General and design features of Padma Multipurpose Bridge

Md. Rafiqul Islam

Padma Multipurpose Bridge Project, Bangladesh Bridge Authority, Bangladesh

ABSTRACT: The paper deals with general features of Main Padma Bridge including salient design aspects. The Padma Bridge, costing more than a billion US$, is the largest infrastructure project Bangladesh has ever undertaken and it is also ranked as A-Category project in World Bank, ADB and JICA who are the main co-financiers. It is a 6.15 km long 4-lane road cum single track rail multipurpose fixed crossing over the Padma River to connect the isolated south-west region of Bangladesh. The main bridge is in the form of composite steel truss with two levels, railway at lower deck level and highway at upper deck level suitable for fast track construction. 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. 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. The roadway slab is reinforced concrete in the transverse direction, and is a prestressed concrete structure in the longitudinal direction. Typical piers have V shaped reinforced concrete columns, with internal void, supported by a deep pile cap and a group of eight, 3m diameter deep foundation steel tubular piles raking in symmetric pattern. There are 41 spans each 150 m in length optimized in the computer program. The bridge has been designed mainly using BS5400 design criteria. Software package MIDAS has been used to carry out dynamic and static analysis. Global and local analysis using MIDAS software is done using 3 construction sequences which amongst others are governing criteria for design. Geotechnical design includes an assessment of liquefaction potential and ground treatment as required to meet seismic performance levels, slope stability requirement, ground lateral displacement and settlement criteria. The main bridge behaves in complicated manner due to its height (120m) and the large mass of the superstructure pile cap and pile. Systematic analysis is carried out in sleeting seismic isolation system especially in consideration of vertical load capacity, lateral stiffness, self-centering capability, durability and similar application round the globe. The 100km/h 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. The structural forms and methods of construction have been chosen to fulfill the appropriated safeguard durability. Like Jamuna Bridge, British Bridge Code BS5400, which has a much heavier live loading than the HS20-44 loading, is adopted as design live load. 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 robust, safe, aesthetically pleasant and suitable for fast track construction.

1 INTRODUCTION

The three major rivers of Bangladesh - the Padma, Brahmaputra-Jamuna and the Meghna - divide the country into four principal regions such as north-west, north central, eastern and south-west regions. The Padma River separates the South-west region from the capital city and requires time consuming ferry crossings to major destinations. At present, transportation of passengers and freight across the river is by ferries and to a lesser extent by launches and manually-operated boats, but their services are grossly inadequate in both capacity and service level. The existing ferry services involve long and unpredictable waiting time at terminals lacking basic service facilities. They are prone to suspension or cancellation due to flood, fog and inclement weather conditions.
The proposed Padma Bridge is expected to make cross-Padma transport more reliable and drastically reduce the travel time and cost across the river. The proposed bridge plans to build a multipurpose crossing with additional utilities like rail, telephone, gas and power lines across the Padma. It is designed to remove the last major physical barrier in the road connection between Dhaka and the South-west region of Bangladesh, where about one quarter of the population of Bangladesh is living. The bridge will shorten the distance from the South-west to Dhaka by 100 km and travelling time will considerably be reduced. The project is viewed as a very important infrastructure and transportation network, which will hugely facilitate social, economic and industrial development of this relatively underdeveloped region of the country. The padma Bridge will help to stimulate economic activity in the SW region by providing a reliable and rapid transport connection. It is estimated in the feasibility study that the project will increase the GDP by 1.2% and that of South-West Region by 2.3%.

The Padma Bridge is on the Asian Highway Route A-1 and Trans-Asian Railway Route. When the railway will be effectively connected, the Padma Bridge will contribute to the multimodal international transport network for the Eastern Region of the Indian sub-continent and substantial benefit to GoB for bi-lateral cargo movement between India and Bangladesh.

