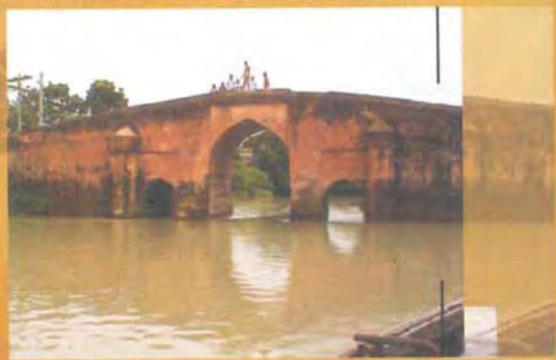
Souvenir of the

Japan-Bangladesh Joint Seminar on Advances in Bridge Engineering

WITH SPECIAL ATTENTION TO STEEL & COMPOSITE CONSTRUCTION



10 August 2005, Dhaka, Bangladesh

Organized by

JSCE 社団法人 土木学会
JAPAN SOCIETY OF CIVIL ENGINEERS

Civil Engineering Division
Institution of Engineers, Bangladesh

Committee of Steel Structures
Japan Society of Civil Engineers

In association with

Jamuna Multipurpose Bridge Authority
Government of the Peoples' Republic of Bangladesh

Roads and Highways Department
Government of the Peoples' Republic of Bangladesh

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Jointly Published by:

Civil Engineering Division, The Institution of Engineers, Bangladesh.
Roads and Highways Department, Government of the Peoples' Republic of Bangladesh.

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August, 2005

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On the front cover page

Left: The Akashi Kaikyo Bridge (AKB) is a three-span, two-hinged stiffening girder system suspension bridge that spans the Akashi Strait between Maiko, Tarumi-ward in Kobe, and Matsuho, on Awaji Island. After various investigations including aerodynamic tests on large scale three dimensional prototypes, actual construction of the bridge began in May 1988, and took a total of ten years. The AKB was opened to traffic on April 5, 1998. The AKB become the longest suspension bridges in the world, surpassing the Humber Bridge (England, 1,410 meter center span) by 581 meters. Although in primary design the AKB was 3,910 meters long overall, with a center span of 1,990 meters, it was extended 1 meter by the Great Hanshin Earthquake (January 17, 1995). Source: Honshu-Shikoku Bridge Authority, Japan.

Right: The photo depicts one of the known oldest bridges of Bangladesh. It is a masonry bridge built in the 17th century during Mughal period over the Mir Kadim Canal, Munshigonj, Dhaka Division. The bridge has a center arch of 4.3m span and 8.5m in height above the bed of the canal with two side arches of 2.2m span each and 5.2m high. The piers are 1.8m thick. The wings are straight back and the whole length of the bridge is 52.7m. Source: Dani, A.H. (1961). Muslim Architecture in Bengal, Asiatic Society of Pakistan Publication No. 7, Dacca. Courtesy: Engr. Emdadul Huq, Retd. Additional Chief Engineer, Public Work Department, Bangladesh. Photo: Dr. Engr. A.F.M. Saiful Amin, BUET.

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JSCE 社団法人 土木学会
JAPAN SOCIETY OF CIVIL ENGINEERS

Barrister Nazmul Huda
Minister
Ministry of Communications

Message

It gives me immense pleasure to know that the Civil Engineering Division of the Institution of Engineers, Bangladesh and the Japan Society of Civil Engineers are jointly organizing a seminar on Advances in Bridge Engineering in association with the Roads and Highways Department and Jamuna Multipurpose Bridge Authority.

The adaptation of modern technology in the field of Bridge Engineering to keep pace with the developed world is of utmost importance. The participation of civil engineers and academicians in the seminar will surely enhance the quality and standard of our bridges. The participation of Japan Society of Civil Engineers in this seminar is a milestone for our technological development and will build a good collaboration between the engineers of the two countries.

I wish Japan-Bangladesh Joint Seminar on Advances in Bridge Engineering a great success.

Barrister Nazmul Huda

Professor Jamilur Reza Choudhury
Convenor, Steering Committee
(Past President, Institution of Engineers, Bangladesh)

Message

I am very happy to note that the Civil Engineering Division of the Institution of Engineers, Bangladesh is organizing a seminar on Advances in Bridge Engineering jointly with Committee of Steel Structures, Japan Society of Civil Engineers. This is for the first time that a joint Japan-Bangladesh seminar is being organized in the field of Bridge Engineering.

The support of the two major government agencies involved in construction of bridges in Bangladesh, viz. Roads and Highways Department and Jamuna Multipurpose Bridge Authority has helped us a great deal in organzing this seminar.

Recent growth of international trade resulting from globalization, coupled with increasing urbanization, is leading to increasing demands on construction of necessary infrastructure. Bridges for highways and railways form an essential component of this infrastructure and are going to play an important role in accelerating the pace of socio-economic development. It is heartening to note that over the last few years, efforts have been initiated to develop performance-based model codes which are accepted internationally. The efforts of Japanese engineers to develop such a code are extremely laudable.

In response to our call for papers, a total of 14 papers written by the experts in the broader field of Bridge Engineering have been selected for publication in the proceedings and oral presentation in the Seminar. Bangladeshi engineers will benefit greatly from this seminar where papers dealing with some of the latest advances in steel/composite bridge design and construction are going to be presented and discussed.

On behalf of the Steering Committee, it is my pleasure to welcome all the participants to the Seminar. I deeply appreciate the hard work of the members of the organizing committee in organizing this seminar and am confident that the initiative would lead to continuing collaboration between Japanese and Bangladeshi engineers, particularly in bridge engineering.

Professor Jamilur Reza Choudhury

JSCE 社団法人 土木学会
JAPAN SOCIETY OF CIVIL ENGINEERS

Teruhiko Yoda
Chair, Committee on Steel Structures
Japan Society of Civil Engineers

Message

The Committee on Steel Structures of JSCE (Japan Society of Civil Engineers) would like to congratulate the first Japan-Bangladesh Joint Seminar on Advances in Bridge Engineering. We are very happy to be working with you as a partner on this worthwhile effort. High quality technical seminars such as this in the Asia-Pacific region are vital for enhancing international cooperation.

In 2004, a subcommittee was established by the Committee on Steel Structures to make the Performance-based Design Standards for Steel/Composite Structures in a limit state philosophy with partial factor verification, in recognition of Asian Model Codes. Clearly, research and development in this area must rely on the international collaboration with Asia, Europe and North America. It is hoped that this Joint Seminar would serve as a platform for improved relations and better cooperation among the individuals and organizations from Bangladesh and Japan.

Teruhiko Yoda

Takeshi Mori
Secretary General, Committee on Steel Structure
Japan Society of Civil Engineers

Message

Our Society (Japanese Society of Civil Engineers, JSCE) has fortunately made an agreement of cooperation with your Institution (The Institution of Engineers, Bangladesh, IEB) five years ago. However, It is also a fact that there were not so many opportunities for you and us to contact with each other in technical issue. I am very pleased and honored to have a chance to come to Bangladesh and organize a seminar with you.

In recent years, every structural engineer in the world recognizes the importance of the international code, and is interested in the code such as ISO. I hope and trust this meeting will be the first step to make the model code for bridges accepted in Bangladesh and Japan, and to lead to the Asian code.

Takeshi Mori

Prof. Dr. Ing. M. Anwarul Azim
President
The Institution of Engineers, Bangladesh

Message

I am very delighted to learn that for first time the Civil Engineering Division of The Institution of Engineers, Bangladesh is going to organize a seminar on bridge Engineering with Japan Society of Civil Engineers.

The fate of the people will be determined by their technological capability and flexible knowledge generation and its implementation.

We should be global in our thinking and action. There should be interactions and co-operation between the engineers with a view to developing ourselves.

On behalf of the Institution of Engineers, Bangladesh and on my own behalf, I am conveying my heartful thanks and appreciation to the office bearers and all beloved members of Civil Engineering Division for taking the noble endeavors to organize such an important and eventful solemn occasion.

I wish the all success.

Prof. Dr. Ingr. M. Anwarul Azim

Engr. A.K.M. Faizur Rahman
Chief Engineer
Roads and Highways Department

Message

The importance of bridges in developing an uninterrupted communication network in Bangladesh is unquestionable. In this context, we are always keen to know the technological advances in Bridge engineering in order to make a sustainable development of our communication network with the optimum uses of resources. Furthermore, Japan is a time trusted friend of Bangladesh and has a long history of cooperation in the infrastructure development of our country.

To this end, we are very happy that the Civil Engineering Division of the Institution of Engineers, Bangladesh has joined its efforts for the first time with the Japan Society of Civil Engineers to organize the seminar on Advances in Bridge Engineering. The Roads and Highways Department, Government of the Peoples' Republic of Bangladesh feels very proud and delighted to be a part of the significant event as a co-organizer. In this regard, it is my profound request to all the organizers and participants of this occasion to join hands together for making it a success in Bangladesh.

I am confident that this Seminar will lead to a successful exchange of knowledge, transfer of technology and share of experiences. Also I hope that the friendship between Bangladesh and Japan will increase manifold through this event. I wish all the delegates from Japan Society of Civil Engineers a great and memorable stay in Bangladesh, the land of natural beauty.

Finally, I would like to extend my congratulations and appreciations to the Civil Engineering Division of the Institutions of Engineers, Bangladesh and the Japan Society of Civil Engineers for all the hard working and earnest effort in making this seminar possible.

Engr. A.K.M. Faizur Rahman

JSCE 社団法人 土木学会
JAPAN SOCIETY OF CIVIL ENGINEERS

Engr. Md. Nurul Huda
Vice-President (Academic & International Affairs)
The Institution of Engineers, Bangladesh
& Co-Convenor, Steering Committee

Message

I am glad to know that the Civil Engineering Division of The Institution of Engineers, Bangladesh in collaboration with the Roads and Highways Department and Jamuna Multipurpose Bridge Authority are going to jointly organize a seminar on Bridge Engineering with Japan Society of Civil Engineers on 10 August 2005 at Dhaka.

I am confident that this will provide an opportunity to the eminent speakers to exchange their ideas and experiences for the advancement of technologies.

On behalf of the Institution of Engineers, Bangladesh and on my own behalf, I am conveying my thanks and appreciation to the office bearers and all beloved members of Civil Engineering Division in taking the noble endeavors to organize such an important and eventful occasion.

I wish the seminar a great success and convey my good wishes to all the members of Civil Engineering Division. I appreciate Roads and Highways Department and Jamuna Multipurpose Bridge Authority for their valuable contribution.

Engr. Md. Nurul Huda

Engr. A.N.H. Akhtar Hossain, PEng.
Honorary General Secretary
The Institution of Engineers, Bangladesh

Message

It's a matter of immense pleasure to learn that the Civil Engineering Division of The Institution of Engineers, Bangladesh in collaboration with the Roads and Highways Department and Jamuna Multipurpose Bridge Authority is going to jointly organize a seminar on Bridge Engineering with Japan Society of Civil Engineers.

It is again heartening to note that the Civil Engineering Division has been contributing significantly to the fulfillment of the objectives of the IEB since its creation. Holding of such a seminar is the testimony of their untiring efforts to uphold the cause of the IEB. I hope that the seminar create an unique opportunity for the members of the Civil Engineering Division to share their experience and knowledge.

I would like to take the opportunity to congratulate the members of the Civil Engineering Division on the eve of this event. Further, I would also like to thank the organizers for their hard work for excellent arrangements.

I wish all success of the seminar.

Engr. A.N.H. Akhtar Hossain, PEng.

Engr. Md. Rezaul Karim
Chairman, Civil Engineering Division, IEB
& Chairman, Organizing Committee

Message

I consider it is a great privilege to say a few words on the occasion of the seminar Jointly organize by the Japan Society of Civil Engineers with Civil Engineering Division, The Institution of Engineers, Bangladesh (IEB) in collaboration with the Roads and Highways Department and Jamuna Multipurpose Bridge Authority.

We are in the new millennium. To meet the challenges of the Globalization, we will have to increase and uphold the professional efficiencies. Our whole approach should be integrated to global development. To attain that goal the interaction between the professionals should be intensified.

I am confident that this seminar will create and opportunity to the Civil Engineers to Exchange their ideas and experience for advancement of technological development in the field of Bridge Engineering.

Civil Engineering Division, The Institution of Engineers, Bangladesh has been trying relentlessly to improve the professional excellence and also playing an important role for advancement of technological development.

I express my gratitude to all the Engineers ,The Executive Committee members of Civil Engineering Division and also to the Engineers of the Roads and Highways Department (RHD) and the officials of Jamuna Multipurpose Bridge Authority for jointly organize such a seminar. I would also like to thank Executive Office bearers of the Institution of Engineers, Bangladesh and the various Engineering Organizations for their advice and co-operation.

Engr. Md. Rezaul Karim

Engr. Md. Nurul Islam
Secretary, Civil Engineering Division, IEB
The Institution of Engineers, Bangladesh

Message

Civil Engineering Division of The Institution of Engineers, Bangladesh in collaboration with the Roads and Highways Department and Jamuna Multipurpose Bridge Authority is going to organize jointly a seminar on bridge Engineering with Japan Society of Civil Engineers on 10th August 2005 at Dhaka with the intention to exchange views, ideas and share experiences among professionals and academicians in the fields of Bridge Engineering.

We are grateful to members and officials of the IEB and the Civil Engineering Division and also to the Engineers of Roads & Highways Department (RHD) for their wholehearted support and co-operation to make the program a success. I heartily congratulate the authors from home and abroad, who took part in presenting their papers in the seminar. I believe that with their active participation and valuable presentation, the seminar on Bridge Engineering will be successful. I must pay special thanks to my divisional committee members & all seminar Committee Members.

I am thankful to IEB executives, specially Prof. Dr. Ing. M. Anwarul Azim, President, IEB, Engr. Md. Nurul Huda Vice-president (Academic), IEB, Engr. A.N.H. Akhtar Hossain, PEng., Honorary General Secretary, IEB, Prof. Dr. Engr. Jamilur Reza Choudhury, Vice-Chancellor, BRAC University and Chief Engineer, Roads & Highways Department, for their kind assistance, co-operation and suggestions.

Finally, I would like to thank Japan Society of Civil Engineers, all the Civil Engineers, members of the Electronic/Printing Media & the various Engineering organizations for their advice and co-operation.

Engr. Md. Nurul Islam.

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Japan-Bangladesh Joint Seminar on Advances in Bridge Engineering

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Japan-Bangladesh Joint Seminar on Advances in Bridge Engineering

Paper Presentation Schedule

Technical session A: Geotechnical aspects

Date: 10 August 2005 Time: 11:00 am-12:15 pm	Chairman: Professor Hitoshi Yamada Co-chairman: Professor M. Hossain Ali

A cyclic model for pressure insensitive soil
M.R. Hossain, M.S.A. Siddiquee, F. Tatsuoka

A nonlinear model for soft rock and its application in bridge pier settlement calculation
M.S. Islam, M.S.A. Siddiquee, F. Tatsuoka

Geotechnical problems of bridge construction in Bangladesh
A.M.M. Safiullah

Technical session B: Steel, composite bridges and advanced materials

Date: 10 August 2005 Time: 1:15 am-3:15 pm	Chairman: Professor Jamilur Reza Choudhury Co-chairman: Professor Eiki Yamaguchi

Highway bridge specifications and recent development of steel-concrete composite bridges in Japan
Masatsugu Nagai

Numerical model for predicting composite behavior of stud shear connectors
Md. Khasro Miah, Akinori Nakajima, Ahsanul Kabir

Analytical study on steel-concrete composite girders
Yoshiaki Okui

Evaluation method for bending capacity of corroded steel girder
Takeshi Mori

Scope of application of composite materials in bridge construction from Bangladesh perspective
M.A. Sobhan

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Technical session C: Structural dynamics

Date: 10 August 2005	Chairman: Professor Takeshi Mori
Time: 3:30 pm-4:45 pm	Co-chairman: Professor A.M.M.T. Anwar

Recent topics in the wind engineering
Hitoshi Yamada

Dynamic behavior of cable-stayed bridge with damping
Md. Toihidul Islam, Tanvir Manzur, Alamgir Habib

Vibration serviceability requirement in the design of arch-supported suspended footbridge
A.F.M. Saiful Amin, Tahsin Reza Hossain, Alamgir Habib

Technical session D: Instrumentation and monitoring

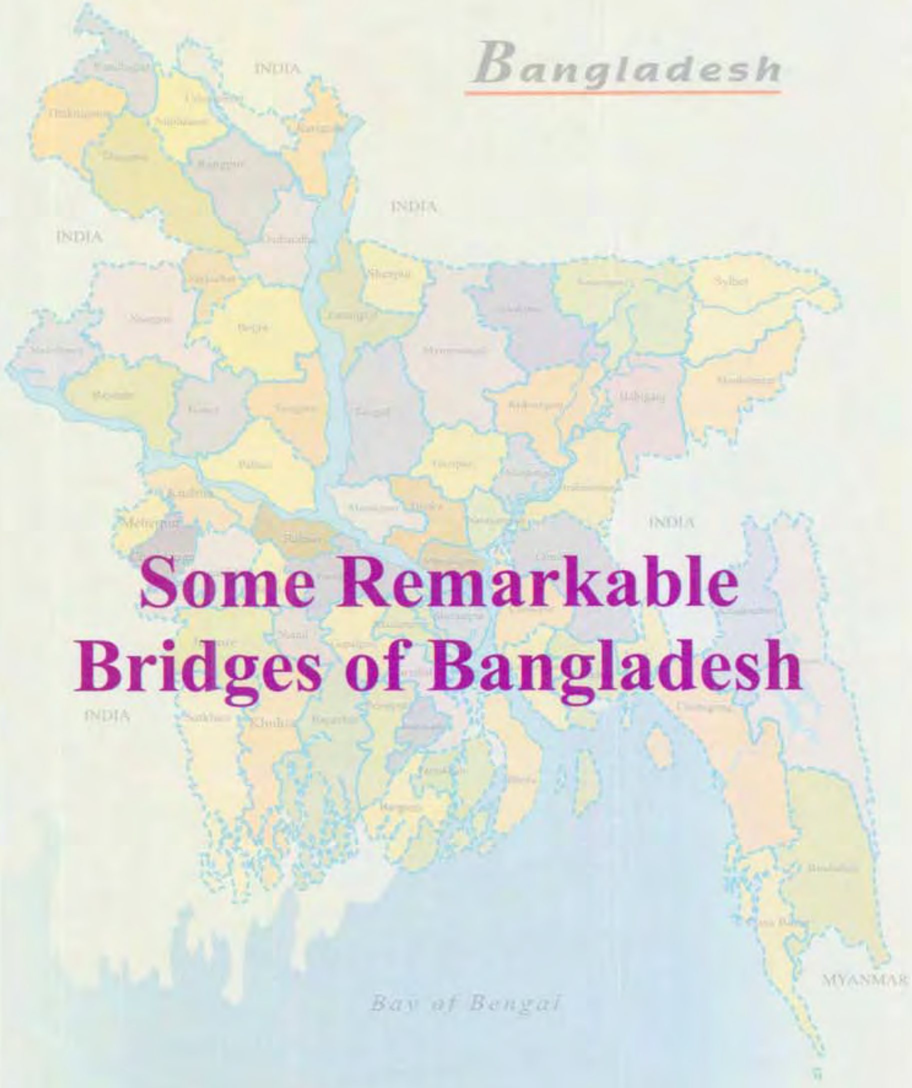
Date: 10 August 2005	Chairman: Professor A.M.M. Safiullah
Time: 5:00 pm-6:15 pm	Co-chairman: Dr. Yoshiaki Okui

Identification of dynamic parameters of the Jamuna Multipurpose Bridge in ambient transverse vibration
R. Ahsan, T.M. Al-Hussaini, M.A. Ansary, M.M. Rahman

Seismic protective systems for bridges and highway structures in Bangladesh
Asif Iqbal

A method for observing weights of trucks running on a bridge
Eiki Yamaguchi, Kazushi Matsuo

Some Remarkable Bridges of Bangladesh



Foreword

I am very pleased that Roads and Highways Department (RHD) and Jamuna Multipurpose Bridge Authority (JMBA) with the joint cooperation from Civil Engineering Division, Institution of Engineers, Bangladesh (IEB) and Japan Society of Civil Engineers (JSCE) are jointly organizing a seminar on "Advances in Bridge Engineering" to be held in Dhaka from 10th August to 12th August 2005.

