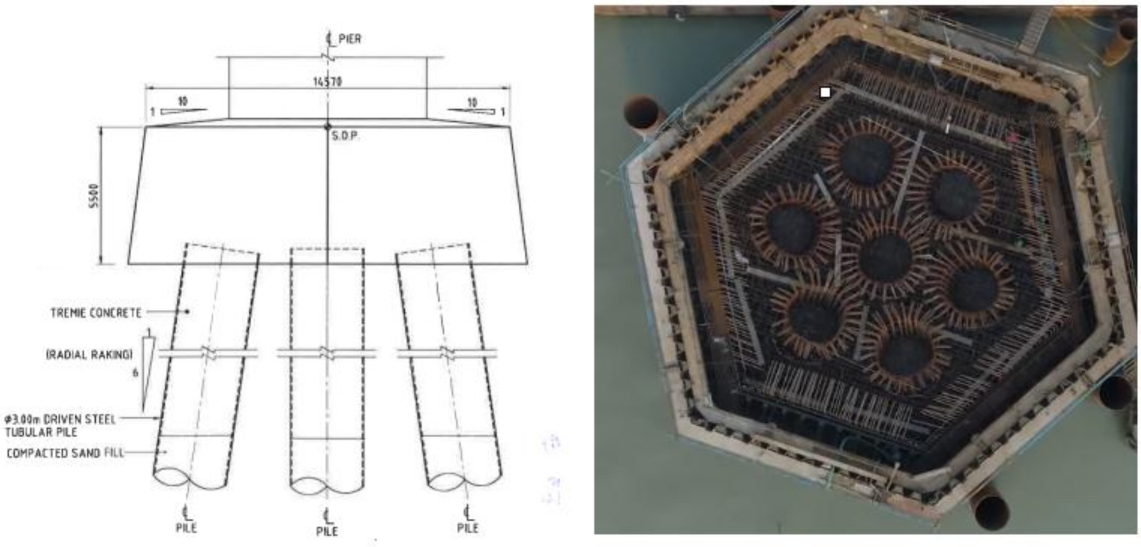


Figure 7: Typical Configuration of Steel Tubular Pile Cap for Raker Piles

Structural steel grades used in the Padma Bridge are: Steel tubular piles (S355JO), Bearing plates (S355J2G3), Maintenance walkways, ladders, staircases, railings, parapets, lamp posts, etc (S355N), Structural steel work (plates <50mm) (S420M), Structural steel work (plates>50mm) (S420ML).
Abbreviations used: For example S355N- structural grade steel with a minimum yield strength of 355 N/mm².
The class of concrete used in the construction of the Bridge was the specified cube strength at 28 days. Different grades of concrete were used. Those were Grade 60, Grade 50, Grade 45, Grade 35, Grade 30, and Grade 25. Grade 20 and below. Minimum cement contents (kg/m3) were 400, 375,350,330,310,290,270 and water cement ratio was 0.35, 0.40, 0.40, 0.45, 0.47, 0.50, and 0.60 respectively.
BS 2600 for Radiographic examination of fusion welded butt joints in steel for steel 2mm to 59mm thick and over 50mm upto and including 200mm thick.Ultrasonic testing has performed as per BS5996. Non-destructive examination of welded joints by BS EN 970.

Table 1: Design Load Cases for Main Bridge Steel Tubular Driven Piles

CASE	Load Combinations	FACTORS OF SAFETY		
		FOS ON SKIN FRICTION IN COMPRESSION	FOS ON SKIN FRICTION IN TENSION	FOS ON END BEARING
1	SW + SDL + LL	1.5	3	3
2	SW + SDL + SHIP IMPACT	1.25	2.5	2.4
3	SW + SDL + LL + W	1.25	2.5	2.4
4	SW + SDL + LL + SHIP IMPACT + 10 YR SCOUR	1.25	2.5	2.25
5	SW + SDL + 1/3 HA (1 LANE) + RL + 100 YR EARTHQUAKE + 100 YR SCOUR	1.25	2.5	2.4
6	SW + SDL + 1/3 HA (1 LANE) + RL + 475 YR EARTHQUAKE + 100 YR SCOUR	1.1	2.2	1.1
7	SW + SDL + CHECK FLOOD SCOUR (500 YR SCOUR) DOWN TO - 70 m PWD	1.25	2.5	2.4

15) Temperature effects: The Temperature effects considered for in accordance with the BNBC guide. The design effective bridge temperature range of the deck has been taken as: from 200 C to 450 C,
For the calculation of the range of thermal movements for expansion joints and bearings, the datum temperature taken as 250 C, and thus the nominal range of movement for expansion taken as 12.50 C and for contraction 12.50 C.