2 PROJECT COMPONENTS

Among the project components main bridge is by far the prime component of the project covering about 50% of the project cost. The main components of the Padma Multi-Purpose Bridge Project consist of:

- A 6.15km long two-level steel truss main bridge (four-lane divided highway on top and single track rail on the bottom deck);
- The Approach Road to the bridge consisting of a 12.4 km four-lane divided highway and includes five minor bridges of 150–270m length over local waterways, 21 drainage box culvert and 8 local road underpasses.
- Transition structures that includes the Approach Viaduct at Mawa length of 721.250m and 756.788m for the northbound and southbound carriageways respectively. The length of the Approach Viaduct at Janjira is 873.250m and 797.315m for the northbound and southbound carriageways respectively;
- Bridge End Facilities on both sides of the river that includes Toll Plazas and Service Areas;
- Access roads totaling about 8.9 km and 14.5 km of service road.
- Four Resettlement villages (two on the Mawa side and two on the Janjira side).
3 MAIN BRIDGE

The total length of the main bridge is 6150m and the main bridge is connected to approach viaducts on both ends and overall width of the bridge is 22.0m. The main bridge is in the form of composite steel truss with two levels, railway at lower deck level and highway at upper deck level suitable for fast track construction. 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. 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. The roadway slab is reinforced concrete in the transverse direction, and is a prestressed concrete structure in the longitudinal direction. There are 41 spans each 150 m in length optimized in the computer program. It is sub-divided into 7 continuous bridge modules, and each module is comprised of 5 or 6 spans. At the interface between adjacent modules, a movement joint is present to accommodate the movement due to various actions.

The major portion of the bridge is flat (0% vertical gradient) except at the two ends the bridge level decreases with approximately 0.5% vertical gradient to match with the adjacent approach viaducts. The horizontal alignment of the bridge consists of straight sections, curved sections with constant radius and short transition curves. The tightest radius is found in Module 7, where the radius is 3000 metres.

4 CROSSING REQUIREMENTS

The bridge is to carry the following facilities:
4.1 Highway

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 650mm wide median. The bridge is intended to carry motorized vehicles only.

Figure 3: V-shaped pier

4.2 Railway

Provision shall be made for future addition of a single track broad gauge railway along the bridge. The railway is proposed to be an extension of the Indian Railways Dedicated Freight Corridor (DFC) and is likely to be part of the Trans-Asian Railway. The design rail speed is 160km/hr for passenger trains and 125 km/hr for freight trains.
4.3 Power Transmission Line

The bridge will be required 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.

4.4 High Pressure Gas Transmission Line

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 shall be hydro tested to a pressure of 1710 psi in accordance with procedures approved by Petrobangla. The high pressure gas main shall be designed in accordance with the requirements of Petrobangla with reference to appropriate recognized international design standards such as the American API and ANSI codes as well as the Bangladesh Natural Gas Safety Rules 1993.

5 ADDITIONAL TECHNICAL STUDIES AND SURVEYS

A substantial program of additional studies and surveys including Geotechnical Investigations, Seismic studies, Pier scour model test was conducted to supplement the current knowledge base for the main bridge foundation design. The information obtained from these investigations was fed into the detailed design process. Geotechnical design includes an assessment of liquefaction of potential ground treatment as required to meet seismic performance levels, slope stability requirement, ground lateral displacement and settlement criteria.

6 BRIDGE VIADUCTS

The viaduct spans are separated into the approach road and the railway viaducts. The main bridge is a two level structure which required a challenging task in the arrangement of the viaducts to separate the railway from the highway and alternative options were considered during the Scheme Design Phase of the project. There are a total of four viaducts supporting the highway, two on each side of the river. The length of the approach road viaducts ranged from 720m to 875m long and consists of 38m spans. The superstructure consists of precast, pre-tensioned concrete Super-T girders which will become the first Super-T girder structure to be constructed in Bangladesh. The Super-T girder is an economical beam commonly used on highway bridges in Australia and is becoming more widespread on projects throughout Asia. The introduction of the Super-T girder to Bangladesh presents an opportunity for future use on other projects throughout the country. This paper describes the design features of the Super-T girder. There is a total of two viaducts supporting the railway, one on each side of the river. The length of the railway viaducts ranged from 2.36km to 2.96km and
consists of 38m spans similar to the approach road viaducts. The superstructure consists of precast, post-tensioned concrete I-girders.

The detailed design of the viaduct structures posed some major challenges in bridge engineering specifically involving earthquakes under soil conditions highly susceptible to significant depths of liquefaction. A multi-modal response spectra analysis was used to analyse and design the viaducts for a seismic event with a return period of 475 years. This paper describes the dynamic analysis procedure and the design features of the structure to withstand these seismic events.