National Land Transport Policy 2004 has called for fostering Inter-National road links for the greater national interest. Therefore, GOB is relentlessly looking forward to build up regional cooperation to develop regional and Inter-National road network through proposed Asian Highway.

Roads and Highways Department (RHD) has to manage a total bridge length of little more than 184000 meter. For each km of its 21500 km road network there is a 12 meter bridge. Around 80% of the bridges are in good condition. In order to provide special emphasis on Bridge Maintenance, RHD has created a new Bridge Management Wing headed by an Additional Chief Engineer. A computerized Bridge/Culvert Maintenance Management System (BCMMS) have been developed by RHD to facilitate the use of Road Asset Management System (RAMS) to be prepared under World Bank funded Road Sector Reform Project (RSR-P). At present DFID funded Narrow Bridge replacement project is underway to reconstruct some of the nation's narrow and old bridges at different locations within Bangladesh. Some of the major bridges are to be constructed in years to come.

This seminar on "Advances in Bridge Engineering" is an opportunity for the Engineers to attain in-depth knowledge from the Japanese civil engineers who have always been the pioneers in the civil engineering community with their remarkable structural masterpiece, construction, innovative design and maintenance approach.

RHD and JMBA have presented technical data on ten of their most remarkable bridges. I believe this would help all attending the seminar to know about the construction methods being used in construction and maintenance of major bridges of Bangladesh.

I am confident that attendees of this seminar will be highly benefited from the deliberations given by the learned speakers from Japan and Bangladesh.

I convey my heartfelt gratitude to Engr. Md. Ashraful Islam, Superintending Engineer, RHD and all others in RHD, IEB, JSCE and JMBA who have worked relentlessly to bring success to this prestigious international seminar.

A.K.M Faizur Rahman
Chief Engineer
Roads and Highways Department

Hazi Shariatullah Bridge

Background

The development of Dhaka-Mawa-Bhanga-Bhatiapara-Mollahat-Town Nowapara National Highway has been built to ensure safe and easy transport of South-West region of Bangladesh with the capital city, Dhaka under the head line,"South-West Road Network Development Project".

A View of Hazi Sharitaullah Bridge

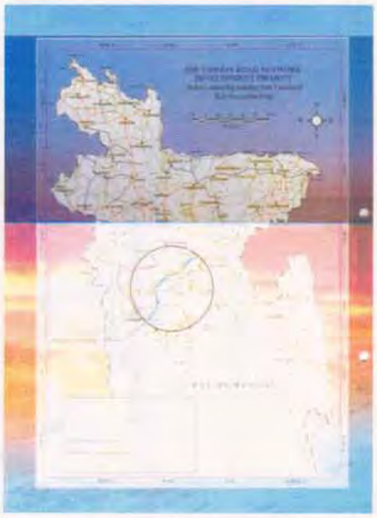
The communication with this road is interrupted by the river, Arial Khan at 9th km of Mawa-Bhanga section. The construction of the bridge is, therefore, very important in connecting divisional head quarter, Khulna and Barisal, land port, Banapole and river port, Mongla with Dhaka city. The bridge will also ensure the communication of Sundarban, the largest mangrove of Bangladesh and beautiful sea-beach, Kuakata with Dhaka city.

Salient Features

The development of Dhaka-Mawa-Bhanga-Bhatiapara-Mollahat-Town Nowapara National Highway has been implemented under five contracts. The construction of this bridge has been completed successfully under contract No.2. The Korean construction firm, Hanil Construction Co. Ltd. has completed the construction of the bridge under the supervision of consultant, JOC-BCL. The bridge was opened to traffic on 15 May, 2005. The bridge is 450m long and 10m wide. The superstructure of the bridge consists of simply supported prestressed concrete I-girder and in situ RCC slab. The bridge has 10 simply supported spans each 45m long. In designing the bridge AASTHO live load and specifications have been followed.

Foundation

Each Pier and abutment is founded on RCC bored piles. The foundation of the bridge consists of 1.0m diameters RCC bored



Location Map of Hazi Shariatullah Bridge pile. Each pier consists of 16 nos. bored piles of length 58m including full-length steel casing of 12mm thickness and the abutment on each side of the bridge is founded on 8 nos. bored piles of length 50m including full-length 12mm thick steel casing.

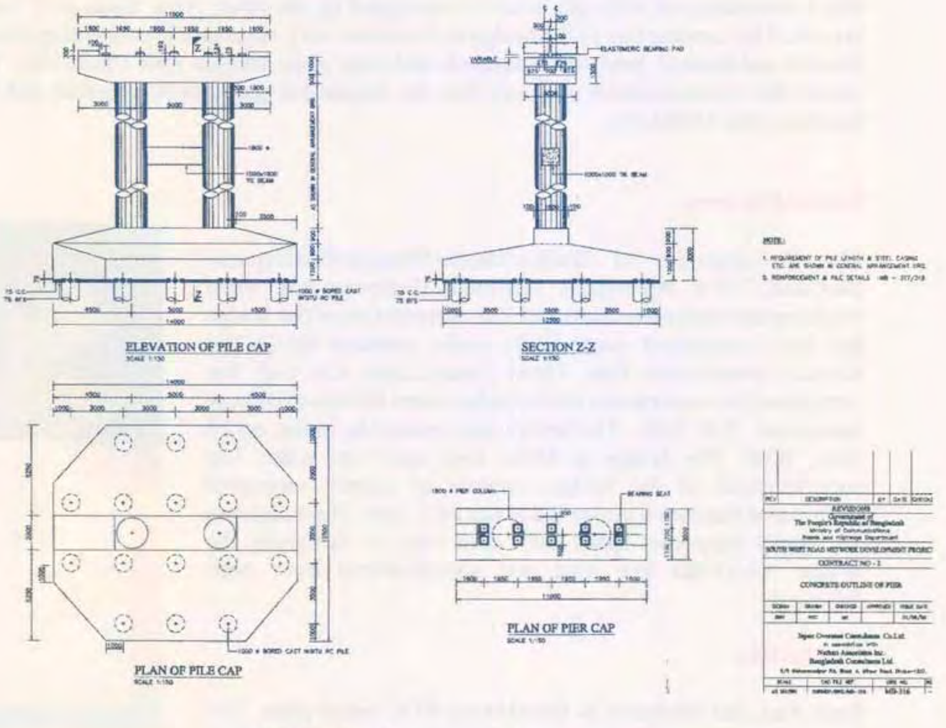
Load Test on Pile (Cast in situ)

Re-bar Basing of Pile Cap and Pier Column Substructure

Boring was done under each pier and abutment using bentonite up to full depth of piles. Steel casing was placed in position and mud was cleaned by reverse circulation method. Then pouring of grade 30 concrete was done after placing steel cage.

Substructure

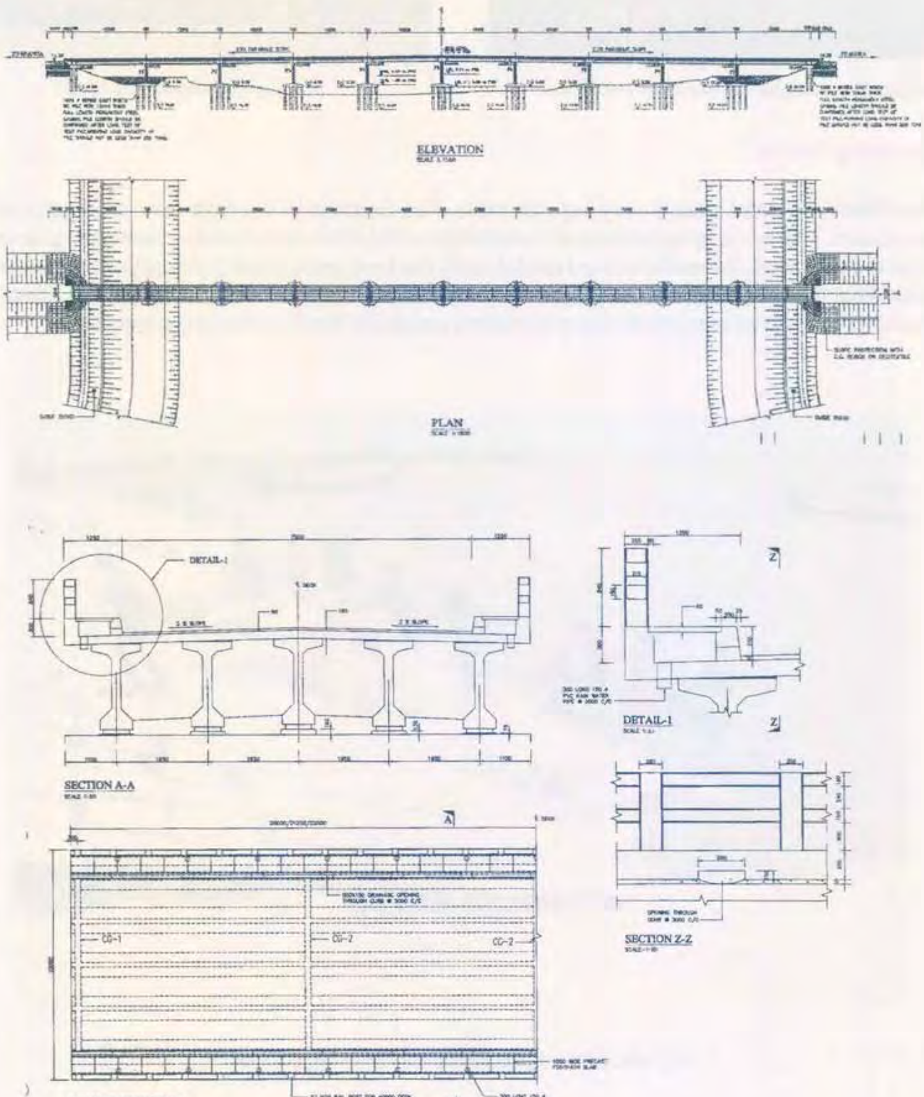
The decking is supported on RCC piers having two circular columns spaced 5m center to center. A horizontal tie beam of 1m x 1m sizes was introduced at different height from the base.



Pile Cap Details

Superstructure

Each span comprises 5 nos prestressed concrete girder launched in position by means of launching truss and placed over bearings on piers or abutment. Overall depth of each of the 5 girders is 2.08m. The web thickness is 200mm at center. The flange thickness varies from 210mm to 225mm at end and center of girder. The width of top flange is 1.05m and that of bottom flange is 700mm. Each beam consists of 9 cables. Prestressing tendon is low relaxation strand with ultimate strength of 1870 MPa and confirmed to the requirements of ASTM-A 416-85 or equivalent. Stiffening diaphragms have been provided in each span at 11.1m intervals.



Schematic Structural Details

Staging Formwork for Casting Deck and Girder

Lifting of Launching of Girder

River Training Works

The flow of the river Arial khan is very unpredictable. The direction of the river flow changes every year during monsoon. Moreover, geography and morphology of the river changes take place during devastating flood. Due to this reason, the mathematical model study has been performed to determine the movement of the river and the intensity of scour.The physical Model study of the river has also been done. Based on the above study result river training works have been done and guide bund has been constructed.

CC Blocks Over Guide Bund for River Training Works

Cost

The construction cost of the bridge is Tk.87.00 (eighty seven) crore.

Doratana Bridge

Introduction

Bagerhat district town stands on the river Bhairab. Khulna-Bagerhat-Perojpur Regional Highway (R770) crosses this river at Bagerhat. Two divisional towns Khulna and Barisal are connected through this highway. Prior to construction of this bridge the road communication was being maintained by RHD ferries. Construction of Doratana bridge over the river Bhairab was a long waiting demand and widely felt need of the people of these areas. The construction of bridge over the river gap is not only of strategic importance in the national highway network, but regionally its construction facilitates the movement of people, resources and products between the central and south-west areas of Bangladesh. It facilitates the smooth movement of people to the Majar of Khan Jahan Ali (R) located at Bagerhat. Tourists are also enjoying unhindered road communication to visit historical Sat Gumboj Mosque.

A View of Doratana Bridge

Site

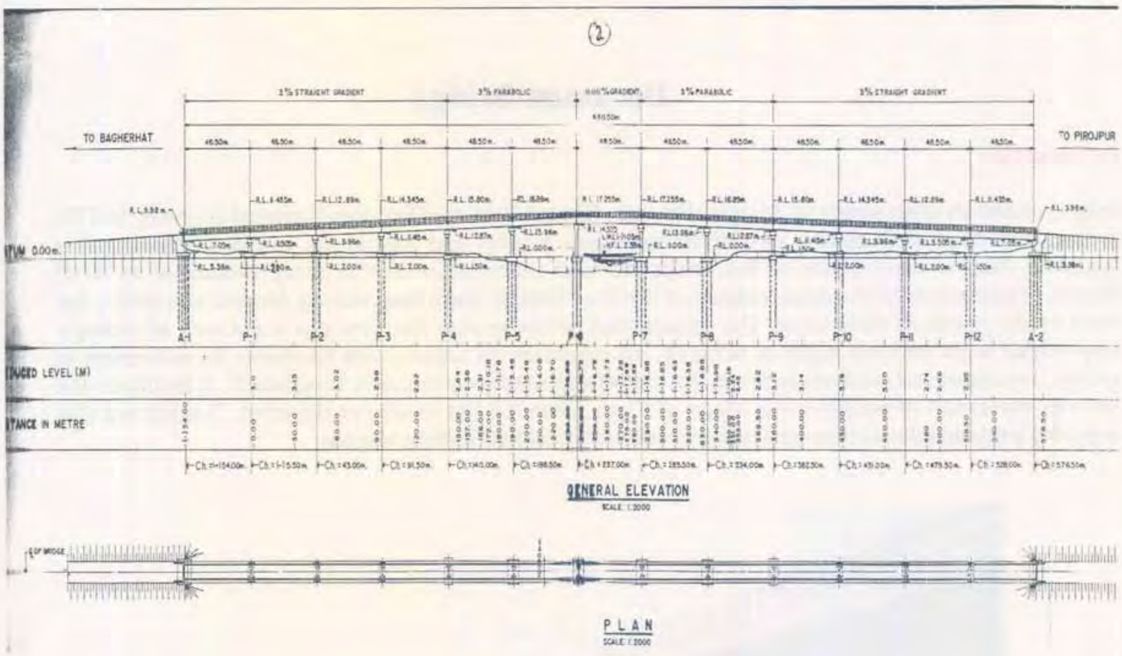
The bridge is located over the river Bhairab near Bagerhat district town at 2nd km of Bagerhat-Perojpur road.

Location Map

Salient Features

The bridge is funded entirely by internal resources and designed by Roads and Highways Department. The Executing Agency was Roads and Highways Department, Ministry of Communications. The bridge was constructed by local construction firm, Al-Amin Construction Co. Ltd. The bridge was opened to traffic on 28 June 2003.

The bridge is 630.50 m long and 10m wide (carriageway 7.5m and 2x1.25m sidewalk). It consists of 13 spans of 48.5m each. The bridge has been designed for two lanes following AASTHO HS20-44 loading.



General Elevation and Plan

Review of Design During Construction

The preliminary design and drawing of Doratana bridge was sent to the field unit of RHD for taking necessary action for construction of the bridge. While sending the drawings to the field unit, the design unit of RHD provided notes on the drawings stating that a) the construction of the bridge can be taken up by checking the design and drawings by experienced consultant and b) provision shall have to be made in the tender document for checking and reviewing the design and drawing by experienced consultant for construction of the bridge.

Accordingly the field unit of RHD invited tenders providing the above conditions set by the design unit. According to the conditions of contract document, the selected contractor for construction of the bridge engaged Design Planning and Management Consultant for reviewing the design of foundation and substructure of the bridge and BRTC, BUET for checking the superstructure. BRTC, BUET reviewed the design of superstructure.

Foundation and Substructure

According to the preliminary design and drawing this bridge consists of 13-span simply-supported PC girder bridge having equal spans, each 48.5m long between c/c piers, and the end spans are each 48.5m between c/c pier and the center line of the movement joint over the abutment giving a total length of 630.50m. The bridge superstructure comprises 7.5m wide carriageway and 10m out to out width of deck including two sidewalks. The deck is supported over 5 nos. prestressed concrete girders placed at 2.0m intervals. The substructure piers are RCC wall type having 1.5m width x 5.5m length.

The six intermediate pier foundations comprise 10.0m x 5.5m size x 31.5m long RCC caissons. The remaining pier foundations contain 36 nos. 0.35m x 0.35m size x 28.0m long precast RCC piles for each pier. Abutments are RCC wall type having flag type wing walls. Each abutment foundation comprises 40 No. 0.35m x .35m size x28m long precast RCC piles. The main navigational span contains 43.0m horizontal navigational clearance between the adjacent wells and 11.945m vertical navigational clearance above the high water level upto the girder soffit.

Comments made by consultants on the existing design of foundation and substructure

i) The length of the PC girder for this bridge is 48.470m. This is the maximum length of pre-cast I-girder or T-girder constructed using the launching girder available in the country. Besides the cast in -situ construction of such a large size girder using shoring embedded in the soft bed material at the bridge site has risks of formwork settlement. It is therefore considered advisable to select such structural option and construction methodology of the foundations whereby the possibility of increase in the span length due to tilt and shift of the foundations could be minimized.

ii) The sub soil investigation conducted adjacent to the pier locations shows soft to firm, firm to stiff soil having SPT values between 4 and 7 up to about 14m depth below the existing bed level. The harder strata is encountered below. From design point of view, well is an ideal structural option in such soil. However, from the construction point of view the existence of the soft soil in the top strata increase the risks of tilt and shift of the well. The usual method of construction involves developing an artificial island with its top at about the normal high water level. The construction of well will be made from that platform. The contract design shows the top of well cap at El 0.00m PWD whereas the natural bed level around the pier is at about El. -7.00 to -7.50m PWD in deep water. This gives the unsupported height of well above the river bed level about 7.00 to 7.50m. The artificial island of this height supported on the soft soil is likely to incur considerable vertical settlement. Further, the required embedment length of the peripheral tubular supports sustaining the lateral earth pressure for this height of backfill will also considerable.

iii) The three years construction period is likely to provide maximum two working seasons for construction of all the six wells, otherwise completion of the work within the contract period might be difficult. The harder strata underlying the top soft strata is again likely to reduce the rate of penetration of the wells considerably. The sinking of the 31.5m length of well might even consume the whole of the available three working seasons. This means even if all the six wells are started at one time, the completion of wells themselves might consume the entire contract period, due to the field subsoil conditions.

iv) This will necessitate maintaining the wells during the three flood seasons. The six rectangular shaped islands with semi-circular noses inside river, having plan size of about 20.00m width x 30.00m length is likely to constrict the passageway of the flood water, and thereby enhancing the local scour around the island considerably. The observed maximum scour depth at that case might exceed the design value. If the construction is further delayed, this constriction of the water way might affect the morphology or the regime of the river permanently.

v) Further, although from the structural point of view the steining thickness of the designed RCC caisson is found adequate, it might not be found adequate from the construction point of view. To facilitate sinking of caisson in the hard strata needs overcoming the skin friction on the surface of the well. The relevant Indian Road Congress (IRC) code recommends about double steining thickness than provided in the contract drawings from construction point of view, which increases cost. In addition, sinking of well will need further kentledge arrangement.

vi) The other pier and abutment foundations comprising 0.35 m x 0.35m size x28.00m long precast piles may also generate difficulties in construction in the lower hard strata. The long precast slender piles might require to be driven in two pieces. This will require normally expensive patented moment splicing, for example, Hercules splicing or equivalent, which is difficult to be mobilized for this local currency project.