16) Earthquake analysis: Response spectrum to be used in the dynamic analysis of the piers shall be normalized response spectra for 5% structural damping ratio. Damping ratio depends on the material and the structural system. 5% of damping is adequate when considering damage in the structure during a seismic analysis (nonlinear behavior).

Damping also depends on the number of joints, restraints, etc. which represent the points of the structure that will be favour energy dissipation. Acceleration and period to be used in the FEM for 5% damping are:

Acceleration	0.41	0.41	0.21	0.16	0.12	0.08	0.06	0.05	0.04	0.03	0.02
Period	0.21	0.61	1.10	1.41	1.80	2.20	2.60	3.0	3.40	3.61	4.01

Table 2: Design Traffic Lanes for Different Deck Width used in Design Review

SI No.	Clear Roadway width (Distance between curbs in meter)	Number of design lane	% of lane used
1	6	1	100
2	6-10	2	100
3	10-13.4	3	90
4	13.4-17	4	75
5	17-20.4	5	75
6	20.4-23.7	6	75
7	23.7-27.4	7	75
8	>27.4	8	75

- Table 3.6.1.1.2.1 AASHTO LRFD 2007

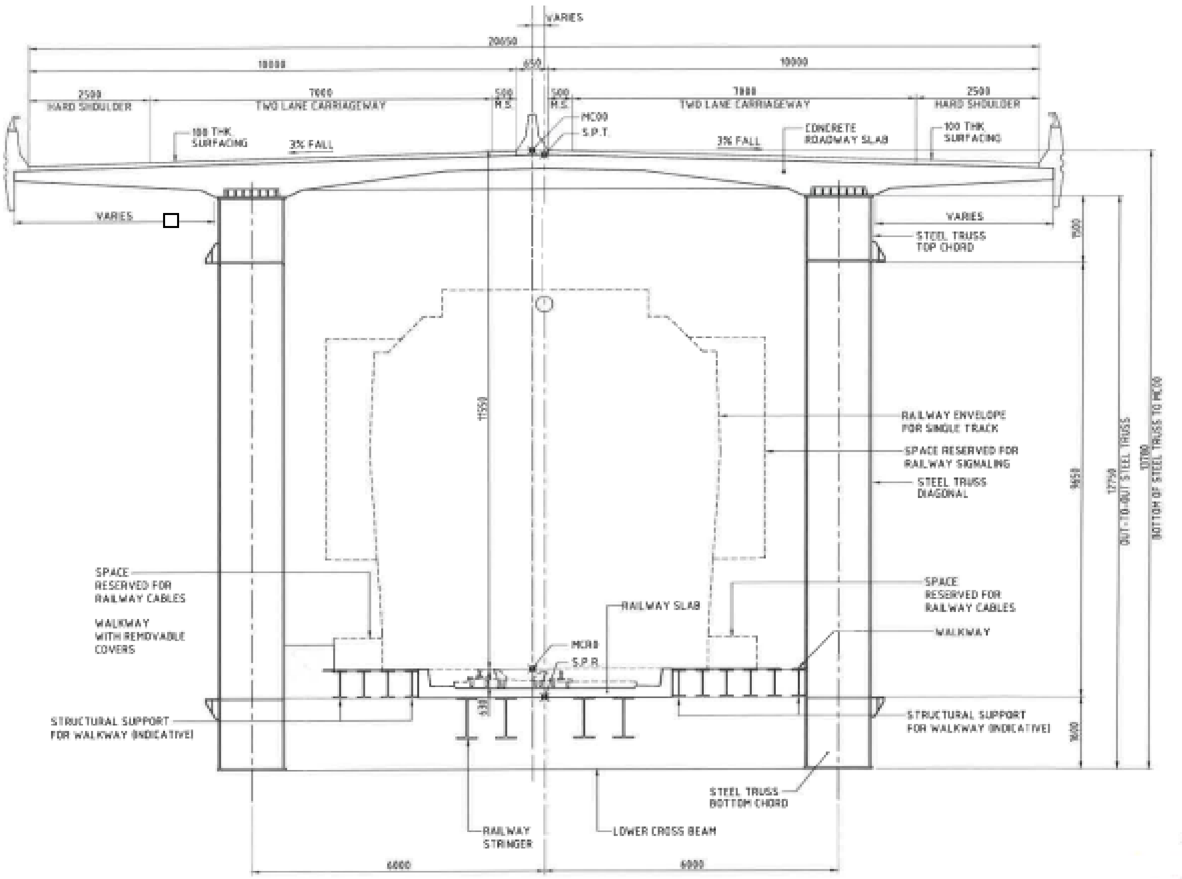


Figure 8: Typical Cross Section of Deck Between Piers

Top Level Highway Deck Slab (Total 5400 nos.) connected module wise by longitudinal prestressed tendons. The main bridge is in the form of composite steel truss with railway at lower deck level and highway at upper deck level.
Longitudinally, the main truss is in the form of a continuous warren truss and the concrete roadway slab is connected to the top chord by shear stud.

Figure 9: Typical Parts of Main Bridge Warren Trusses

The roadway slab is reinforced concrete in the transverse direction, and is a prestressed concrete structure in the longitudinal direction. The railway deck comprises longitudinal steel beams spanning between lower cross beams and a concrete railway slab which is also compositely connected to the beams.

Design Review analysis at each stage of construction