A transition pier is located at the interface of the viaduct spans to the river spans and supports the end spans of the main bridge, the approach road viaduct structure and the railway viaduct structure. The transition pier also provided the location for the diversion of the gas pipe, power cables and telecommunication utilities located on the main bridge whilst also enclosing an access stairwell for inspection, maintenance and emergency evacuations.

7 STRUCTURAL FORM

![Figure 6. Structural form](image)

7.1 Vertical stiffness

Two main truss planes, transversely spaced at 12 metres, form the major structural component. At the lower deck level, transverse lower cross beams at 18.75 metre spacing connect the two bottom chords and form a platform for railway track. At the upper deck level, a concrete slab of approximately 22 metres wide is placed on top of the top chords and carries the highway carriageways. To further increase the member stiffness, the concrete roadway slab is connected to the top chord by shear stud connections so that they can act compositely together. 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. The top chord, bottom chord and diagonal members of the main truss are in the form of a hollow steel box. Plate thicknesses of the boxes vary depending on the location of the member. For thin plate thicknesses, longitudinal stiffeners are present to increase the efficiency of the section in resisting compressive stress. Box section is also adopted for other members including the lower cross beams and upper cross beams. A table below presents the cross section dimension of different member types.

The longitudinal prestress will be carried out before the composite connection is established such that no additional stresses will be generated in the steel truss members. The railway concrete slab is reinforced concrete with no prestress.
7.2 Lateral Stiffness

To increase the lateral stiffness of the truss, plan bracing is added at the lower deck level in the bays adjacent to the piers. Also, additional vertical member connecting top chord and bottom chord is introduced at pier location. Below are two computer model diagrams which help to explain the location of these members.

8 SUBSTRUCTURE

Figure 7 Sub-structural segments

Typical piers have shaped reinforced concrete columns, with a partial internal void, supported by a deep pile cap and a group of eight, 3m diameter steel tubular piles raking in symmetric pattern. The piles have a wall thickness of 60mm and are of Grade S355 steel. A length at the top of the pile is strengthened by filling with reinforced concrete acting compositely with the steel tube. The scour depths corresponding to a 100 year return period has been estimated to be about 50m to 65m, thus resulting in free lengths of piles in the river of about 55m to 65m and length of piles are 100~110m.

Typical piers have shaped reinforced concrete columns, with a partial internal void, supported by a deep pile cap and a group of eight, 3m diameter steel tubular piles raking in symmetric pattern. The piles have a wall thickness of 60mm and are of Grade S355 steel. A length at the top of the pile is strengthened by filling with reinforced concrete acting compositely with the steel tube. The scour depths corresponding to a 100 year return period has been estimated to be about 50m to 65m, thus resulting in free lengths of piles in the river of about 55m to 65m and length of piles are 100~110m.

9 AESTHETICS

The height of the pier at the end of the main bridge is over 30m high and the road viaducts extend up to a kilometre away from the main bridge and the railway viaducts extend up to 2.3km to 3km. The viaducts comprise considerable structures on their own and account for up to 25% of the total road bridge length. The viaducts are also located over land and are readily visible to the surrounding areas and the local communities. The aesthetic appearance is therefore important and has been considered in the design of the viaducts.

The horizontal alignment consists of smooth reversing curves. These curves are located on a vertical grade. The alignment of the viaduct enhances the experience to the road user as the horizontal curves and the vertical
grade enables the road user to get a view of the viaducts and the main bridge as they approach towards the bridge. Many signature bridges around the world do not enable this experience. The road users on the viaducts effectively climb and meander their way onto the main bridge.

![Figure 8: Night view of Padma Bridge](image)

It is envisaged that a gateway structure will be located at the ends of the main bridge. The viaduct structure consists of rectangular blade type piers and the similar span lengths of the viaducts will present an impression of symmetry of the structure. Different pier shapes may be considered during detailed design although the structural concepts will remain. The alignment of the railway viaduct will also consist of an S-curve to separate the alignment of the road and the railway. This also enhances the appearance of the railway viaduct which can be readily seen to the road user approaching and departing the main bridge.