Alternative design recommended by consultant

An alternative design replacing the caisson/precast pile foundations below piers/abutments, by 1/0.76m-dia cast in-situ bored pile foundations for both abutments and piers are proposed. This, compared to the caisson foundation, has an advantage that its tilt and shift is easier to control and its construction is likely to be faster without sacrificing the quality.

The wall type piers have been replaced by the column type piers to reduce cost without affecting the durability of the structure.

10 mm thick permanent steel casings have been provided for pier No.4,5,6,7,8 & 9 to enhance durability.

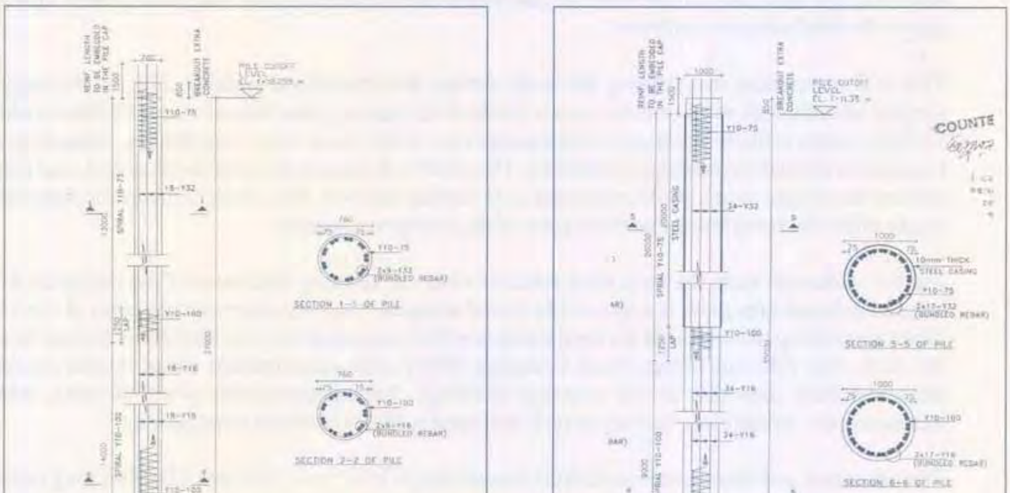
Final design

Taking the comments made by the consultants into consideration, final design and drawing was approved by RHD and sent to the field unit for its implementation.

Foundation

The bridge consists of 12 piers and two abutments. Each pier and abutment is founded on RCC bored pile. Four piers are provided in the river in which 2 of these comprises 12 No.bored piles of 1m diameter, each 35m long with 10mm thick 20m long permanent steel casing at top and other 2 comprises 12 No. bored piles of 1m diameters, each 32m long with 10mm thick 15m long permanent steel casing. Two bank piers comprise 10 nos. bored piles of 1m diameter, each 32m long with 10mm thick 5m long permanent steel casing. The rest six piers comprise 10 nos. bored piles of 0.76m diameters, each 30m long. The Bagerhat side abutment consists of 20 nos. bored piles of 0.76m diameter, each 27m long and the Perojpur side abutment consists of 20 No.bored piles of 0.76m diameters, each 25m long.

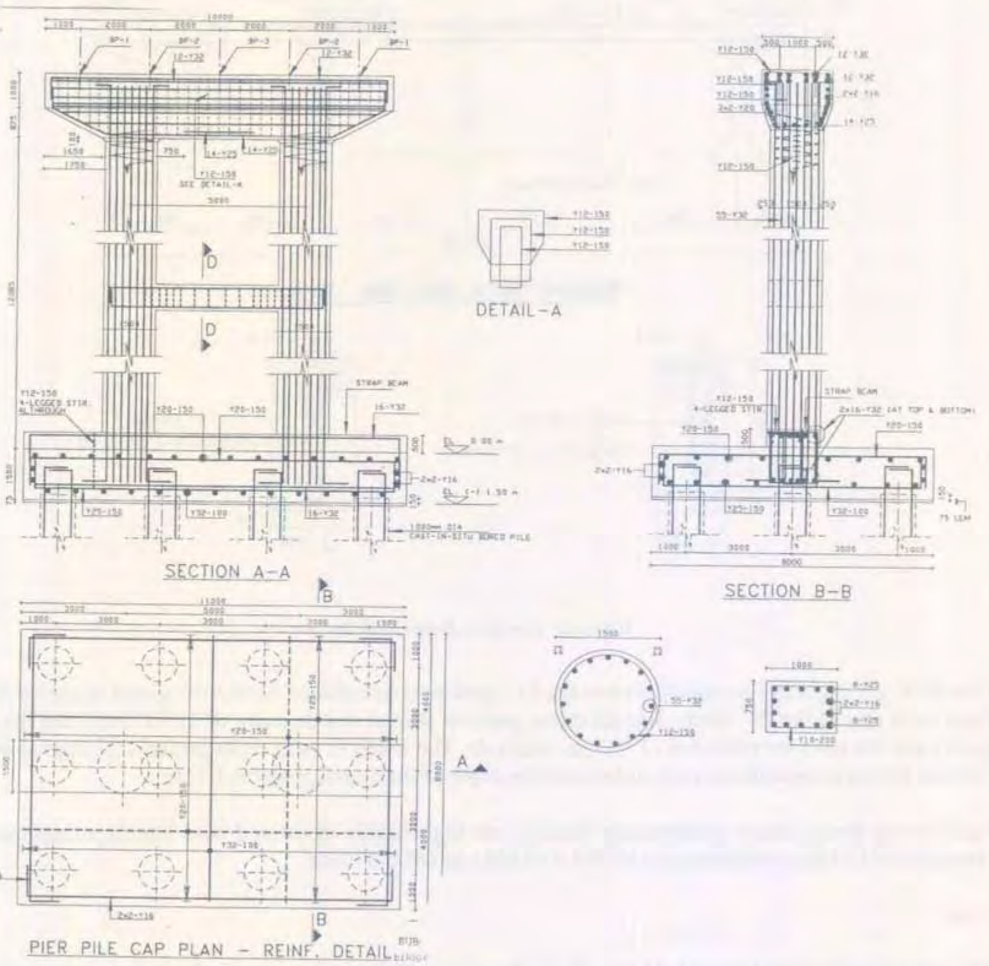
Boring was done under each pier and abutment using bentonite upto full depth of piles. Mud was cleaned properly. Then pouring of concrete was done after placing steel cage.



Details of Bored Pile

Substructure

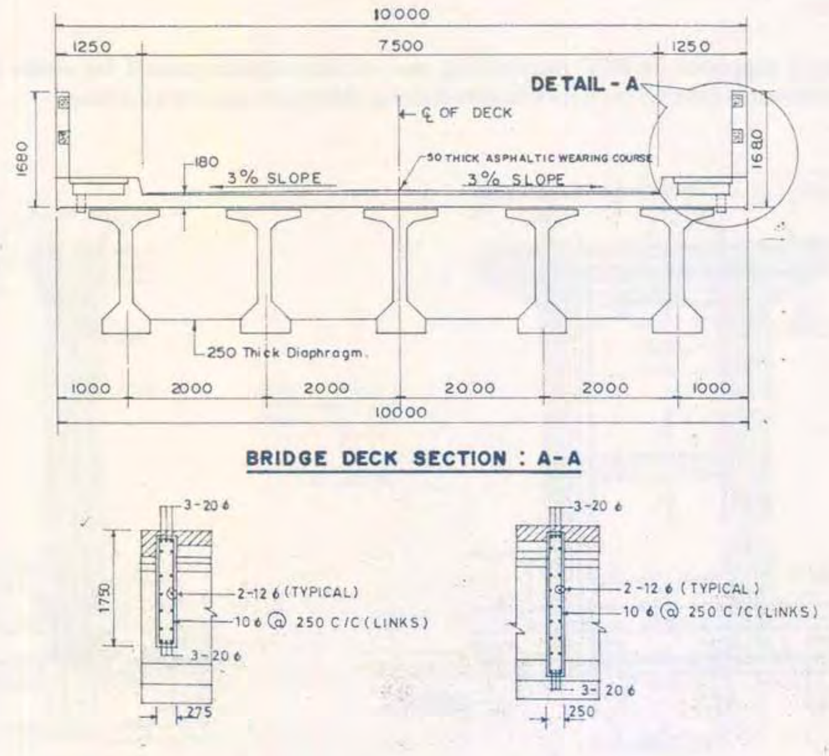
The decking is supported on RCC piers having two circular columns spaced 5m centre to centre. A horizontal tie beam of 1m x 0.75m sizes was introduced at different height from the base.



Detail of Pier 5 & 8

Superstructure

Each span comprises 5 No. Prestressed post-tensioned concrete girder and placed over elastomeric bearings on piers or abutment. Overall depth of each of the 5 girders is 2.6m. The web thickness is 240mm at center of the girder. The flange thickness is 175mm at end and center of girder. The width of top flange is 1.1m and that of bottom flange is 740mm. Each beam consists of 12 tendons and each tendon consists of 6 No (7 wires) strands of 12.7 mm diameter. Prestressing tendon is normal relaxation strand with breaking strength of each strand not less than 183.5 KN conformed to ASTM A 416-85 or approved equivalent. Cylinder crushing strength of prestressed girder is 35 MPa at 28 days and crushing strength of concrete at time of transfer of prestressing force is 28 MPa (Minimum).



Schematic Details of Bridge Deck Section

Five RCC cross girders are used between the P.C. girders at five places. First cross girder is placed 400mm from each end of the PC beam. Second cross girder is placed at a distance of 11.9175m from first cross girder and the rests are placed at 11.9175m intervals. The width of each cross girder is 275mm at end and 250mm for the intermediate cross girders and the depth of each cross girder is 1.75m.

Reinforcing bars (except prestressing tendon) are high tensile deformed bars having minimum yield strength of 415 Mpa conforming to ASTM A 615M / A616M/A706M.

Cost

The total cost of the bridge is Tk.33.31 (Thirty three point three one) crore which was borne entirely by the Government of Bangladesh.

Dharala Bridge

Background

Kurigram is a district of rivers. The big rivers like Brahmaputra, Dharala, Tista and other narrow rivers flow through this district. Dharala is a meandering river. It changes its course frequently. Nageshwari, Bhurungamari and Fulbari upazillas are situated in the north side of this river. In the absence of a bridge over this gap, these upazillas were isolated from direct road communication with the Head Quarter of Kurigram district and also other parts of the country. Prior to construction of this bridge, the road communication was being maintained by RHD ferries. The people of these three upazillas suffered much particularly in the monsoon when the river became widened and tremendous water flow suspended the ferry services. So constructing a bridge over the river Dharala was a long waiting demand and widely felt need of the people of these areas.

A View of Dharala Bridge

Site

The bridge is located over the river Dharala near Kurigram district town at 3rd km of Kurigram-Nageshwari-Bhurungamari road (Z5622).

Salient Features

The preliminary study for construction of Dharala bridge was conducted by Rajshahi Division Development Board in 1978. With the passage of time, record shows that Dharala river is very much meandering in nature and changes its course frequently. This river is found very much unstable and hits the embankment on both sides and often develops char area due to huge siltation. Even Kurigram district town was threatened several times. The Water Development Board (WDB), Bangladesh had to make protection embankment with several heavy groynes to save Kurigram town. So to select a suitable alignment and required river training works it was necessary to conduct hydrological study, physical modeling, sub-soil investigation and detailed design of the bridge through consultant.

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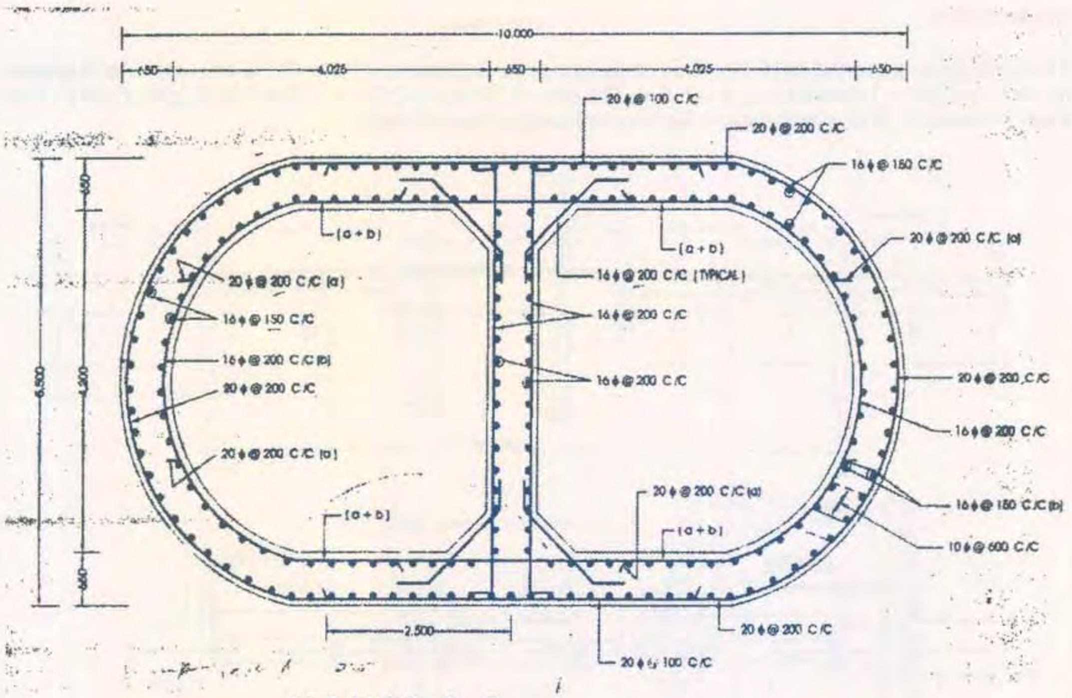

SECTION C-C
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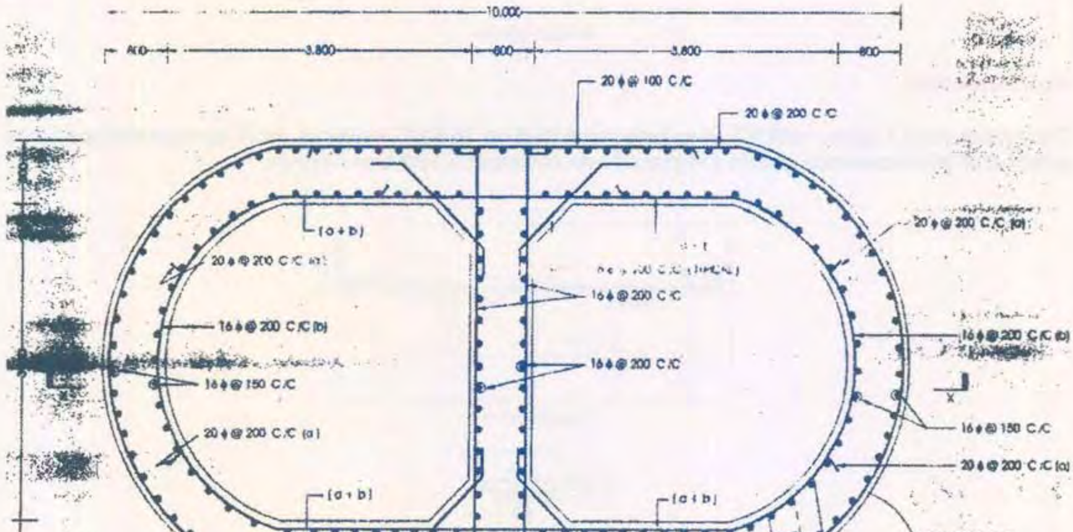

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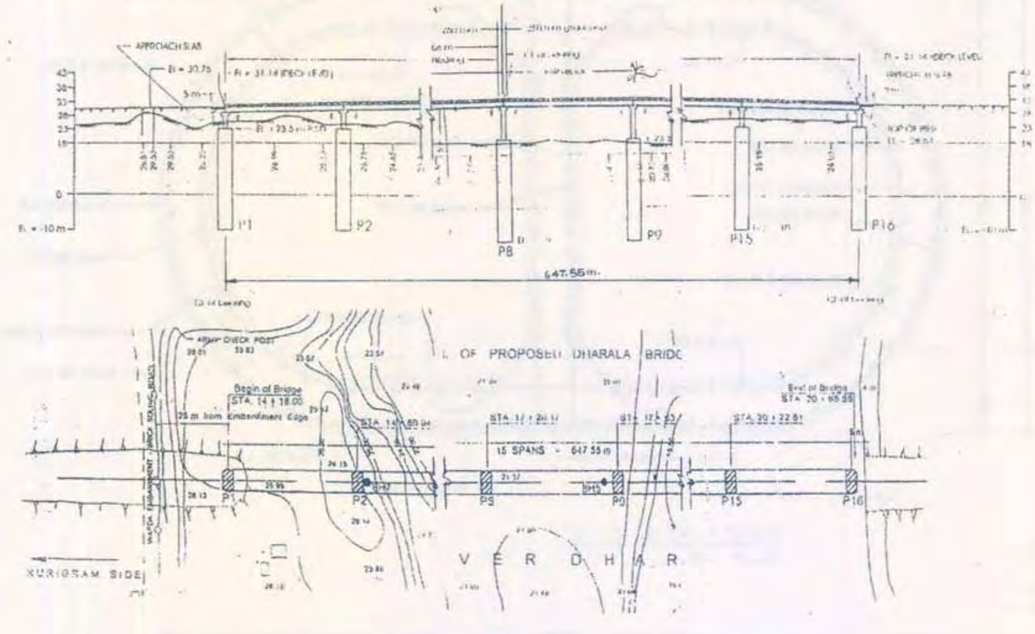
Schematic Details of RCC Caissons: Section

Substructure

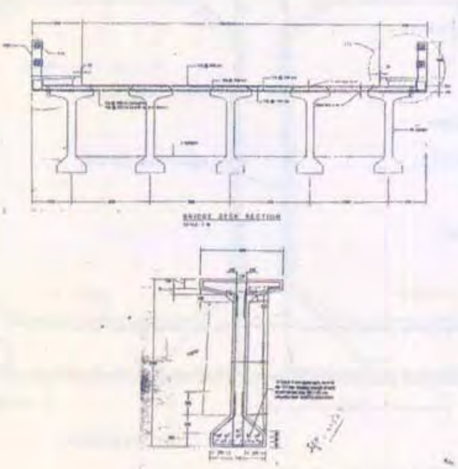
The decking is supported on16 Nos RCC wall type piers founded on 16 Nos RCC caissons. The thickness of wall type pier is 1.5m and length is 5.5 m. The size of pier cap is 2.0m x 1.75m. The height of piers varies from 5.04m to 11.37m. depending on the longitudinal gradient of bridge.