The Design Review has been done mainly using BS5400 and AASHTO. Software packages STAAD & MIDAS has been used to carry out dynamic and static analysis. The main bridge river spans comprises 41 and 6 spans of 150m modules each founded on 42 piers comprising large diameter(3m) raking driven steel tubular to a minimum depth of 120m with in situ concrete pile cap and piers. The deck comprises a two level fabricated steel truss composite with prrestressed concrete beams and a cast in situ reinforced concrete deck slab.

During review time, finite element STAAD & Midas modeling was done by each individual Reviewer to evaluate the design at each stage of construction and to advise the Contractor for the solution proposed during construction.

In certain circumstances it was required to discuss with the Original Design Consultants for complex structural solutions including geotechnical adjustment of piles due to certain variations of soil properties not at exactly tested location previously cited.

The 100kmlhr design speed, high loading and 100 years design life requirements defines the basis for the derivation of the characteristic imposed loads and environmental effects to be considered in the design.

For train DFC (Dedicated Freight Corridor) loading consistent with Trans-Asian Railway loading is adopted. The bridge has been designed using two levels of seismic hazards and corresponding performance criteria. One is operational level of Earthquake and the other is contingency level of earthwork having defined return periods, probabilities, functional and damage levels.

The Padma Bridge design has been based on rigorous extensive investigations and analysis to make the design strong, safe, aesthetically pleasant and suitable for fast track construction. The steel truss is of Warren type with a typical panel point spacing of 18.75m longitudinally.