The span length of 38m for the road viaduct has been selected to match the span lengths of the railway viaduct. This reduces the numbers of pier structures and creates a less congested appearance of the viaducts. This enhances the aesthetic appearance of the viaducts and also improves the hydrology.

![Figure 9: View of the viaduct from the main bridge looking north towards Mawa](image)
10 DESIGN CRITERIA

10.1 Design life

The design life for the crossing shall be 100 years.
The minimum service lives for the various components are as follows:

- Bridge deck surfacing period to first re-surfacing: > 25 years
- Bridge bearings period to first major maintenance/replacement: > 40 years
- Movement joints period to first major maintenance/replacement: > 25 years
- Corrosion protection period to first re-coating: > 20 years
- Corrosion protection period between subsequent re-coatings: > 10 years

10.2 Design standards

The following design standards are adopted for the design of the main bridge:

10.3 Design Software

Software package MIDAS has been used to carry out dynamic and static analysis. Global and local analysis using MIDAS software is done using 3 construction sequences which amongst others are governing criteria for design. Piglet is used for pile design and Shake is used for Seismic analysis.

10.4 Material Properties

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

10.5 Design loadings:
The following loads shall be considered in the design of highway structures:

10.5.a Dead load (DL)

Dead load shall consist of the weights of all structural elements and include concrete barriers and parapets.

10.5.b Superimposed dead Load (SDL)

In general superimposed dead loads shall be considered in two parts.
SDL (A): 100mm bituminous road surfacing
SDL (B): Other superimposed dead loads, including road furniture that can be readily removed and replaced, for example metal parapet rails, drainage, signs and lighting fittings, E&M Systems, noise barriers, gantries.
10.5.c Highway loads
The bridge is required to carry a dual two-lane carriageway road with a design traffic speed of 100 km/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.

10.5.d Railway loads

Vertical train loads
According to Design Criteria, the DFC loadings are wagon loads combined with different locomotives.

Centrifugal loads
The horizontal centrifugal force shall act at a height of 1,830 mm above rail level.

\[ C = \frac{W V^2}{127R} \]

Where
C is the horizontal effect in kN/m
W is the equivalent distributed live load in kN/m
V is the maximum train speed in km/hr
R is the curve radius in meters.

10.5.e 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.

10.5.f Walkway loads
Walkways shall be designed for 5 kN/m2 of live load.

10.5.g Wind loads
Wind loads shall be based on a wind speed of 30 m/s at a height of 10 m above water level and a 100 year return.

10.6 Seismic action
The seismic design generally follows the AASHTO LRFD Bridge Design Specifications, 4th Edition, 2007. Two levels of seismic hazards and corresponding performance criteria shall be considered as follows:

Level 1 – Operating Level Earthquake (OLE)
Seismic Hazard - The OLE events have a 65% probability of being exceeded in the design life of 100 years or a return period of 100 years. The OLE events have a PGA of 0.052g in the very dense sand at an elevation of -120 m PWD.

Level 2 – Contingency Level Earthquake (CLE)
Seismic Hazard - The CLE events have a 20% probability of being exceeded in the design life of 100 years or a return period of 475 years. The CLE events have a PGA of 0.144g in the very dense sand at an elevation of -120 m PWD.

10.7 Temperature effects
The following shade air temperatures are to be adopted for the design of the bridge:

- Minimum shade air temperature: 0.0 °C
- Maximum shade air temperature: 48.5 °C
10.8 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.

10.9 Other loadings

The supports for the gas pipe and their connections to the deck structure shall be designed to support the pipe when completely full of water during the temporary test condition. The bridge structure need not be designed for this loading in conjunction with other extreme live loading conditions. From studies of the river characteristics the maximum flow velocity shall be taken as 4.0m/s. This velocity shall be used to determine the stream pressure acting on the foundations.

10.10 Shrinkage and creep effect

Shrinkage and creep effect will be derived from BS 5400 Part 4 Appendix C and taken as a permanent load (yf at SLS = 1.0, at ULS = 1.2). The relative humidity is assumed to be 80%.

10.11 Differential settlement

Differential settlement will be taken as a permanent load and will be determined from the geotechnical investigation. Differential settlement is taken as 80 mm and is possible to happen at any pier.