Bridge Layout

Superstructure

The bridge has 15 spans each 43.18 m long supported on 16 RCC caissons. Each span comprises 5 nos. prestressed post-tensioned girders and placed over elastomeric bearings on piers.



Girder Details

Overall depth of each of 5 PC girder is 2.3m for bridge. The web thickness is 200mm at center. The flange thickness is 130mm. Width of top flange is 1060mm and that of bottom is 710mm. Each beam consists of 12 tendons and each tendon consists of 6 No (7 wires) strands of 12.7mm diameter. Prestressing tendon is low relaxation strand with breaking strength of each strand not less than 160.1 kN conformed to AASTHO M-203 cylinder crushing strength of prestressed girder is 35 MPa at 28 days and crushing strength of concrete at time of transfer of prestressing force is 28 MPa (Minimum).

Six RCC cross girders are used between the PC girders at six places. First cross girder is placed 250mm from each end of the PC beam. Second cross girder is placed at a distance of 9.484m from first cross girder and the rests are placed at 7.904m intervals. The width of each cross girder is 300mm and the depth is 1.85m.

Reinforcing bars (except prestressing tendon) are high tensile deformed bars having minimum yield strength of 415 MPa conforming to ASTM A 615M /A616M/A706.

Guide Bank

At the site of the bridge the river flows over a large width and during high floods it has the tendency to overflow the banks on Pateshwari side. To restrict the river width and to prevent the overflow of water guide bank has been provided on Pateshwari side. The length of the guide bank is 1.027 km. The waterside of the guide bank has been provided with cement concrete pitching laid in blocks in two layers (first layer 450mm x 450mm x300mm and 2nd layer 380mm x 380mm x 300mm) over a layer of 200mm thick shingles and pea gravels (60mm-40mm and 30mm-10mm). Geotextile is placed between the layer of singles, pea gravels and 100mm thick sand layer over compacted earth. The slope of the guide bank at riverside is maintained 2H:1V removing all bank irregularities. The width of the guide bank at top is 4m. The compressive strength of concrete for making blocks is 15MPa at 28 days according to ASTM C39. 12 m-28.5m wide apron consists of layers of graded stone having a depth of 2m.

Approach Slab

Generally settlement of backfilling takes place behind the abutment wall (between abutment wall and approach road) if its compaction is not done properly which causes hindrance to the smooth plying of vehicle. To avoid this problem a approach slab of 5m long has been provided at both ends of the bridge.

Approach Road

The bridge includes approach roads of length 1.92km at kurigram side and 1.42 km at pateswari side. The width of the approach road 11 meter including 6.7 m carriageway and 2.15m shoulders on each side.

Cost

Total cost of the bridge was Taka 97.50 Crore, which was borne entirely by the Government of Bangladesh.

Meghna Bridge

Background

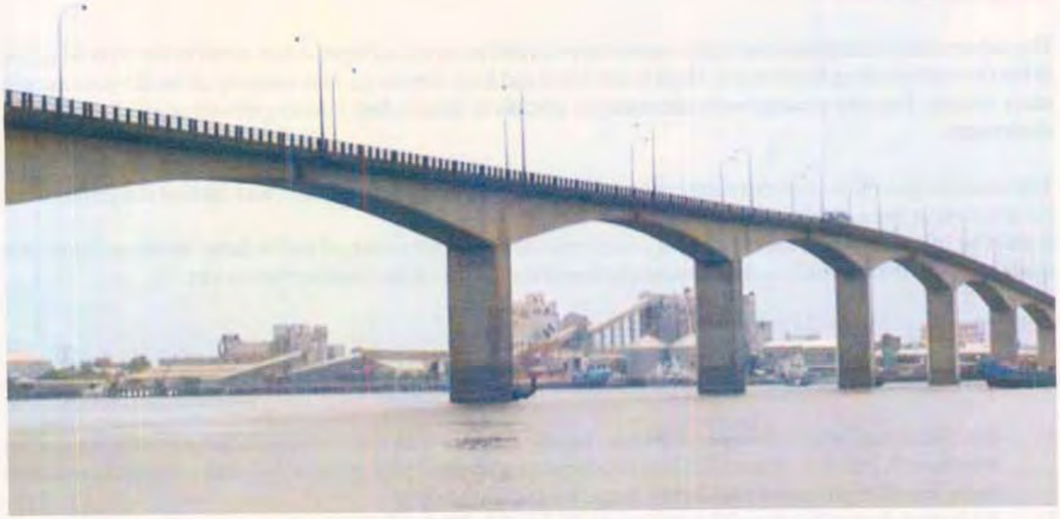
The Dhaka-Chittagong highway is the most vital link between Dhaka, the capital of Bangladesh, and Chittagong, the international port city. The 257 km long Dhaka-Chittagong National Highway (N1) a part of Asian Highway, serves a population of about 15 million of the region. The Highway carries the heaviest traffic in the country in spite of the inconveniences and delays in road transportation caused by two ferries at Meghna and Meghna-Gumti Rivers. The necessity for constructing Meghna and Meghna-Gumti Bridges was to remove the bottle-necks at the ferries, leading to increase economic activity between the two major cities of Bangladesh.

By the completion of the two Bridges, Dhaka and Chittagong are connected entirely by highway. Traveling time between the two cities is three hours shorter than using ferry crossings. Now people are visiting each other within a day. Meghna Bridge is deemed as a symbol of friendship between Bangladesh and Japan, and is known as "*Japan-Bangladesh Friendship Bridge*".

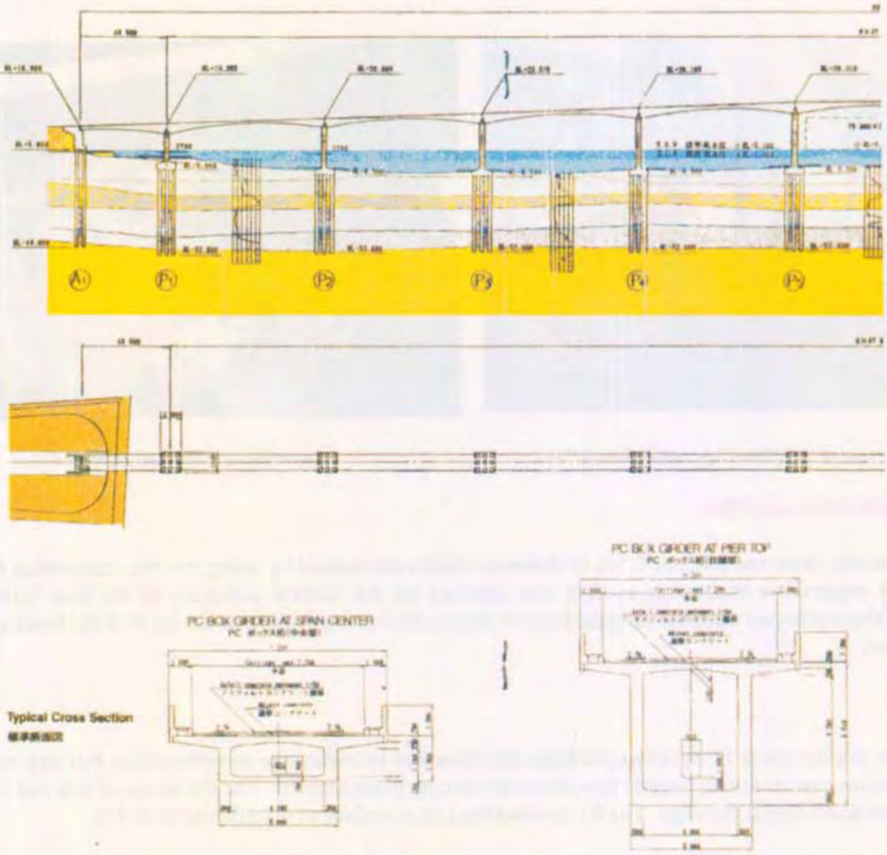
Location Map Bridge Site of Meghna

Salient Features

The bridge consists of 13 spans of 9 spans each 87m, 2 spans each 48.5m and 2 spans each 25m giving a total length of 930m. Total width of the bridge is 9.2m including sidewalk and railing. The Executing Agency was Roads and Highways Department, Ministry of Communications, Government of the Peoples` Republic of Bangladesh. The consultant was Pacific Consultants International, Japan in association with Nippon Koei Co. Ltd, Japan and the Contractor was Obayashi Corporation, Japan. The bridge was Constructed by Japanese Grant Aid. The bridge was designed following AASTHO HS 20-44 loading. The bridge was opened to traffic on February 1991. Meghna Bridge was awarded "Outstanding Achievement Award, JSCE in 1994".



A View of Meghna Bridge



Layout of the Meghna Bridge

Bridge Construction

The substructure comprises cast in situ concrete piles and piers which were constructed in the river Meghna at the time of receding flood water. High water level and high stream current velocity of the River occurs in rainy season. Two dry seasons were necessary to complete these substructures consisting of 12 piers and 2 abutments.

The construction of the superstructure, comprising segmental PC-box girders, was carried out through out the whole year even in rainy season.
It must be mentioned that the successful completion of the construction of cofferdams for the substructure made a great contribution towards the completion of the whole of the construction works.

Cofferdam

The following three types of cofferdam were constructed for the 12 piers and 2 abutments.

1) With steel pipe piles (diameter: 1.016 m, length: 28.5 m) with vertical interlocking system for 8 piers from pier P-2 to P-9. The cofferdam constructed with steel pipe piles of P-2 was constantly watched by means of strain-stress measuring gauge for ensuring safety.
2) With steel sheet piles (type VL) for 2 piers (P-1 and P-10) and 2 abutments.
3) With steel sheet piles type V for 2 piers (P-11 and P-12).

Insertion of Steel Bar Cage inside Bored Pile

Completion of Pile Head Treatment

Cast-in-situ Concrete Piles

106 cast-in-situ concrete piles of 1.5m in diameter were constructed by using reverse circulation drilling method. A supersonic measuring system was adopted for the vertical accuracy of the bore holes. The lengths of these piles are variable ranging from 40.0 m to 58.0 m depending on the level of the bearing strata for the piles.

Pile Cap

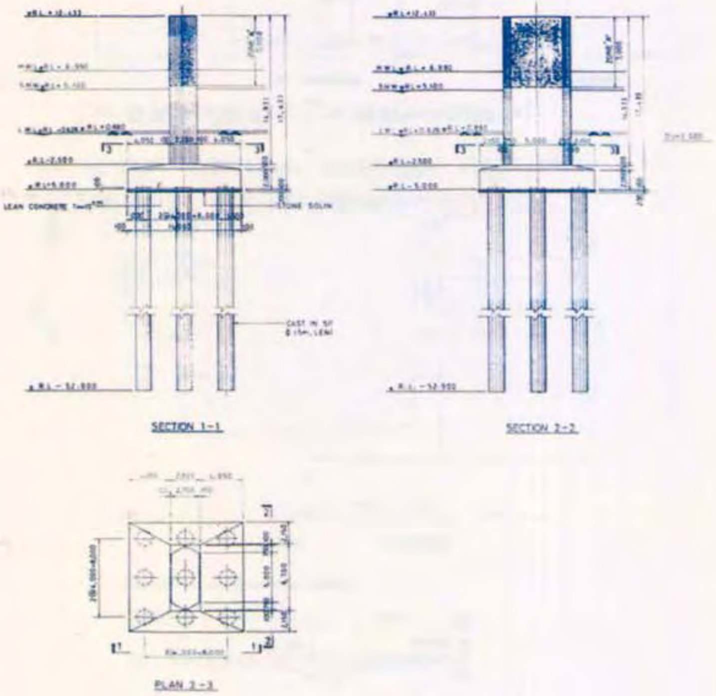
The length of pile cap is 11 m in longitudinal direction and in transverse direction also. Pile cap concrete was poured on cast-in-situ by tremie pipe from the mixing plant directly. The thickness of pile cap is 2.7 m at the center and 2.2 m at the edge. The RL level of the lower surface of the pile cap is -9.5 m.

Scour protection above the pile caps in the river was carried out by boulder pitching from floating vessels. The volume of the works done was 18,800 m^3.

Fabrication of Steel Bar in Pile Cap

Pier Column

The pier column has a hexagonal shape and each pier from pier (P-4 to P-7) was constructed in five operations but other piers in three or four operations. The time of operation was dependent on the height of piers which varied from 10.433m to 29.144 m. Piers of P-11 and P-12 were constructed on the shore.



Foundation Details

Superstructure

10 segments of PC-box girder at both side of each pier-column top were constructed successively by using traveling forms.

This type of construction system is called the cantilever erection method. The depth of PC-box girder gradually varies from about 5.3 m at segment No.1 and No.2 to 1.9 m at segment No.19 and No.20. The PC tendons were inserted into sheath duct provided in the box girder webs and upper deck slab. PC bars at an interval of 0.6 m to 1.6 m were installed in every segment. The number of PC tendons was reduced at the end of every segment. Total 200 segments of PC-box girders were constructed for the ten piers.

Construction of PC Box Girder

General View of Bridge Girder During Construction

River Revetment

River revetment works are the main ancillary works for the protection of river bank from erosion. These works consisted of geo-textile form concrete mat, capping concrete and placing boulder gabions in front of the revetments. River revetment works on Comilla side were constructed after deep consideration of further erosion of the river bank. Geo-textile form concrete mat, the first application in Bangladesh, is used as well as the concrete mat. The total quantity of work done was 657 linear meters out of which 148 m were on Dhaka side and 509m on Comilla side.

After the completion of the Bridge, additional revetment works were carried out in 1994 and 1998, by additional Japanese Grant Aid.

Cost

Total cost of the bridge is 7387000000 Japanese Yen.

Second Buriganga Bridge

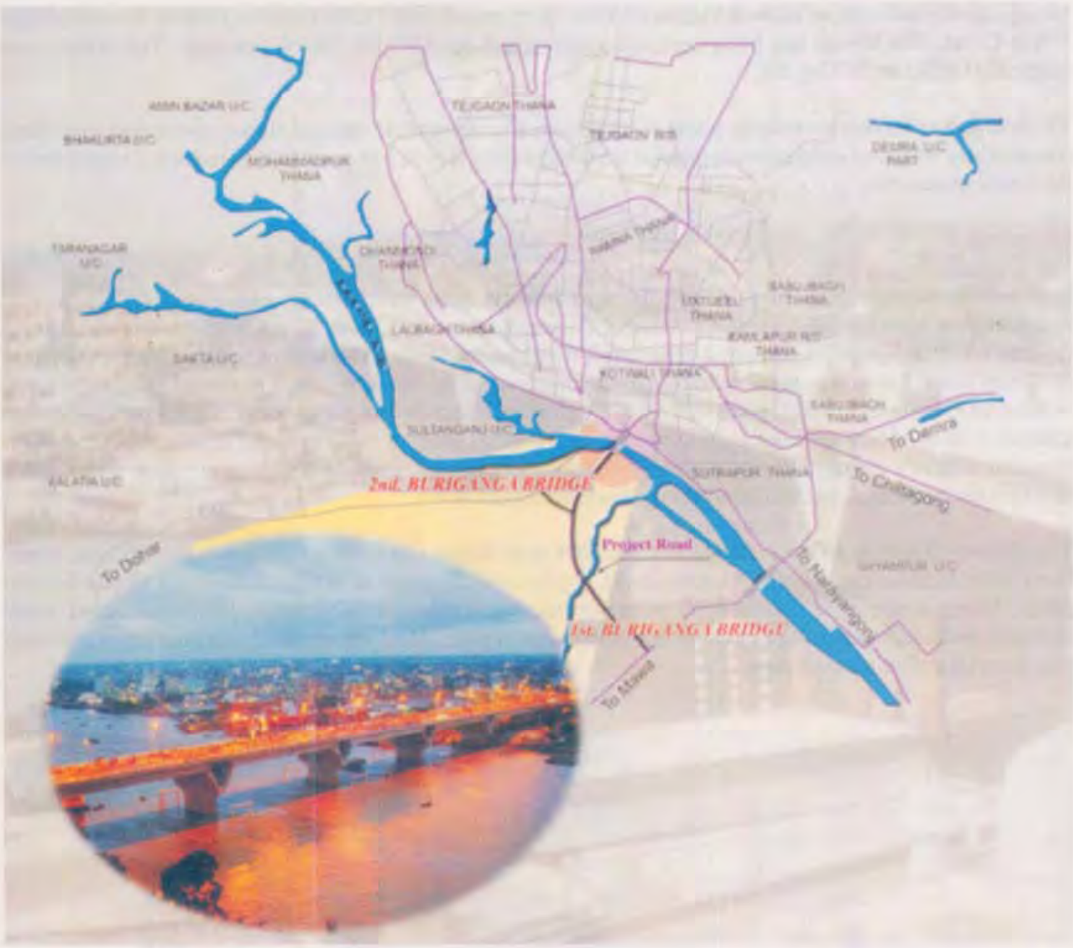
Background

The communication between Dhaka city and South-West part of Bangladesh is interrupted by the river Buriganga. The construction of Bangladesh-China Friendship bridge were helping to reduce the hindrance in part but a necessity of building a second bridge over the river Buriganga was felt. Before the 2nd Buriganga bridge was constructed, road traffic crossed the river by ferry, often subject to considerable delay due to traffic problems or river conditions. The construction of Bridge over the river Buriganga is therefore of strategic importance in the national highway network. Its construction facilitated the movement of people, resources and products between the capital city Dhaka and Karanigonj- Dhohar areas of Bangladesh

A View of 2nd Burigonga Bridge

Location

This Bridge is located about 3 km away from the city centre in the south over the river Burigonga which connects Babubazar and Jinjira. The bridge provides an essential road connection across the river Buriganga in Dhaka city. In addition to providing a fixed crossing close to the city center, it offers more direct access from the old Dhaka town to Dhaka- Khulna Road (N8). It connected not only Babu bazar to Jingira but also connected Keranigonj-Dhohar in the West and Dhaka-Mawa- Khulna National Highway in the East by constructing approach road .



Location of Bridge

Salient Features

The bridge carries a 4-lane roadway and two 1.5m wide sidewalks on its 14.6m wide deck. The structure is 1479m long which includes six river spans totaling 304m in length and shore viaducts and access ramps at each end. Bored cast in-place RCC piles are provided at each pier location. Total length of the flyover is 712 meter and that of approach ramp is 463 meter.

No fixed crossing had existed until the first Buriganga bridge, known as Bangladesh-China Friendship Bridge, was opened to traffic in 1990. The bridge, however, was built primarily to serve the Dhaka-Khulna Road. Being located about 3km downstream from the business district, it did not assist in city's expansion across the river or improve communication to the right bank areas with the Metropolis.