The truss is 13.5m wide and 12.7m deep combined with a composite deck slab.The members of the steel truss are typically welded rectangular hollow sections formed by steel plates with thickness varying from 20mm to 70mm.
North and south viaducts are generally 38m spans comprising of post tensioned concrete beams. The substructure of viaducts comprises reinforced concrete piers supported by bored piles to a minimum depth of 50m.
Locally produced materials used in the bridge construction are: Cement (from Bangladesh cement Manufacturer's Association), aggregates (From Maddhapara Granite Mining Company Ltd), non-woven Geotextiles (from B.J Geo-textile Ltd and Dird Felt Ltd), bricks, etc. A 30 inch (76 cm) diameter gas pipe is to be carried by the bridge, which is expected to operate at a pressure of. 1135 psi. The gas pipe has been hydro tested to a pressure of 1710 psi in accordance with procedures approved by Petrobangla. The high pressure gas line has been designed in accordance with the requirements of Petrobangla with reference to appropriate recognized international design standards. API and ANSI codes as well as the Bangladesh Natural Gas Safety Rules 1993 have been adopted.
Hydrological data of the Padma Bridge is well maintained by a water level gauging station of Bangladesh Water Development Board at the location of 1.3km upstream of the Mawa bridge alignment.
Records of daily water level and estimate of flow are available from from 1968 onwards. The seasonal snow melt of Himalaya and monsoon rainfall in the vast catchment area of Brahmaputra/Jamuna and Ganga, the river starts rising 2 to 2.5m in April and 6 to 7m in July-August.
At the end of September - October,the river gradually reaches to the lower levels again, and the discharge at Mawa area may be as as 3300m3/sec. Flow velocities at the Padma site is very high and sometime it is above 4.0m/sec.
The region in which the project is situated is seismically active. The seismicity and soil characteristics in the top 20m of the ground in the area makes it sensitive to liquefaction.
All materials and workmanship conformed in the latest edition of the relevant Standard Specifications of AASHTO, ASTM, API, RDSO, STP and British Standard. Maximum River Discharges: The design flood discharge is determined as the 100-year discharge based on the historic record of maximum annual discharges at the Mawa gauge plus an allowance of 16% for future climate change.
The Check flood discharge is determined as the 500-year estimate, based on the same historic record plus allowance of 16% for climate change.
Design flood: 148,000 m3/s at Mawa
Check flood: 160,000 m3/s at Mawa
Provisional estimate of natural scour level (100 year) is -50m PWD
Fixing and supports for the 30 inches diameter gas pipeline across the main bridge and down to ground level at each transition pier.
Power Transmission Line has been provided adjacent to the bridge with individual pylons to carry a high voltage power transmission line with a capacity of 400kV as part of the developing power supply network in south west Bangladesh.
400kv electrical transmission tower has been constructed on piled support platforms. Transmission towers have been supported on support platforms similar to those used in the main bridge. The pile sections were fabricated at the site workshop by longitudinal seam welding with full penetration butt welds
To assist penetration of the piles to the design toe levels, the jetting pipes were installed to the inner wall of the pileand evenly spaced around the periphery. The vertcal guide channels for skin grouting were welded to the outer wall of the pile and evenly spaced around the periphery.

Driving of Steel Tubular Piles

Tubular Piles driven with soil removal from inside were backfilled with sand from the top of the concrete plug. When driving the tubes, accelerometers and other monitoring devices were installed to carry out pile driver analyser (PDA) using CAPWAP to monitor the pile during installation and also to asses the capacity of the tubular pile as it is installed. After installation of steel tubular pile at the desired depth based on updated soil boring data, removal the soil from inside the the tubular pile started by a combination of water jetting at the soil surface and airlifting method exercising necessary care not to unduly disturb the soil at the base to prevent sand particularly from sand boiling.

However, a soil plug of minimum length of one pile diameter remained within the pile. Concrete plug placed continuously with trimie equal to 10m above soil plug at the pile base area.
Base preloading supplemented by grout injection through the jetting pipe and that task was performed until at least 48 hours of placing concrete plug.

Tubes driven with soil removal have been filled with clean river sand duly compacted. Base grouting (Base preloading) consisted of a grid of injection pipes beneath the sand plug to preload, consolidate and compact the soil stratum below. The base preload was applied after completing the casting of concrete plug in more than 48 hours. The arrangement of pipes was such that ensured the application of uniform pressure over the whole cross-sectional area of the base either selectively in stages or as a single operation. The grout injected at pressure which preloaded, consolidated and compacted the soil to the required pressure but without causing hydraulic fracture or uplift of the pile.

Where skin grouting required (provisional) to achieve the pile capacity, the grout injected through outlet valves in an approved sequence to cover the whole of the exterior surface of the steel tubular pile from the specified level down to the termination level of the pile. From trial pile load tests, if is observed that the capacity of the pile is inadequate to support the design loads of any given pile, provisions are built into the steel tubular piles to carry out skin grouting.

PDA tests carried out on the pile after completing the maintained load test and taking the the pile to failure to determine the pile capacity of the pile. Using PDA technique for comparison.