10.12 Geotechnical

The following Geotechnical Design Criteria has been adopted:
(a) Static Analysis
(b) Seismic Analysis

Geotechnical design shall include an assessment of liquefaction potential and Ground Treatment as required to meet seismic performance levels, slope stability requirements, ground lateral displacement and settlement criteria.

10.13 Foundations

The factors of safety are to be adopted when designing the pile foundations for the main bridge and approach viaduct structures. The factors of safety are based on unfactored working loads.

<table>
<thead>
<tr>
<th>Case</th>
<th>Load case</th>
<th>FOS on Skin Friction in Compression</th>
<th>FOS on Skin Friction in Tension</th>
<th>FOS on End Bearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SW + SDL + LL</td>
<td>1.5</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>SW + SDL + Ship Impact</td>
<td>1.25</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>3</td>
<td>SW + SDL + 1/3 HA (1 lane)+ RL + 100 yr Earthquake</td>
<td>1.25</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>4</td>
<td>SW + SDL + 1/3 HA (1 lane)+ RL + 475 yr Earthquake</td>
<td>1.0</td>
<td>2.0</td>
<td>1.0</td>
</tr>
<tr>
<td>5</td>
<td>SW + SDL + Check Flood Scour (500 yr scour) down to -70 m PWD</td>
<td>1.2</td>
<td>2.4</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Table: Recommended Geotechnical Factors of Safety for the Various Load Cases (Loads Unfactored)

10.14 Structural analysis for substructure design

Analysis software has been validated against known or published solutions. Global models for structural analysis have been based on the structural geometry and the arrangements shown on the design drawings. Where appropriate the analyses have considered large displacement effects and material non-linear behaviour.
Time dependent effects due to creep and shrinkage of concrete and creep relaxation of cables have been considered.

Self weights have been determined from the dimensions and details shown on the drawings. For services, utilities and other non-structural items to be carried by the bridge, the values of the superimposed dead loads have included sufficient contingency allowance for future requirements. Permanent load effects locked-in to structures as a result of the proposed construction sequence have been accurately determined as part of the analysis. In case where shear lag is significant the analysis has taken into account the effects of shear lag under

10.15 Navigation, river behaviour and scour considerations

10.15.a River levels and navigation clearances

The required vertical clearance over the Standard High Water Level (SHWL) shall be confirmed to provide the necessary navigational clearances in the Padma River and an adequate level of the approach road to avoid regular flooding during the rainy season.

Initially the following shall be adopted for the river levels and navigational clearances:

- Minimum clear horizontal width of navigation channel between any adjacent bridge piers: 250 ft. (76.2m)
- Minimum vertical clearance above SHWL: 60 ft. (18.3m) for at least one principal navigation span and preferably three adjacent spans, and 40 ft. (12.2m) for all other spans within a total navigable river width of 4800m.

Global Warming and Climate Provision:

Extreme hydro-meteorological changes due to climate change potentially affect the design dimension of this proposed national landmark. An additional vertical clearance of 400mm has been included to allow for future tidal variations and global warming. The allowance is being included to account for possible changes to the present value of the Standard High Water Level (SHWL).

10.15.b 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

10.15.c River water levels

- The following are the key water levels at the project site:
  - Standard low water level + 1.2 m PWD
  - Standard high water level + 5.9 m PWD
  - Design high water level + 7.7 m PWD
  - Bankfull water level + 5.5 m PWD

10.15.d Maximum flow velocities

- Design maximum velocity (vertically-averaged), as used for design of protective elements against current erosion, is determined by 2-D numerical modelling calibrated against ADCP velocity measurements at the bridge site in August 2009. The design value corresponds to the 100-year design discharge including allowance for climate change. The check-flood value corresponds to 500-year conditions. The following are the assumed design velocities:
  - Design maximum velocity 4.6 m/s
  - Check-flood maximum velocity 5.1 m/s
10.16 Scour depths for foundation design

Figure 10: Scour Terminology

Local scour will occur at the bridge piers when the local flow field is strong enough to remove sediment. The depth of scour is strongly related to the width of the pier. Typical formulas for estimating local scour include multiplying factors to account for pier shape, flow conditions and alignment, bed conditions, among others. The piers for the Padma Bridge will be complex consisting of a raised pile cap supported by a group of piles. Empirical methods for estimating scour at complex piers may give smaller or larger local scour compared to what actually occurs. For this reason, physical model studies are recommended for complex piers to better estimate the local scour (TAC, 2001; FHWA, 2001; Melville and Coleman, 2000).