Sponsoring agency of the bridge was the Roads and Railways Division, Ministry of Communications (MOC), People's Republic of Bangladesh. Roads and Highways Department was the executing agency. International bids were invited in 1993 for a Design-Build contract. The Engineers Ltd, a local construction firm, was the successful bidder. Government of Bangladesh appointed Bangladesh Consultants Ltd. as the Design Check and Supervision Consultant in June 1994 for the bridge. The work commenced in August 1994.

Navigational clearance of main bridge is 45.73m. (horizontal) and 7.62m (vertical) above Standard High Water Level. The bridge has been designed following AASHTO HS 20-44 loading The bridge was opened to traffic on 20 May 2001.

The bridge was funded entirely by internal resources . The design and construction of the bridge were done successfully by using indigenous expertise and technology which is a great example for the engineers of the future generation.

Foundation

Six river spans were founded on RCC caissons while the shore structures on cast in-situ RCC pile. The foundation of main bridge consists of 5 Nos RCC caissons (size:6mx13.4m). Its wall thickness varies from 0.50m to 0.70m depending on the depth of well from riverbed level. The well curbs are 700mm thick and 2500mm deep. 18mm diameter 0.4m long anchor bars spaced 300mm centre to centre (staggered) was welded to 750mmx3mm M.S plate for mid wall of caisson and for the rest portion, anchor bars welded to 950mm x 3mm M.S plate. The caissons were sunk by open dredging making use of kentledge as and when required. Grabs were used during sinking operation. 3 cassions, each 34.5 m long in deep water and 2 cassions each of length 32.5m on both banks were constructed.

The flyover of length 343m at Dhaka end and 369 m at Jinjira end were constructed over 25 Nos. piers. Piers were founded on 324 Nos. cast in situ RCC piles and abutment at each side contains 18 cast in -situ piles. 750mm diameter cast in situ RCC piles were used under piers and abutments. Boring was done under each pier and abutment using bentonite upto full depth of piles. Mud was cleaned and pouring of concrete was done after placing steel cage.

Construction of Cofferdam for Caisson Foundation

The number and length of cast in situ RCC piles under piers and abutments are shown in the following table.

Name of Structure	Dhaka end			Jinjira end		
	Number	Number of piles	Length of each pile(m)	Number	Number of piles	Length of each pile(m)
Abutment	1	18	20	1	18	22
Pier	12	156	20	13	168	22

Caisson Sinking in Progress

Substructure

The decking is supported on 25 nos RCC wall type piers founded on 324 nos. cast in -situ RCC piles for flyovers and the decking of main bridge is supported on 5 RCC Wall type Y-piers founded on 5 nos. RCC caissons. The bridge consists of two RCC abutments for both sides founded on 36 nos cast in-situ RCC piles.

Caisson and Pier Works in Progress

Concreting of Y-frame of Pier

Superstructure

The main bridge has 6 spans each 44m long having 5 RCC Y-frames each of length 8m giving a total length of 304 m supported on five RCC caissons. Each span of the main bridge comprises 9 nos. prestressed post-tensioned girders launched in position by means of launching truss and placed over elastromeric bearings on piers. Overall depth of each of 9 P.C girder is 2.210m for the main bridge.

The web thickness is 220mm at center. The flange thickness is 150mm. Width of top flange is 1090mm and that of bottom is 720mm. Each beam consists of 10 tendons and each tendon consists of 6 No (7 wires) strands of 12.7 mm diameter. Prestressing tendon is normal relaxation strand with ultimate strength of 1850 MPa and conformed to ASTM A-416-85 or approved equivalent.

The length of flyover with footpath at Dhaka end is 85 m which contents 3 spans and that of Jinjira end is 84m consisting of 3 spans. Each span of these flyovers comprises 9 prestressed post-tensioned girders. The length of flyover without footpath at Dhaka end is 258m which contents 9 spans and that of Jinjira end is 285m.consisting of 10 spans. Each span of these flyover comprises 8 prestressed post-tensioned girders. The span length of flyovers varies from 28m to30m.

Overall depth of each of PC girder is 1.530m. The web thickness is 210mm at center. The flange thickness is 150mm. Width of top flange is 510mm and that of bottom is 670mm. Each beam consists of 8 tendons and each tendon consists of 12 No 7 mm dia HT wires. Prestressing tendon is normal relaxation 7mm dia HT wire with ultimate strength of 1650 MPa and conformed to ASTM A421-85WA or approved equivalent.

The length of approach ramp at Dhaka side is 239m and that of Jinjira side is 224m and its width is 15.2m. Total width of the bridge is 17.60m with 14.60m carriageway and1.5m footpath on each side for a length of 473 m. (including 169 m flyover).The width of rest of the flyover is 15.2 m without footpath. RCC deck slab is cast over the prestressed post-tensioned girders.

Y-frame Constructed in-situ for Supporting 44m Long PC Girders

Fabrication of 44m PC Girder in Progress

Stressing of PC Cables

Launching of PC Girder

Rebar Placing on Bridge Deck

A View of the Bridge Soffit

A View of the Approach Viaduct

Service Road

The service road on each side of flyover and approach road at Dhaka end and Jinjira end has a length of 1164m and 1186m respectively. The width of the service road is 7m including 1.5m wide footpath.

Approach Road

The bridge includes 3.25 km of roads connecting the bridge with Dhaka- Mawa National Highways (N8) at Jinjira end. It also includes 1.00 km of road connecting the bridge with Keranigonj- Dhohar road. The approach road comprises one bridge of length 38m and seven culverts of 67m long.

Problems During Construction

There were serious difficulties and long delay in sinking the caissons due to resistance from a stiff thick layer of clay found below the river bed. This was not, however, the only obstacle the project had to overcome during its construction. Intense commercial activities at the left bank was a continuing constraint throughout the construction period. Land acquisition, relocating utility services and shifting of road ferry terminal on the city side were particularly difficult. Severe floods of 1998 and 2000 resulted in suspension of work, seriously affecting the progress. Rapid progress of the work was made once these impediments were removed.

Total Cost

Total cost of the Bridge was divided into three following parts.

Main Bridge	: Taka 57.32 Crore
Consultancy	: Taka 4.48 Crore
Approach road (Including land acquisition)	: Taka 86.81 Crore

Total cost of the bridge was Taka 148.61 Crore which was borne entirely by the Government of Bangladesh .

Bangladesh - UK Friendship Bridge

Background

It has long been recognized by the Government of Bangladesh that the socio-economic development of North Eastern Bangladesh has been inhibited in part due to the difficulty of access to the central and western regions including the national capital of Dhaka. National Highway No. 2 is the main highway between the North-East Region and the capital city Dhaka and this is interrupted by the Meghna River at Bhairab. The construction of Bridge over the river Meghna at Bhairab is therefore not only of strategic importance in the national highway network, but regionally its construction will facilitate the movement of people, resources and products between the Central and North-Eastern areas of Bangladesh.

Bangladesh - UK Friendship Bridge

Location of Bridge

The Megna is the third largest of Bangladesh's rivers and conveys flows not only from catchments within the country but also from catchments outside the international boundary. The Meghna has a meandering character but at Bhairab the reach is funnel shaped.

Bridge Location

The Bridge is located at the start of the narrow throat where the river is approximately 800m wide. The flow in the river varies throughout the year from a few hundred cumecs in the dry season to at least 8000 cumecs in the period encompassing the monsoon (July to September). A peak flow of 22000 cumecs can be expected , based on the 100 year return period. There is a history of bed and bank scour at the site and it has been estimated that the river bed in its deepest channel can scour during flood to -34m PWD.

A major Char exists close to left bank which has two homestead blocks and large cultivated areas. The nature of the Char is such that future downstream movement of the bed is likely to occur.

Bridge Location

At the start of construction a substantial dredging and filling operation was undertaken to bring the area within the project land boundary to a level above the 1998 peak flood level and to provide fill material to the bridge approach road embankments.

Salient Features

Before the new bridge was built, road traffic crossed the river by ferry, which often delay due to traffic problems or river conditions. In 1995, a commitment was made by the Bangladesh government to improve communications to stimulate the north-east region and provide a road bridge across the Meghna between Bhairab and Ashuganj. In parallel, the existing Dhaka-Sylhet road was to be upgraded over its entire length. A series of economic, social and engineering studies for the crossing were carried out. The economics and need for the crossing were verified by the studies.

In 1997 a study was carried out on behalf of the UK Department for International Development (DFID) and the Government of Bangladesh in which various aspects of the proposed bridge crossing were appraised and recommendations were given for the design and construction of a new crossing.

The report concluded that a new dual two lane multi-span bridge should be constructed at Bhairab, approximately 110m upstream of an existing steel truss railway bridge built over sixty years ago. The proposed project should also include the construction of new highway approach embankments and connecting roads and the provision of river training works and bank protection.

Rail and Road Bridge Run in Parallel

The report also concluded that procurement of the bridge should be by the design and build route, let under the FIDIC Conditions of Contract for Design, Build and Turnkey.

Following a decision by the Government of Bangladesh supported by DFID to proceed with the construction of the Bhairab Bridge Project, Halcrow was appointed Employer's Representative in August 1998 for Phase 1 of the project. This involved surveys and investigations, preparation of tender documents, including firm design requirements, assisting with prequalification of contractors and evaluation of contractor's tender submissions. To confirm the selected route alignment and to provide the maximum freedom to the tenderer's designs, preliminary geotechnical, bathymetric and topographic surveys together with mathematical and physical modeling of the river were carried out as part of the Phase 1 activities. The land acquisition requirements for the project were also determined in this phase and a Social Action Plan to mitigate adverse impacts was formulated in accordance with Government of Bangladesh and Organization for Economic Corporation and Development (OECD) guidelines.

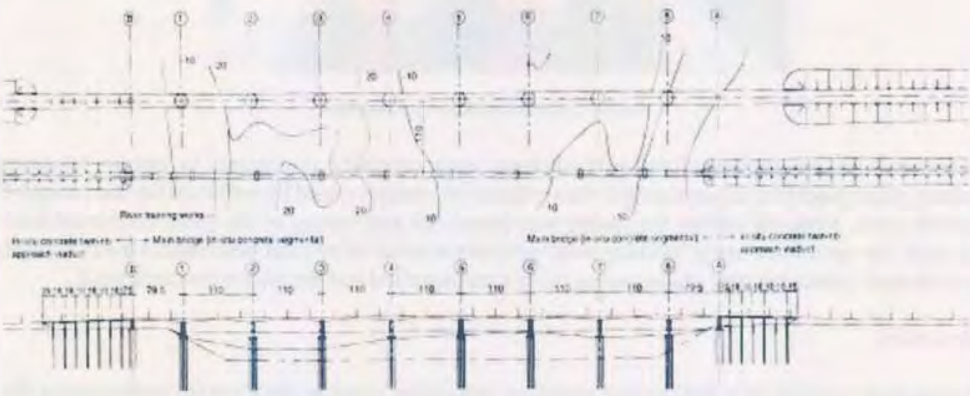
Contract documents for a design and build contract based on the FIDIC Orange Book conditions for international design and build contracts were issued at the end of 1998 to five prequalified UK contractors. Tenders were submitted in Spring, 1999 and a contract for the design and construction of Bhairab Bridge was awarded to Edmund Nuttal Ltd of UK with Jacobs, Benaim and DDC as their designer team . The project commencement date was 3 November 1999.

The Roads and Highways Department under the Ministry of Communications was the Executing Agency and the 'Employer' for the Design- Build contract.

Halcrow was appointed as the Employer's Representative(ER) for the construction stage (Phase 2). The ER's duties included audit of the design to ensure the Employer's requirements and quality standards were achieved and construction supervision within the framework of the project Quality Assurance (QA). The ER also provided technical and contractual assistance to RHD and assisted RHD with the implementation of the Social Action Plan for Project Affected Persons including compensation payments.

The Employers Requirements gave loading and dimensional criteria for particular elements of the design. It was a requirement that the bridge be designed to BS 5400 with HA and 30 units of HB Loading.

The Main bridge comprises seven 110m spans and two 79.5m spans of post-tensioned concrete box girders constructed as in-situ segmental balanced cantilevers. Four elastomeric bearings support the deck on twin-walled reinforced concrete piers, which in turn are supported on reinforced concrete pile caps. Six 2m diameter, Bored cast in-place piles are provided at each pier location . These are up to 66m long below the pile caps with permanent steel casings over part of their length to protect against scour .



General View and Plan

Main Bridge key Facts

Bridge length	929m
Bridge span	7 spans (110m) and 2 back spans(79.5m)
Piling	48 No x 2m dia piles
Piers	8 No
Carriageway	2 X 7.4m , 2 x 1.5m footway and 1.2m central reserve

Foundation

The key to the design was bridge foundations. The design was based on 2m diameter piles, but 1.2m diameter test piles were chosen as these required significantly less load to failure than a 2m diameter pile but were large enough to avoid major scale effects. To avoid the need for large tension piles and jacking beams the contractor proposed the use of Osterberg cells to test the pile. This concept was developed into a double-cell test that would give information on end bearing and shaft friction at various elevations. Pile testing was carried out in the summer of 2000 and monitored by geotechnical engineers from the designer and the Employer's Representative. Base grouting of the piles was recommended to limit settlements at high loads. The bridge piles have a cut-off level at the pile cap of approximately -10.0m and a toe between -60.0m and -74.0m. The upper part of the pile is within a permanent steel casing 28mm thick taken to

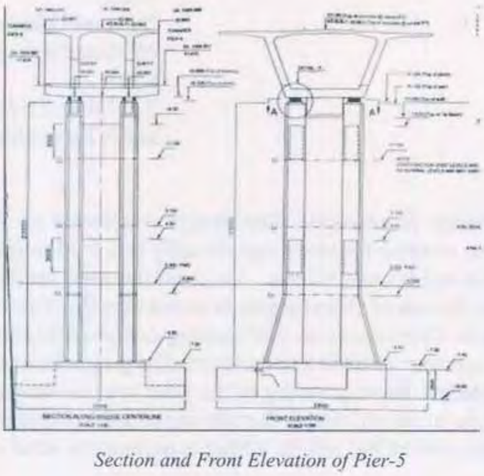
-41.0m . The casing acts as a protective barrier to avoid attrition of the pile concrete from river-borne sediment . The casing is also used as a part of the seismic containment required at the interface between pile and pile cap. The piles carry significant bending moments under ship impact and seismic loads, and are heavily reinforced in their upper regions.

Bridge Foundation under Construction

The position and inclination of the pile casings were carefully monitored to ensure accuracy and procedures were modified as necessary so that reduced tolerances could be achieved for the casings for the jack-down piers. Material within the casing was bored out and boring of the piles continued below the casing with the open bore using 'drilling mud' polymer instead of normal bentonite. Heavilly reinforced cages with steel 'sonic-iogging' and grouting tubes were installed and the piles were concreted.

Substructure

The bridge pier consists of a double-leaf structure, providing a stable platform for constructing the deck using balanced cantilevering. The pier separation of 6m was chosen to provide sufficient lever arm to avoid uplift at the bearings. The lower section of the pier splays from 6m to 12m to spread load to the piles more efficiently. Four large elastomeric bearings were used at top of piers separating substructure from superstructure.



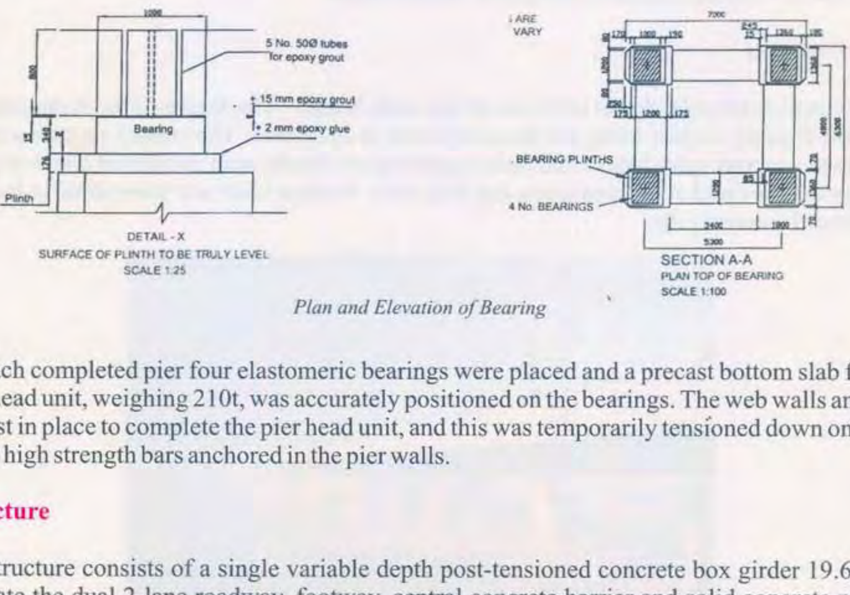
Section and Front Elevation of Pier-5

For the five piers (P1and P5 to P8) located in the shallower water the pile caps and piers were constructed within conventional circular cofferdams which allowed clear working space. Nuttall chose to use reinforced concrete underwater plugs anchored to the pile casings to seal the cofferdams, rather than the more usual mass concrete, owing to the much reduced depth of concrete needed. In deep water the pile caps and piers were built above water and incrementally lowered down the piles using strand jacks. The pile casings were specially extended so that the strand jack lowering system could be installed above the pile cap/pier being constructed at high level on a temporary soffit shutter. Once the cast weight reached 2500t (the safe working load of the jack down system) the pile cap with partially completed pier was lowered into the water to reduce its effective weight and pier construction could continue.

Dewatering Cofferdam

Deepwater Pilecap Ready for Lowering

To create the dry environment under water at -10m for making the structural concrete connections between the piles and pile cap, 4m diameter steel water tight caissons, sealed to the top of pile cap, were located around each pile. Special 'donuts' incorporating specially developed triple seals, activated by the hydrostatic pressure of the river water, were installed around each pile casing below the pile cap to keep water out of each connection zone. Hydraulic jacks at pile cap level were used to adjust the location of pile cap in plan relative to the piles, to ensure that the pier aligned accurately with the bridge centre line and chainage after lowering. once the six connections had been made, the temporary works were removed and the last lift of the pier was completed.



Plan and Elevation of Bearing

on top of each completed pier four elastomeric bearings were placed and a precast bottom slab for the pier (hammer) head unit, weighing 210t, was accurately positioned on the bearings. The web walls and the deck were the cast in place to complete the pier head unit, and this was temporarily tensioned down onto the four bearings by high strength bars anchored in the pier walls.

Superstructure

The superstructure consists of a single variable depth post-tensioned concrete box girder 19.6m wide to accommodate the dual 2-lane roadway, footway, central concrete barrier and solid concrete parapets. A hammer head 10m long and 6m deep sits on the bearings with two full-height diaphragms and this forms the root of the cantilevers. Ten segments 4.76m long each side of the hammer head form each cantilever span. Each segment was stressed to the previously constructed cantilever sections, with between two and six tendons in the top slab and webs of the box girder. Each tendon consists of nineteen 15.4mm strands stressed to 77% of the 279 kN ultimate tensile strength.