If skin grouting adopted for the working piles, the pile lengths determined based on the results from the skin grouted trial load tests. Roadway slab and railway slab shall be grade 60 concrete. Parapet shall be grade 50 concrete. For all steel members except railway slab beams, the steel grade shall be S420M for plate thickness up to 40mm and

S420ML for plate thickness over 40 mm. For railway slab beams, the steel grade shall be S355M. Structural Steel: Grade S355M/ S420M/ S420ML Concrete: Grade 50 / Grade 60, Reinforcement: High Yield Steel.

Friction Pendulum Bearings

Friction Pendulum Bearings by Earthquake Protection Systems, use the characteristics of a pendulum to lengthen the natural period of the isolated structure so as to reduce the input of earthquake forces. The damping effect due to sliding mechanism also helps mitigating earthquake response. Since earthquake induced displacements occur primarily in the bearings, lateral loads and shaking movements, transmitted to the structure are greatly reduced.

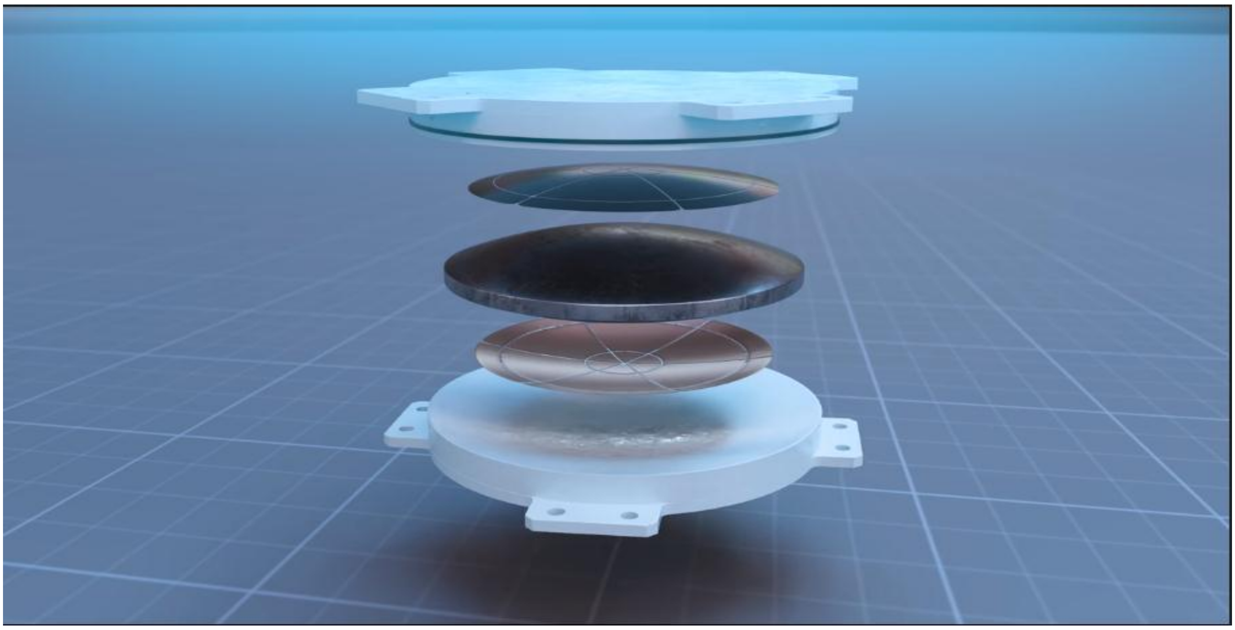


Figure 10: Friction Pendulum Bearings used to reduce lateral loads and shaking movements to the Superstructures

Concluding Remarks

1) Padma bridge piles have a diameter of three meters and placed at a depth of 122meters under the piers. No bridge in the world has ever been piled so deep and thick piles have not been laid.
2) Friction pendulum bearings have been installed to serve the padma bridge from earthquake.The bearing capacity is 10 thousand tons.. So far no bridge in the world has been fitted with bearings of such capacity. The bridge will be able to withstand 9 magnitude earthquake on the Richter scale.
3) Ultra fine cements were imported from Australia and those microfine cements have been used in piling and some parts of poles in Padma Bridge. Such ultra-fine cement is not commonly used.

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