To assess the local scour due to pier a pier flume model test was conducted in Vancouver, Canada for different pier and pile arrangement. And it was feed into pile length design of the bridge.

Design scour levels shall be taken as:
- Lowest bed level outside of the flood season: -37m PWD
- Provisional estimate natural scour level (2 year) -39m PWD
- Provisional estimate natural scour level (100 year) -50m PWD

These values make an allowance for natural bend scour and some confluence scour effects. To these values estimates of local scour should be added, which for raked piles would be of the order of 8m. The physical model studies will provide more certainty on local scour assumptions.

10.17 Bearings and restraints

At piers, the main truss is supported on bearings. Longitudinal fixity is provided in three piers at the middle of each module. In this way the longitudinal wind loading can be distributed more evenly and at the same time the effect due to temperature variation can be minimized. Transverse fixity is provided at all piers in the form of transverse shear keys. During seismic events, longitudinal force is transmitted from the superstructure to substructure through shock transmission units.

Isolation bearings have been used worldwide to mitigate seismic response by isolating structures from seismic input. Isolation bearings can accommodate thermal movements with minimum resistance, but will engage under seismic excitations. In this strategy, all primary structural members will remain elastic without any damage (or plastic hinging).

Isolation bearings comprise the following key elements: an element that provides rigidity under service loads and provides lateral flexibility beyond service loads, an element that provides self-centring capability and an element that provides energy dissipation. These key elements have to be properly designed and fine tuned to achieve an optimal seismic behaviour.

Friction Pendulum Bearings by Earthquake Protection Systems, Inc. (EPS) shown below, FIP Industriale and Maurer Sohne Friction pendulum bearings 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. There have been two types of friction pendulum bearings developed: Single Friction Pendulum Bearing and Triple Friction Pendulum Bearing (by EPS only).

The triple friction pendulum bearings comprise three pendulums and their sliding mechanisms can be activated sequentially as the earthquake motions become stronger. For the lower (operating) level earthquakes, only the low friction and short period inner pendulum will be activated. For the upper (contingency) level
earthquakes, all three pendulums with a much larger sliding area will be activated, referring to the illustration below. The bearing friction and period both increase and result in lower bearing displacements and lower seismic force input.

Figure 11: Friction Pendulum Bearing

The self centering capability of the bearings is very good and the residual displacement after seismic events is small, comparing to the spans of the bridge. The self-centering capability comes from the static downhill force and from the smaller ground motions at the tail end of the earthquake event which stabilizes the bearings to its lowest center point by gravity.

Padma Multipurpose Bridge carries both highway and railway traffic, and is subjected to high permanent vertical loads and two levels of seismic hazards. Therefore, due to their high vertical load capacity, self-centering capability and efficiency for multi-level earthquakes, the triple friction pendulum bearings are considered the best candidate for seismic design strategy with isolation bearings.

11 FUNDING MODEL

The Padma Multipurpose Bridge Project (PMBP) is a priority project of the Government of Bangladesh (GOB). An accelerated design programme has been adopted to start the construction of the bridge within 2010. The project is co-financed by GOB, the World Bank (WB), the Asian Development Bank (ADB), the Japan International Cooperation Agency (JICA) and the Islamic Development Bank (IDB). The Bangladesh Bridge Authority (BBA) is the executing agency.

12 CONCLUSIONS

Implementation of Padma Multipurpose Bridge Project is strategically important for Bangladesh. The new Padma Multipurpose Bridge will provide a vital missing link in the transport network of Bangladesh. The bridge will provide significant travel time savings, particularly between the Dhaka Division to the south-east of Bangladesh and possibly onto India. These travel time savings are expected to be in the order of 2 hours for cars and bus to 10+ hours for trucks by 2014. The operation of the Padma Bridge, with its large step change in transport costs, will result in significant economic changes to the southwest region reduced through a safe and easy fixed river crossing replacing the often unsafe and unreliable ferries. Also for the population living in the neighborhood of the bridge the project will offer improved connections and mobility and opportunities for development of new businesses, improved marketing of produce and new employment.