Balanced Cantilever Construction

Lifting a Pier Head Base Unit

The concrete for the superstructure was specified as grade 50 concrete. The deck was constructed using balanced cantilever methods. Construction took place simultaneously at two pier locations requiring two pairs of underslung steel formwork travellers,which were manufactured for the project. The design of the travelers enabled much of the deck reinforcement to be prefabricated in the yard thereby speeding up the cycle time. Match curing was used to optimise traveller moving times and the bridge was designed to allow the traveller to be moved prior to post-tensioning of the segment. pier head unit construction was speed-up by using precast base units.

Different combinations of superplasticisers, retarders and stabilisers were used to provide the concrete with suitable workability for placing and pumping and where necessary to provide varying degrees of workability retention or retardation. Concrete mixes were designed for high to very high workability (slumps of 100 to >200mm) and for a maximum 1h transit time.

Approach Viaducts

Approach Viaducts are provided at each end of the main bridge . The length of the Ashuganj viaduct is 122m and the Bhairab viaduct 140m and these terminate at abutments. The viaduct superstructures are in-situ reinforced concrete spine beams and slabs supported on slender twin reinforced concrete piers. Steel pot bearings are provided at the abutments and link piers. Viaduct loads are transmitted to bored cast in-place reinforced concrete piles.

Approach Viaduct-Bhairab

Viaduct Key Facts

Bridge length	122m Ashuganj 140m Bhairab
Bridge span	Typically 18m
Piling	2m dia bored cast in-place reinforced concrete piles.
Piers	26 No 900 x 900mm square columns
Carriageway	2x7.4m, 2x1.5m footway and 1.2 m central reserve.

River Training Works

River training works have been constructed to stabilize the Bhairab and Ashuganj banks and prevent possible erosion at both the new bridge and the existing railway bridge foundations. The overall geometry of the river training works was based on both physical and mathematical modeling.

Completed River Training Works-Bhairab

Completed River Training Works-Ashuganj

Edmund Nuttall commissioned HR Wallingford (UK) to carry out the physical model investigations. These comprised a local scour model to investigate scour at the Bridge piers and a general physical model to investigate the suitability of the forms and alignment of the left and right banks. Mathematical modeling was undertaken by SWMC in Bangladesh and was used to predict the effect of the works on general scour levels in the river and assess the impact of future movement of the Char on general scour levels.

On Bhairab bank, the works extend from 200m downstream, where they tie in with the Railway Bridge protection, to 350m upstream of the road bridge. The revetment was formed with a maximum 1:3.5 slope. A falling apron was constructed on the existing river bed which varies in width from 15m to24m with an average thickness of 1.7m. It is designed for a maximum river bed scour level of -38m PWD.

On Ashuganj bank, the works extend from 250m downstream to 180m upstream of the road bridge with a revetment slope of 1:6. The river bed was dredged to -10m PWD to allow a falling apron 11m wide with an average thickness of 1.7m to be constructed. It is designed for a maximum river bed scour level of -17m PWD.

In general, below 0.0 PWD the revetment profile was constructed by cutting high spots using a clamshell and filling low spots with sand bags. Non-woven geotextile was attached to bamboo fascines and placed on the profiled riverbed. Boulders were placed on the geotextile to form armour of minimum thickness 350mm, designed to resist a near-bank velocity of 2.2 m/sec.

Above 0.0 PWD compacted soil was placed to form the revetment profile. Geotextile with an attached stabilizing layer was placed on the slope and covered with boulders to form a 650mm thick armour, designed to resist a wave attack of 1 m height.

Approach roads and toll plazas

Just under 1.5 km of approach roads connect the new bridge with the existing highway system. These have dual 7.3m wide carriageways. Embankments were formed using sand dredged from the Meghna and the road pavement design is based on the AASTHO specification.

Bridge end facilities are located at Bhairab and Ashuganj and include a toll plaza and booths, control buildings, security stations, standby generator buildings and water storage tanks. In addition, a maintenance building is provided at Ashuganj.

Each toll facility consists of toll booths, barriers, data recording equipment, vehicle classification equipment and cash facilities. A fully electronic toll collection system has been provided. The Lane Processor System (LPS) is installed in each tollbooth and is responsible for the registering of tolls collected and controlling various signs/indicators in the lane

Completed River Training Works-Bhairab

Completed River Training Works-Ashuganj

Social Action Plan (SAP)

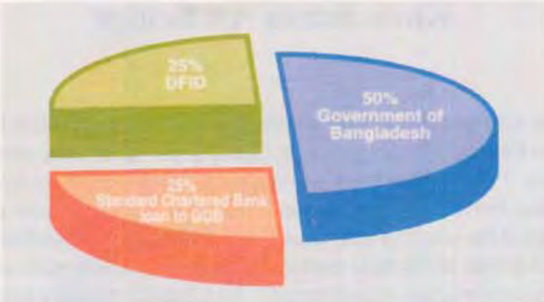
The primary objective of the social action plan (SAP) was to minimize an mitigate adverse social impacts due to bridge construction and to formulate an appropriate framework and procedures for compensation payments for lost assets to titleholders and financial assistance for resettlement of project affected persons (PAPs).

47 hectares of land were acquired for the project of which 66% was owned by Bangladesh Railways and Roads and Highways Department. More than 3400 PAPs eligible to receive compensation were identified through a Socio Economic Survey (SES). The Government of Bangladesh via the Roads and Highways Department undertook the implementation of the SAP.

Environmental Management Plan (EMP)

An Environmental Management Plan (EMP) was prepared for the project and operated by Employer's Representative . It covered all Environmental issues, their assessment and mitigation, the roles and responsibilities of the organizations involved.

Some of the construction related Environmental impacts were :



- Hydrology and water quality
- Pollution from waste
- Protection of human health
- Noise
- Air quality and dust
- Disruption to navigation
- Disruption to Char dwellers
- Vibration from piling works.

These issues were successfully addressed through appropriate components of the Environmental Management Plan (EMP) .

Project Cost and Funding Arragement

Funding	
Govt. of Bangladesh	£35.184 million
DFID grant	£17.780 million
Standard Chartered Bank Loan to GOB (with ECGD guarantee)	£17.780 million
Total Construction Cost	£70.744 million
Total Project Cost (Construction Cost + Land Cost + Social Action Plan +	£85.270 million
Total GOB Contribution	£49.709 million

Conclusion

The design and construction of the bridge were achieved in less than three years as planned. The project was completed and opened to traffic on 10th September, 2002.

Khan Jahan Ali Bridge

Background

Khulna city, the 3rd largest city and the hub of commerce and administration in the southwest region, is located 150 km away from Dhaka. The Rupsa river disrupts the urbanized area that has been developed along National Highway No. 7 and Rupsa ferry was only one transport means to connect. The ferry service on the river Rupsa was the barrier of communication between north-west and south-west region of Bangladesh and also disrupted the internal easy movement. Agricultural product, fertilizer, factory goods, raw material and delivered goods at Mongla port etc. are being carried each and every day through this route. The scheme of bridge construction was deemed to be a drastic measure to improve the situation.

A View of The Khan Jahan Ali Bridge

Considering all these things, Government of Bangladesh requested Government of Japan to provide necessary assistance for construction of a bridge over the river, Rupsa. In response to the above request the feasibility study was conducted by Japanese technical assistance and Government of Japan agreed to provide ODA loan for construction of Khan Jahan Ali Bridge. The loan agreement (BD-P47) was signed between Government of Bangladesh (GOB) and Japan Bank for International Cooperation (JBIC) on 29 March 2001.

Khan Jahan Ali Bridge will enhance the transportation system by establishing through communication between North West region with South West region and Mongla Port. This bridge will contribute for transit cargo movement to the land locked countries like Nepal and Bhutan from Mongla port.

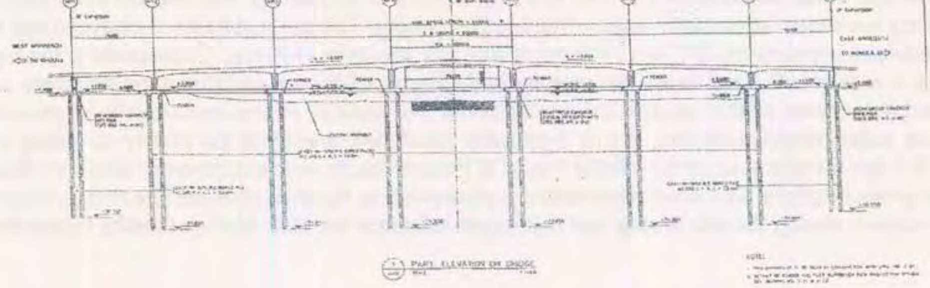
Location of Bridge

During the feasibility study survey was carried out along the 3 (three) alternative routes. Due to high land availability, least adverse social impacts, construction economy and high development impact the site was selected about 2 Km downstream of the Rupsa ferry ghat.

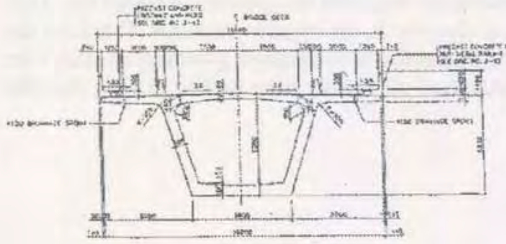
Salient Features

Roads and Highways Department, Ministry of Communications was the executing agency for the project. GOB appointed Pacific International, Japan in association with Japan Overseas Consultants Co. Ltd, Japan, Consulting Engineering Services (India) Ltd., India, Development Design Consultants Ltd., Bangladesh as the Construction Supervision Consultants. Shimizu-ITD Joint Venture comprising of Shimizu Corporation, Japan and Italian-Thai Development Public Company Ltd, Thailand was appointed as Contractor for construction of Khan Jahan Ali Bridge with approach road. In designing the bridge AASTHO live load and specifications have been followed. The bridge was opened to traffic on 21 May 2005.

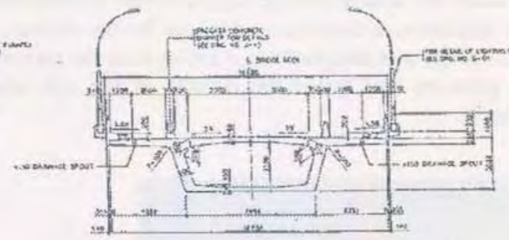
Bridge Location



Part Elevation of Bridge



Deck section at Pier



Deck Section at Midspan

Main Bridge Key Facts

Main bridge length	640m
No. of Span	7
Span arrangement	70m + 5x 100m + 70m
No. of Piers	8
Piling	60 x 2.5m diameter, length 60m ~ 75m
Carriageway	2x 4.25m + 2x0.5m barrier+ 2x 2m slow vehicle lane+ 2 x 1.25 m walk way

Foundation

Khan Jahan Ali Bridge is located at the southwest region of this country and known to be within a very deep geo-synclinal area in the Bengal Basin. The character of the sediments in this Project Area that has been floored by the Ganges-Brahmaputra river system from the surrounding highlands is mainly fine silty sand with sporadic mixture of clay and peat.

Main pier foundation for Khan Jahan Ali Bridge consists of 6 nos. 2500mm dia. cast-in-situ pile with 35m long steel casing for the scouring protection at each pier location. The piles were designed to 75m long and had a working load of 2250 ton of which major component of pile capacity would be shared by skin friction and remaining by end bearing as the pile founded on the solid ground was not possible due to the deep sediments in this region.

The foundation work for the main bridge was started from driving 2.65m dia Steel Casings to the depth-35m. A total of 60 numbers of 2.5m dia cast in-situ piles were constructed for the main bridge pile cap and for fender pile caps within Rupsa River. Reverse Circulation method was used for the excavation of 2.5 m dia. piles. Once the excavation was started, the piling work was continued round the clock till completion.

Prior to the production of the permanent piles for main bridge, two test piles (TP1 and TP2) were constructed and tested consecutively in May and July, 2002 by static loading. The result of both tests shows a significant settlement at the early stage of the load increment. The test results were analyzed and found that the ultimate capacity of TP1 was 1650 ton while TP2 was only 1100 ton. Consequently, the work to river piles was suspended and an extensive study including an additional soil investigations were carried out to find the reasons of this unexpected pile behavior and suitable countermeasures to overcome this unforeseen underground condition. It was eventually concluded among all the parties including advice from BUET that the character of the subsoil was to be blamed due to its extraordinarily sensitive character of poorly graded uniform fine sand. Such soils are susceptible to loose its strength due to their dispersive behavior caused during the pile boring and that might influence the skin friction thereby lessen the pile capacity.

Through the intensive research, it was concluded that adopting the relatively new shaft grout technique was the best way forward to resolve the problematic piling situation.

Shaft grouting is achieved by cracking the pile concrete surface with high pressure water through grout pipes which are attached to the outside of the pile reinforcement cage and the grouting through the crack will be applied as a continuous process for the surface of the pile in the regular intervals. Cracking the concrete of the pile and pushing it out against the surrounding soil and subsequent grouting develops the lateral pressure and hence the density of the soil which had otherwise been soften during the pile excavation.

Casing Driving

Boring Piles with Reverse Circulation System

To assess the pile capacity and confirm the efficacy of the technique before adopting in the permanent piles, it was decided to conduct the 3rd instrumental loading test (TP3) by Osterberg Cell method. TP3 was constructed with shaft and base grout enhancement measures from December 2002 and the test was carried out in January 2003. The test result was simply remarkable. The maximum ultimate figure of the pile capacity was as high as more than 8,500 ton or could be over 10,000 ton in long term capacity due to the remolding effect of the surrounding soil over the years. Following to the above experience of shaft grout at TP3, the piles construction was finally back on the truck and carried out from February 2003 till May 2003.

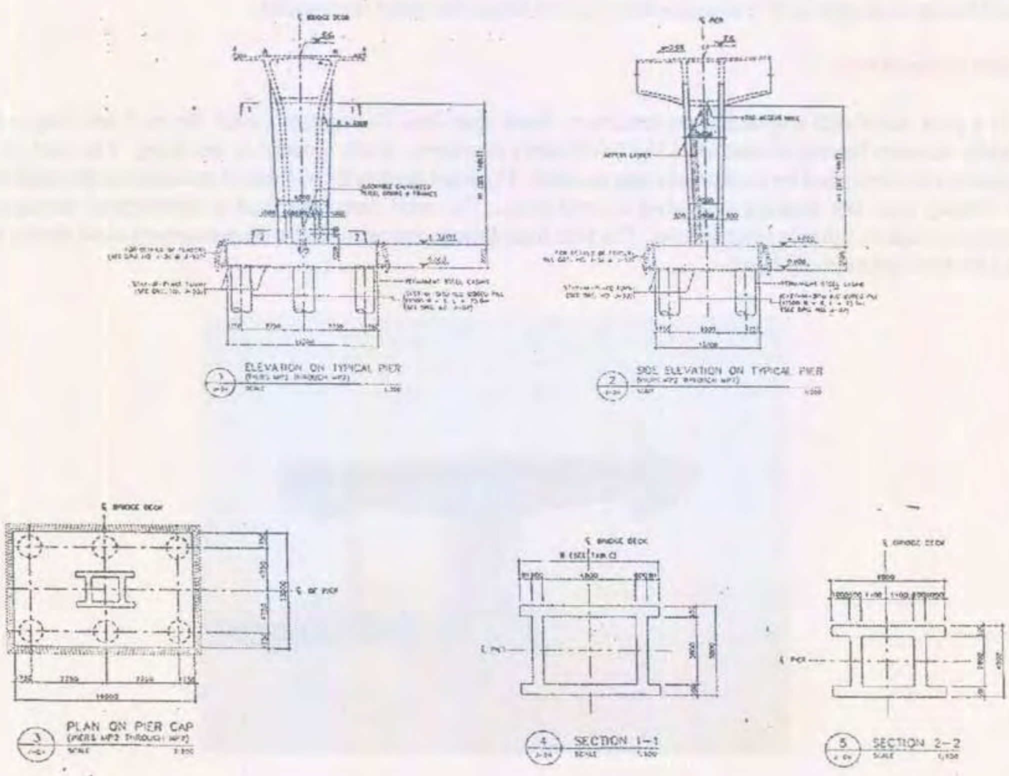
Grout Pipes Attached with Reinforcement Cage

Shaft and Base Grout Operation

Adoption of such extensive shaft grouting technique is the first time of its kind in Bangladesh and it is hoped that as an engineering exercise, our experience during the river piling works at Rupsa Bridge Construction Project will be a good predecessor for many challenging future projects on similar ground conditions within Bangladesh.

Main Bridge Substructure

Main bridge Consists of 8 nos. pile cap, pier and pier head. River portion contains 6 nos. of pier and 2 end pier at land.



Schematic Details of the Piers

In order to construct pile cap below the water level the precast concrete shell forms were constructed and hanged around the steel casing for main piles above the water level

Main Bridge Superstructure

It is a post tension cantilever box-section with 13 segments constructed on each side of the pier head by cast in situ segmental progressive cantilever method using the form traveler technique. At the junction of the main bridge and approach bridge modular type of expansion joint is provided.

Main Bridge Deck

It is a post tensioned segmental construction. Each span has 26 segments each 3m to 3.6m long with a middle closure having a total of 156+5 (closure) segments. Each closure is 4m long. The cast in situ segments are stretched by post tensioning method. The total deck is fixed farmed structure and is supported by sliding type pot bearing provided on end piers. The total structure load is transferred through the piers/pile caps to the pile foundations. The pile foundations are provided with permanent steel casing upto (-) 25m form pile cut-off level

Construction of Main Bridge Superstructure

Approach Viaduct

Approach Viaduct are provided at each end of the main bridge.. Each approach bridge (viaduct) consists of 12 span @ 30m of total length 360m. There are 11 (eleven) nos. pier and 1 no. abutment for each approach bridge on both side of the main bridge. The pier/abutment are provided with 900 mm dia cast in situ RCC bored pile. Pile cap and pier head supported by 4 nos. pier column in each pier. Deck slab of approach viaduct consists of 7 nos. post tensioned pre-cast I-girder over which 200mm thick slab with 60mm asphalting wearing course was provided. Expansion joint of 20mm width are provided at 30m interval filled with joint sealant.

Viaduct Key Facts

Total length	:	2x 360 m
Span	:	2 x 12 Span, each span 30 m length
Piling	:	0.9 m dia cast in situ R.CC bored pile
Carriageway	:	2x 4.25 m + 2x0.5 m barrier + 2x 2 m slow vehicle lane+ 2 x 1.25 m walk way

Approach Road and Toll Plaza

Total length of approach road is 8.68 km. Approach road at Khulna end is 5.89 km and approach road at Mongla end is 2.79 km. Road pavement design is based on the AAATHO specification. Bridge end facilities are included Toll Plaza and booths, control building, Generator & substation building are located on east side of the bridge.

The toll plaza has eight tollbooths, barriers, data recording equipment, vehicle classification equipment and cash handling facilities. A fully electronic toll collection system has been provided. The Lane Processor System (LPS) is installed in each tollbooth and is responsible for the registering of tolls collected and controlling various signs/indicators in the lane.

Special Features of Khan Jahan Ali Bridge

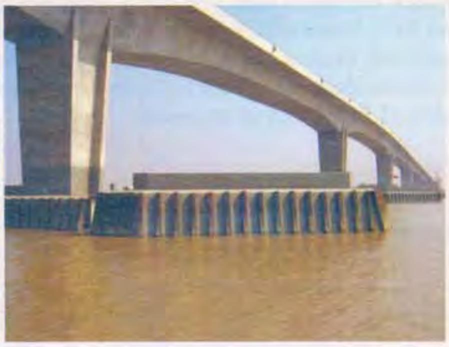
Khan Jahan Ali Bridge, has the highest clearance (18.3m) at the mid point of the bridge in Bangladesh to allow for large vessels to navigate from Mongla Port. In order to make this clearance at the mid point of the main bridge and to minimize the total length of the entire bridge length from the economical point of view, the general gradient of the bridge is designed at 3% slope. As this slightly steep gradient of the bridge would likely cause the reduction of the traffic capacity on the bridge by the mixture of fast-moving vehicles and a large number of slow-moving vehicle, that were seen as the traffic characteristic in this region, the carriageway on the bridge is separated between main two lane and slow track carriageway for such as mini cub and rickshaw by continuous barriers.

Due to the saline contents in Rupsa River water, the special care was taken in design of the structure to protect the concrete from deterioration by salination by providing steel casing at piles, providing adequate concrete cover from minimum 65mm to 150mm, paining bituminous coating around the pile caps and epoxy paint on the pile cap surface and pier surface up to +3m high.

Toll Plaza and Toll Both at Khan Jahan Ali Bridge

Another special feature of this bridge Fender Pile Caps were constructed to protect the main pile cap from the possible collision with ship. Precast fender units and timber fenders were installed on the outer wall of main pile cap and fender pile cap in order to alleviate the collision impact on the pile caps by ship.

Construction of Shell Form for Fender Pile Cap



Timber Fenders on Precast Fender Units

Other special feature of this bridge is four Staircases at the both side of the riverbank. The staircase is beautifully designed imaging Islamic culture with two distinctive towers and blue doom on the top of the column. The staircases and the stair plaza will serve as an amenity for people in this area as it would provide an easy access to the top of the bridge to enjoy the view from there.

Resettlement Action Plan

A comprehensive Resettlement Action Plan to rehabilitate the Project Affected People (PAP) has been implemented by Roads and Highways Department assisted by an NGO namely Polli Unnayon Andolon (RDM) as per the policy of the Government of Bangladesh and in accordance with the guidelines of JBIC, Japan. This involves providing compensation and financial assistance for lost assts and to restore or enhance the livelihoods of all affected persons.

78 hectres of land were acquired for the project . More than 4000 PAPs eligible to receive compensation were identified through Socio Economic Survey.

Environmental Action Plan

Assessment of the environmental impact of the project has been done not only at the initial design stage but also done periodically in accordance with "Guidelines for Confirmation of Environmental and Social Consideration", which were implemented by JBIC, Japan. It covered all environmental issues, their assessment and mitigation, the roles and responsibilities of the organization involved.

Project cost and Funding Arrangement

Project Cost		
Total Project Cost	:	Taka 724.15 crore (US$ 121 million)
Construction of Khan Jahan Ali Bridge	:	Taka 421 crore (US$ 70.2 million)
Construction of Khulna Bypass Road	:	Taka 100 crore (US$ 16.7 million)
Consultancy Services	:	Taka 39 crore (6.5 million)
Other Costs(Land, Taxes and Duties, Utility reallocation, L/C Charge)	:	Taka 164.15 crore (US$ 27.4 million)

Meghna-Gumti Bridge

Background

The Dhaka-Chittagong highway is the most important link between Dhaka, the capital city of Bangladesh, and Chittagong, the international port city. The 257 km long Dhaka-Chittagong National Highway (N1), a part of Asian Highway, serves a population of about 15 million of the region. The highway carries the heaviest traffic in the country in spite of the inconveniences and delays in road transportation caused by two ferries at the Meghna and the Meghna-Gumti Rivers. The necessity for constructing the Meghna and the Meghna-Gumti Bridges was to remove the bottle-necks at the ferries, leading to increase economic activity between the two major cities of Bangladesh. The bridge is located at 40 km away from Dhaka over the river Meghna and the Gumti. After construction of the Meghna-Gumti Bridge, Dhaka and Chittagong are connected entirely by highway. Traveling time between the two cities is three hours shorter than using ferry crossings. Meghna-Gumti Bridge is deemed as a symbol of friendship between Bangladesh and Japan, and is known as *"Japan-Bangladesh Friendship Bridge"*.

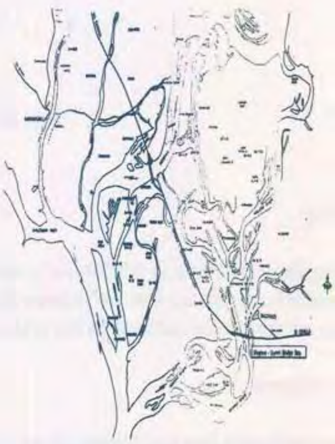
A View of Meghan-Gumti Bridge

Salient Features

The bridge consists of 17 spans of 15 spans each 87m and 2 spans each 52.5 m giving a total length of 1410m. Total width of the bridge is 9.2m including sidewalk and railing. The Executing Agency was Roads and Highways Department, Ministry of Communications, Government of the Peoples' Republic of Bangladesh. The consultant was Pacific Consultants International, Japan in association with Nippon Koei CO. Ltd, Japan and the Contractor was Obayashi Corporation, Japan. The bridge was constructed by Japanese Grant Aid. The bridge was designed following AASTHO HS 20-44 loading. The bridge was opened to traffic on 01 November, 1994.

Bridge Construction

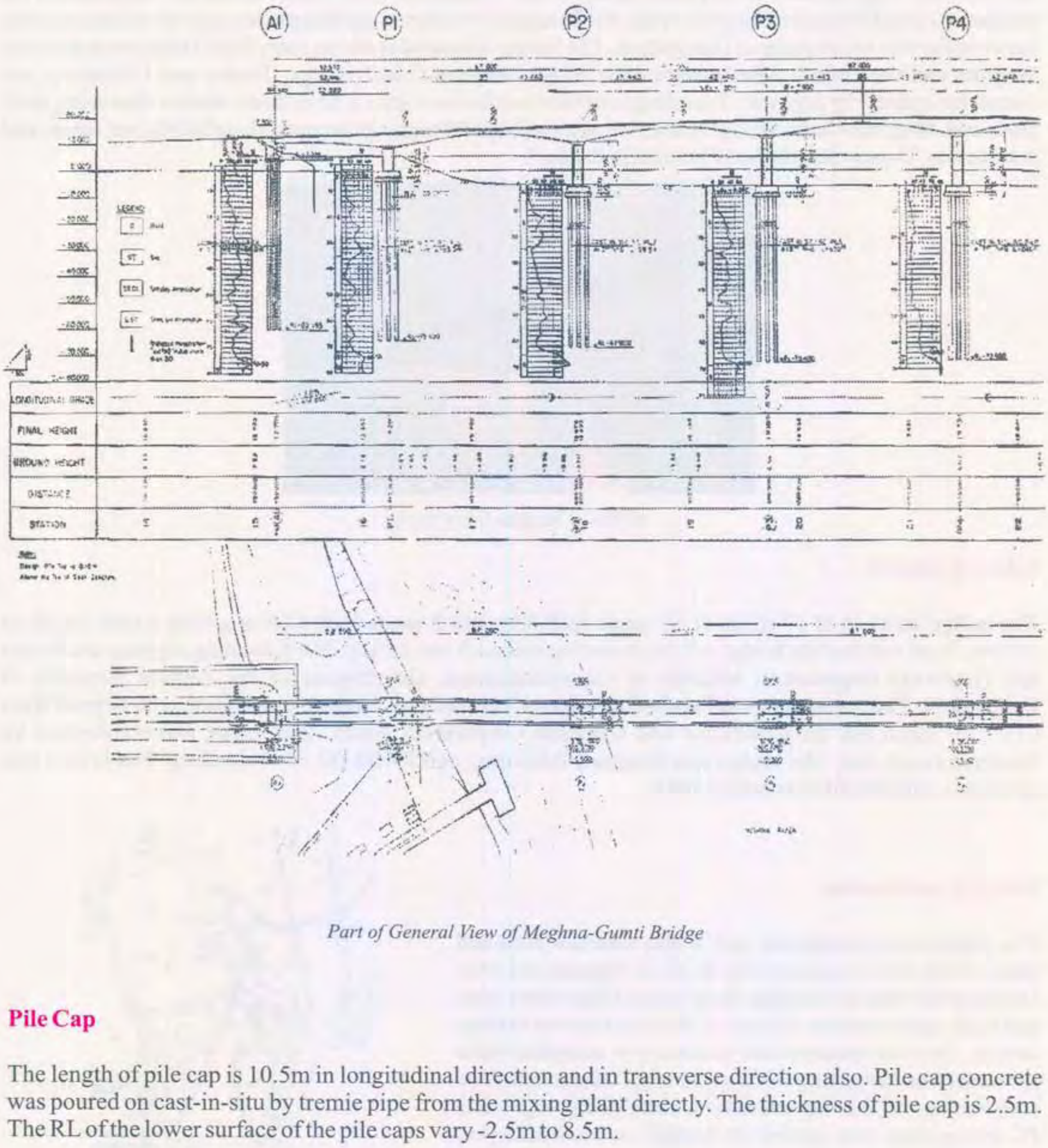
The substructure comprises cast in situ concrete piles and piers which were constructed in the river Meghna and river Gumti at the time of receding flood water. High water level and high stream current velocity of the rivers occurs in rainy season. Two dry seasons were necessary to complete these substructures consisting of 16 piers and 2 abutments. The construction of the superstructure, comprising segmental PC-box girders, was carried out through out the whole year even in rainy season.



Location Map of Meghna-Gumti Bridge Site

Cast-in-Situ Concrete Piles

138 cast-in-situ concrete piles of 1.5m in diameter were constructed by using reverse circulation drilling method. A supersonic measuring system was adopted for the vertical accuracy of the bore holes. The lengths of these piles are variable ranging from 54.0m to 75.0m depending on the level of the bearing strata for the piles.



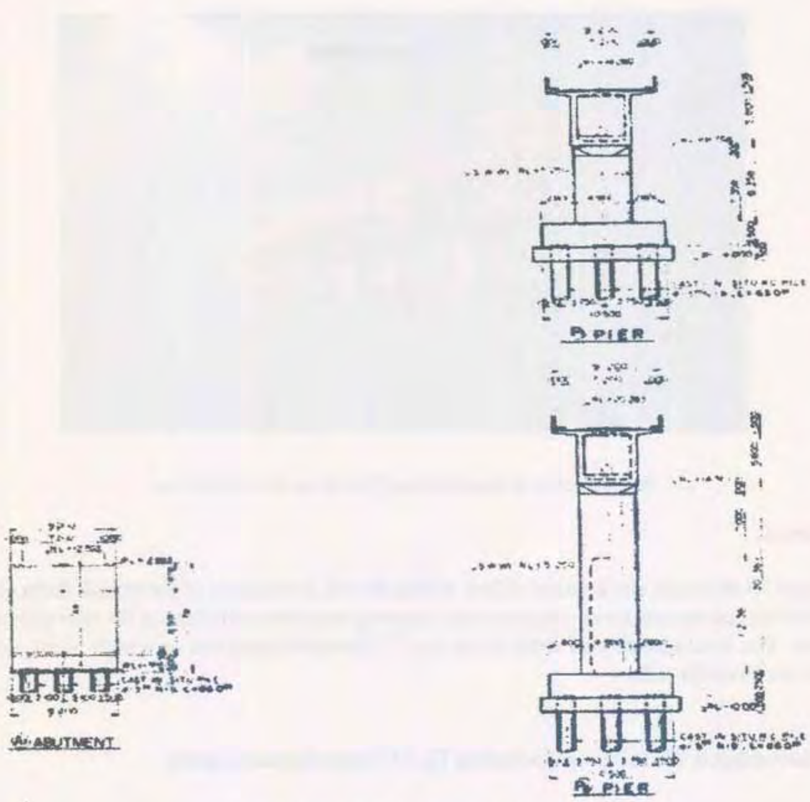
Part of General View of Meghna-Gumti Bridge

Pile Cap

The length of pile cap is 10.5m in longitudinal direction and in transverse direction also. Pile cap concrete was poured on cast-in-situ by tremie pipe from the mixing plant directly. The thickness of pile cap is 2.5m. The RL of the lower surface of the pile caps vary -2.5m to 8.5m.

Pier Column

The pier column has a circular shape with 4.9 m in diameter. The heights of the bridge piers vary 8.5m to 20.4m.

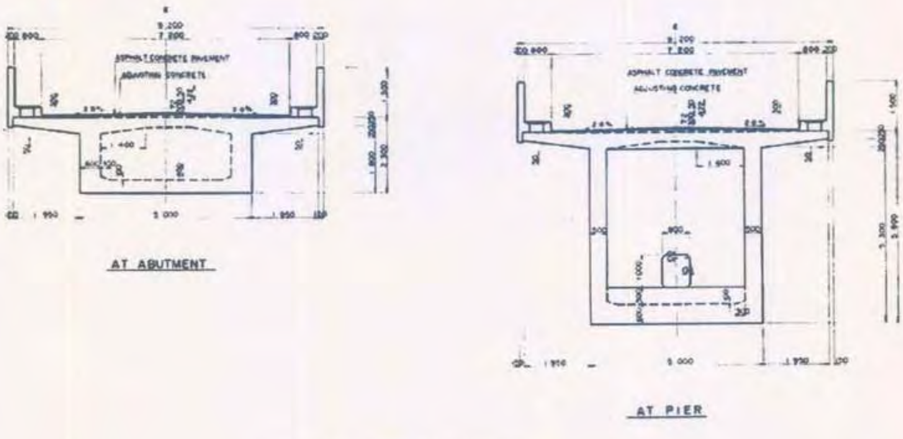


General View of Bridge Pier and Abutment

General View of Bridge Pier and Abutment

Superstructure

This type of construction system is called the cantilever erection method. The depth of PC-box girder gradually varies from about 5.8 m at segment No.1 and No.2 to 1.9 m at segment No. 19 and No. 20. The PC tendons were inserted into sheath duct provided in the box girder webs and upper deck slab. PC bars at an interval of 0.6 m to 1.6 m were installed in every segment. The number of PC tendons was reduced at the end of every segment.



General View of Bridge Girders

Superstructure of Meghna-Gumti Bridge under Construction

River Revetment

River revetment works were the main ancillary works for the protection of riverbank from erosion. These works consisted of geo-textile form concrete mat, capping concrete and placing boulder gabions in front of the revetments. The total quantity of work done was 773 linear meters out of which 585m were on Dhaka side and 188m on Comilla side.

Cost

Total cost of the bridge is Tk.313 crore including Tk.257 crore Japanese grant.

Lalon Shah Bridge

Background

Lalon Shah Bridge is of strategic importance to the road and bridge infrastructure improvement program of Bangladesh. Communication with the South West of Bangladesh, and Mongla Port facilities, through to the North west part of Bangladesh and Nepal and via Jamuna Bridge to Dhaka, the capital and commercial center of Bangladesh, depends on crossing the River Padma at Paksey.

A View of Lalon Shah Bridge

The economies of the Northwest and Southwest were not closely integrated with each other or the rest of Bangladesh, principally because of the river barriers which had effectively cutoff from the main industrial areas in Dhaka Division and the main port of Chittagong. A major objective of constructing the Jamuna Bridge was to open up the Northwest for development. However, the Jamuna Bridge did not effect the economic development in the Southwest because of not having a fixed road crossing of the Padma (Ganges). It was therefore felt that linking the Southwest of the country by constructing a bridge over Padma (Ganges) river would link the region to the northwest and the rest of the country via the Jamuna Bridge.

The most important crossing with respect to the Paksey Bridge would enable the Mongla Sea Port and Benapole (A Land Port) to serve the whole Bangladesh and help to realize the considerable costs saving. The Paksey Bridge was vital to the development of trade with India through the land port at Benapole. Development of the Mongla EPZ and Iswardi EPZ and other initiatives at the port could help to pass benefits on to the economy of the Southwest.

In keeping with those points mentioned above the Government of the People's Republic of Bangladesh decided to construct a bridge at Paksey over Padma (Ganges) for improving the road network system in the Southwest and Northwest of the country.

Location of Bridge

The bridge is located at Paksey in Pabna District in the western part of the country over the river Padma. The bridge is constructed about 300m downstream of the existing Hardinge Railway Bridge which was built in 1915.

Salient Features

The Government of Bangladesh obtained a loan from the Japan Bank for International Cooperation(JBIC) for the construction of Paksey bridge. The construction of the bridge was carried out under three contracts:

Contract-1 : Main Bridge and, River Rraining Works, constructed by Major Bridge Engineering Bureau, People's Republic of China.

Contract-2 : West Connecting Road, constructed by Abdul Monem Ltd, Bangladesh.

Contract-3 : East Connecting Road, constructed by BDC- NCE Consortium, Bangladesh.

The Contractor for Contract-1 was procured under International Competitive Bridge (ICB) and the contractors for Contract-2 and 3 was done under Local Competitive Biddings (LCB). Bidding procedures were based on guidelines set by Japan Bank for International Cooperation (JBIC).

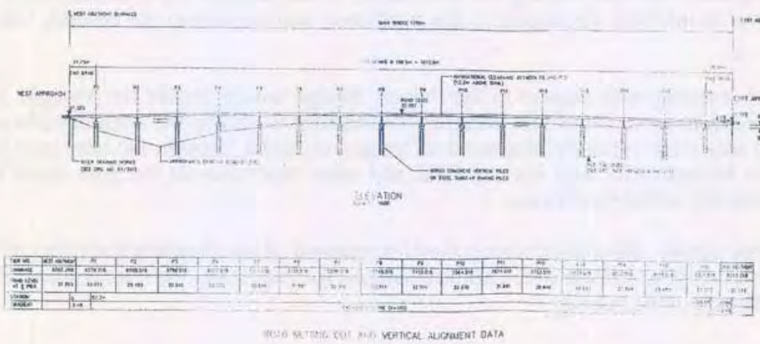
Roads and Highways Department, Ministry of Communications was the executing agency. The Government of Bangladesh appointed Parsons Brinkerhoff International Inc., USA with their associates Kulijian Corporation, USA, Worley International, New Zealand, SARM Associates, Bangladesh and KS Consultant, Bangladesh as the design review and construction supervision consultants. The bridge was opened to traffic on 18 May, 2005.

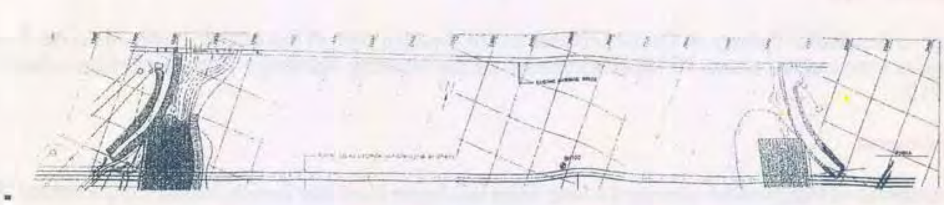
Location Map of Lalon Shah Bridge

Lalon Shah Bridge included some of the largest concrete piles in the world and the longest continuous segmental deck in the world, erected using balanced cantilever technique.

Provision is made for future installation of electrical conductor towers and for gas transmission pipes on the bridge structure.

The bridge has an overall length of 1786 m, consisting of 15 spans each 109.5 m long and two shorter end spans each 71.75 m long. Total width of the bridge is 18.03 m. It provides two 7.5 m wide carriageways (two lanes each) and 1m wide side strips for emergency footway use. The bridge has been designed following AASHTO HS20-44 loading.





Bridge Layout

Foundation

The typical substructure consists of concrete piers on pile foundations, with each pier foundation comprising a group of four piles. The concrete piles are 3.0 m diameter and over 91m in length. They were founded in dense sand, which is present to considerable depths at the site, and were designed to resist both deep scour of the riverbed and seismic (earthquake) forces.

Piling Work in the River

The bridge piling works include the largest piles in size ever constructed on one project. These piles are reinforced concrete cast in place with a permanent steel casing used for the upper 50 meters approximately. This requirement was due to the riverbed being scoured out to that depth during the worst expected monsoon. The piles are 91 meters long and 3.0 meters in diameter. The pile base was pressure cement grouted after construction to ensure good load bearing characteristics. The concrete quality was checked using ultrasonic technology, after casting.and over 91m in length. They were founded in dense sand, which is present to considerable depths at the site, and were designed to resist both deep scour of the riverbed and seismic (earthquake) forces.

Installing the Reinforcing Cage of P13 Pile Cap

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Substructure

The typical substructure consists of 16 concrete piers and 2 abutments on pile foundations. The piers are supported on reinforced concrete pile caps which in turn transfer the bridge loads to four very large piles at each pier location.

Completed Bridge Piesrs

Superstructure

The superstructure has been designed as a continuous, prestressed concrete deck and has been constructed using the precast segmental balanced contilever erection method. The bridge was constructed using the post-tensioned segmental box girder system, erected using the balanced cantilever technique with a launching Gantry. A total of 490 post tensioned concrete deck segments were erected in this way.

Erecting Bridge Deck Segment

Deck Segments (units) were precast in almost factory conditions, the largest unit being at the pier location and weighing approximately 170 tons. These units were then transported to the bridge location and installed using a temporary steel truss launching gantry. The deck units are finally joined together with stressing cables. This balanced cantilever technique is used when access to the area below the bridge is restricted (for example, river and sea crossing, deep gorges and crossing over inhabited areas).

These bridge deck units were supported on reinforced concrete piers using two bearings, each carrying 3000 Tons vertical load, together with an earthquake protection device (Shock Transmission Unit) capable of absorbing up to 2300 Tons of longitudinal (horizontal) force.

The piers are supported on reinforced concrete pile caps which in turn transfer the bridge loads to four very large piles at each pier location. These piles are 3 meters in diameter and more than 91 meters long (equivalent to a 30 storied high building).

River Training Works

Extensive river training works have been designed to guide the river and to protect the banks and thus the bridge itself. The guide bank protection consists of rock placed on fascine mattresses with geotextiles. These works extend the existing work from Hardinge Bridge downstream by approximately 500m on the East side and 700m on the West side and also at Sara 990 meters.

During the design review period the existing river training works for Hardinge Bridge were studied. The protection work at Sara, 5 kilometers upstream was originally constructed in 1935 and has performed well over the last 70 years. However, this review recommended rebuilding approximately 1 kilometer of these works in order to protect both Hardinge and Paksey Bridges into the foreseeable future. This rebuilding work was done during construction of this bridge.

The river training works involved bank protection using concrete blocks placed on geotextiles fabric for the "above water" slopes and large rock for the "below water" slopes placed on geotextiles fabric for the slope area and in a mass (launching apron) at greater water depths.

Approach Roads

The bridge also includes about 16 km of roads connecting the bridge with the National Highways Network on both sides of the river. These are generally two-lane, single carriageway roads and include culverts and subways and a 61.80 m long bridge over the GK Project irrigation canal on the west side.

The Connecting Road on the East side is approximately 10 km long and joins the bridge to the National Highway (N6) between Pabna and Natore at Dasuria. This road improvement generally follows a new alignment with only a short section of existing road upgraded.

The Connecting Road on the West side is approximately 6 km long and follows a new alignment to meet the National Highway (N74) at Baromile. This work involves construction of a bridge crossing the GK Irrigation canal just outside Bheramara.

Toll Plaza

Bridge end facilities are located at Bheramara and Paksey and include a toll plaza and booths, control buildings, security stations, standby generator buildings. Each toll facility consists of toll booths, barriers, data recording equipment, vehicle classification equipment and cash facilities. A fully electronic toll collection system has been provided. The Lane Processor System (LPS) is installed in each tollbooth and is responsible for the registering of tolls collected and controlling various signs/indicators in the lane.

Social Action Plan

A comprehensive Social Action Plan for resettling Project Affected Persons was implemented by Roads and Highways Department in accordance with Government of Bangladesh and International Guidelines. To this end, RHD employed a consultant NGO, CCDB to provide compensation negotiation and financial assistance/advise for lost assets to restore or enhance the livelihoods of all affected persons, assistance with resettlement and the reconstruction of community and civic facilities.

River Training works at East Guide Bank

Environmental Action Plan

Assessment of the environmental impact of the project was made and the contractors took measures to mitigate construction affects on hydrology, water quality, noise, vibration and dust. Contractor's activities were monitored by the concerned authorities accordingly. The contract also provided a health clinic for all personnel associated with construction work. Tree plantation program along the sides of road and in the vicinity of toll plaza, offices, accommodation area etc. was also included to improve the local environment.

Project Cost and Funding

Construction Cost	
Main bridge and river training works	Taka 648 crore (US$ 111.7 million)
West connecting road	Taka 35 crore (US$ 6.0 million)
East connecting road	Taka 45 crore (US$ 7.8 million)
Consultants	Taka 43 crore (US$ 7.4 million)
Physical and Price Contingency	Taka 90 crore (US$ 15.5 million)
Other Costs(Land,utility relocation,taxes and duties, GOB administration)	Taka 204 crore (US$ 35.2) million)
Total Project Cost	Taka 1065 crore (US$ 183.6 million)
Funding	
Govt. of Bangladesh Taka 245 crore (US$ 42.2 million)	
JBIC(Donor Loan) Taka 820 crore (US$ 141.4 million)	

Jamuna Multipurpose Bridge

Background

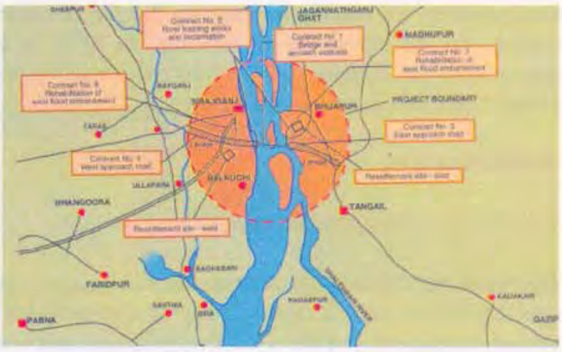
The Jamuna, one of the world's largest rivers, enters Bangladesh from India in the North and flows down to the Bay of Bengal, dividing the country in two halves. The Jamuna river ranks as the world's fifth largest river in terms of volumetric discharge and second largest river in terms of sediment load.

Jamuna Multipurpose Bridge

Prior to construction of Jamuna bridge the vehicular traffic used to cross the river by ferries which were generally slow, inefficient and of inadequate capacity to meet the demand for cross river transport. This was a major constraint on the development of the agricultural western Zone, effectively isolating it from the commercial and industrial centers and potential markets in the eastern half of the country. There was also a need to provide facilities for the transfer of additional electricity and gas across the river from energy sources in the eastern zone. After constructing the Jamuna bridge, a long cherished dream of the people of Bangladesh has been fulfilled. Railway which when fully developed will provide an uninterrupted international road and railway link from South East Asia to North West Europe.

Location

The bridge is located at about 120 km away from the capital city, Dhaka over the river Jamuna, which crosses the National Highway No. N405. The bridge is situated on the strategic Asian Highway and Trans-Asian Railway which when fully developed will provide an uninterrupted international road and railway link from South East Asia to North West Europe.



Location of the Jamuna Bridge

Salient Features

Preliminary feasibility study which recommended rail-cum-road bridge near Sirajgonj was undertaken by Freeman Fox and Partners of the UK in 1969. Cost of the project was estimated to be US$ 175 million. As the study was conducted over a short period (6 months) and was preliminary in nature, a detailed study was recommended. The process was interrupted by the political unrest prevailing in erstwhile Pakistan at that time. After the liberation of the country, Government of Bangladesh (GOB) took immediate steps to pursue the bridge project in right earnest. It requested the Government of Japan (GOJ) for technical and financial assistance. This culminated in a feasibility study into the viability of a rail-cum-road bridge, which was commissioned by Japan International Co-operation Agency (JICA). The JICA study completed in 1976 concluded that the project would cost US$ 683 million with an EIRR of only 2.6%

In 1982 GOB commissioned a study to determine the feasibility of transferring natural gas to the Western zone from the Sylhet gas fields across the river Jamuna.The study was carried out by Rendel Palmer and Tritton (RPT) and Pencol Engineering consultants, both of the UK and Bangladesh consultants Ltd (BCL). The conclusion of the study was that an independent gas connector on its own was not economically viable. However, the consultants made an assessment on the engineering feasibility and cost of a combined road and energy bridge, and thus the concept of a multipurpose bridge was born. It was estimated that a 12 km long bridge with three road lanes would cost US$ 420 million. On this basis the Bangladesh Government discussed the potential for developing the project with the World Bank.

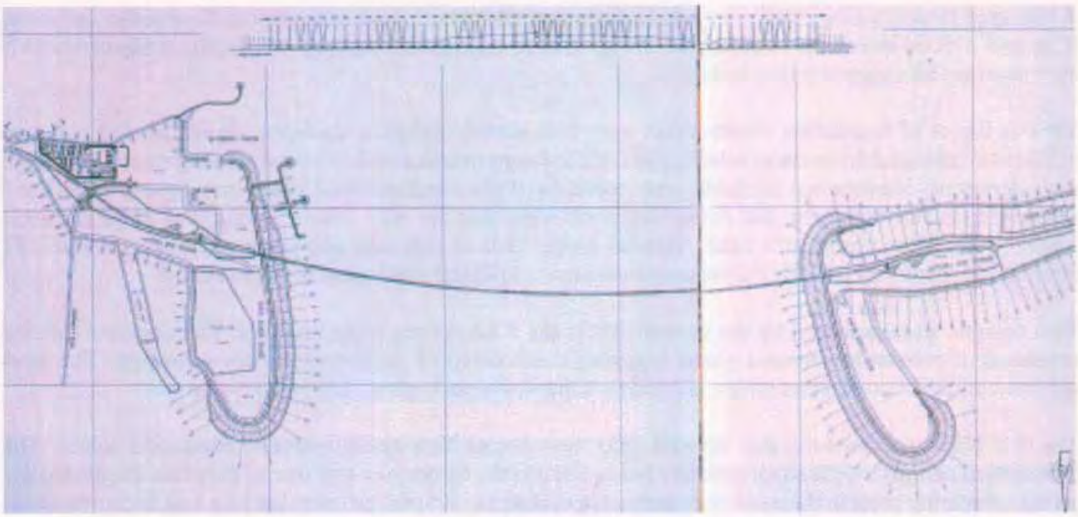
In 1986, the Government of Bangladesh appointed RPT, Netherlands Engineering consultants (NEDECO) and BCL to undertake Phase-I feasibility study which involved selection of the most favorable location for the bridge. Out of seven locations considered, the site between Sirajgonj and Bhuapur was found the best. Stability of the channels, their configuration and width of the braid belt were the determining factors behind this decision. In June 1987, RPT, NEDECO and BCL were commissioned to undertake the Phase-II feasibility study. This included review of Phase-I costs and benefits, development of the appropriate configuration for the bridge geometry and preparation of detailed designs for approaches and river training works. In 1986-87, the bridge location was decided mainly on the basis of satellite imagery and earlier bathymetric surveys which indicated that at the chosen site the river flows in a relatively narrow belt and mostly in one channel. Considering the fact that the width of the main channel generally does not exceed 3.5 km and after making allowances for a one in 100 year flood discharge as well as concerns for backwater effects, a bridge length of approximately 5 km was considered adequate. The study concluded that a road-cum-rail-cum-power bridge was both economically and technically viable. It recommended early implementation of the Jamuna Multipurpose Bridge Project (JMBP).

A pre-appraisals team comprising representations of IDA, ADB and OECF visited Bangladesh in July-August 1990. The Government of Bangladesh launched all-out efforts for arranging funds for JMBP in 1991 and funding arrangements were finally made with IDA, ADB and OECF by GoB in 1992. In 1993, on fulfillment of all conditions imposed by the co-financiers, tenders were invited through international bidding for the construction contracts. In 1994, in the same group (RPT, NEDECO and BCL) was appointed as the engineer for the construction of the project by GOB. Hereafter, the RPT-NEDECO-BCL group was referred as the consultant.

Design Features

Main bridge and approach viaduct

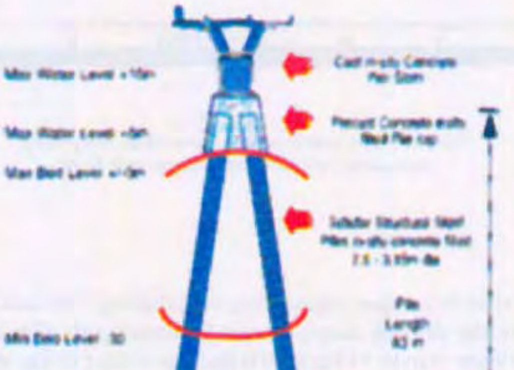
To ensure appropriate competition for the bridge contract, the consultant prepared tender designs for a concrete scheme and a steel scheme. It also included a detailed design specification. Contractors were invited to bid on one of the consultant's designs and to submit an alternative in accordance with the design specification.



General Layout of Bridge

A principal factor influencing the design was that the Jamuna riverbed consists of approximately 70m of alluvial deposits of loose to medium dense highly micaceous sands overlying denser sands. This micaceous material has an extremely low capacity to resist lateral loads.

The site is within an area of seismic activity. Reports of an earthquake in 1885 suggested that it had a magnitude of approximately 7 on the Richter scale and that its epicentre was approximately 50 km from the site. It is probable that this event emanated from the Bogra fault system, which lies some 25-50 km to the northwest.



X-section of bridge showing dual-2 lane road, rail, gas main and 230 KV power inter connector

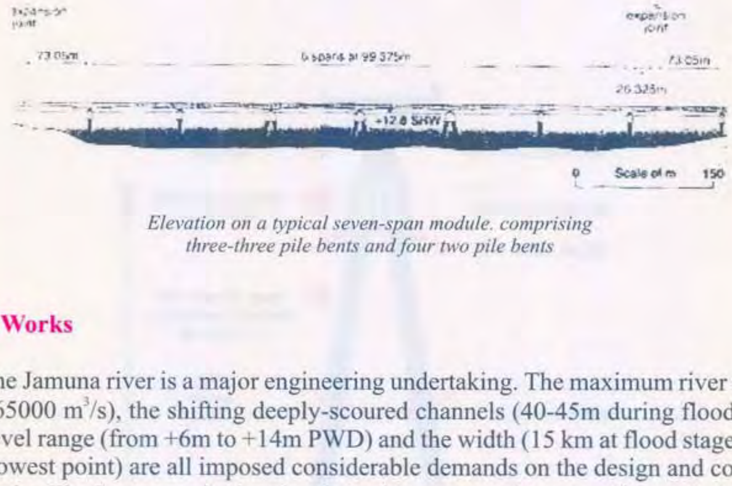
A site-specific seismology study provided a design spectrum with peak acceleration close to the surface of 0.2g and a peak structural response of 0.47g. Under earthquake shaking the depth of liquefaction is estimated to 15m below the riverbed level.

Various forms of foundation construction were considered, including caissons, driven precast concrete cylindrical piles and driven steel tubular piles. Following a detailed review encompassing structural design considerations, construction methods, transportation of plant and material, programming constraints and season-dependent activities, the consultant concluded that the only viable option was large diameter tubular steel piles driven at a rake. Vertical units, such as caissons and in practice all concrete pile alternatives, could not provide the necessary resistance to lateral movement in the weak soil.

Two designs were prepared by the consultant for the 4.8 km long superstructure. The concrete scheme consisted of precast prestressed glued segments constructed by balanced cantilever method. The steel scheme comprised a steel box girder, erected on a span-by-span basis with top slab cast in situ.

The 4.8 km superstructure was divided into modules of five spans between expansion joints. The articulation comprised the superstructure being fixed to the center pier and free to translate longitudinally on the remaining piers in the module in normal operating conditions. Seismic loading was accommodated by providing shock transmission units (STU) at each of the free piers and energy absorption steel pintles at all the piers. In the event of an earthqueke, the STU would lock the superstructure with the piers thus sharing the loads between all the piers. The energy absorption would be through the deformation of the steel pintles. The selected contractor adopted a similar concept in its alternative design.

In accordance with the tender requirements, the selected contractor priced one of the consultants designs (steel scheme) and proposed also an alternative design similar to the consultants concrete scheme. The contractor adopted fewer but larger diameter piles utilizing its large offshore pile driving barge and a seven-span module.



Elevation on a typical seven-span module. comprising three-three pile bents and four two pile bents

River Training Works

The control of the Jamuna river is a major engineering undertaking. The maximum river discharge during flood (average 65000 m^3/s), the shifting deeply-scoured channels (40-45m during flood conditions), the seasonal river level range (from +6m to +14m PWD) and the width (15 km at flood stage and 5 km at low water at its narrowest point) are all imposed considerable demands on the design and construction of the river training works. The 8m ranges in river levels lead to a seasonal construction period of 6 $^{1/2}$ months for the river training works.

The layout of the river training works as determined at the feasibility stage in 1986 was based on a comparatively stable situation of the main river channel, where only limited shifting of the river banks had been observed for some years. Later, in 1987-1989, it became apparent that the extreme floods in the Jamuna of 1987 and 1988 had considerably distorted the equilibrium, which had previously existed in the selected bridge corridor.

Landsat image of early 1987

Landsat image of February [illegible]

Landsat Image of March 1991

Landsat Image of January 1995

A second major channel was developed along the west bank while both the east and the west channel tended to move east and west, respectively. In the period 1987-1992, the banks at the proposed bridge axis moved 1 km to the east and 1.5 km to the west, respectively. This completely distorted the idea of having a 5 km long bridge with guide bunds built in the flood plains at both sides. As, a longer bridge meant additional cost, it was decided to study the possibility of constructing one of the guide bunds on a mid-river char (the local name for a sand bank) or in a shallow river channel during the dry season. This could turn out to be costly, depending on the level of the riverbed and / or the location of the char. However, at the time of construction an effort would be made to find an optimum between (a) extending the length of the bridge in order to build the guide bund on a char, (b) constructing a more expensive guide bund in a shallow channel without extending the bridge length.

This approach by the consultant was accepted by the employer and co-financiers and proved most successful. The final location of the west guide bund could only be determined by the consultants on 15 October 1995 as the river levels fell -19 month after award of the major construction contracts. This approach involved no additional project costs and the relevant provisional sums for contingencies were not required.

The cross-sectional design of the guide bunds adopted during the design stage was based on the following principal considerations:

- extreme bend scour
- a depth of bund that is capable of being dredged having due regard to economic considerations
- slope stability
- protection of slope
- economic considerations

Design adaptations during construction

It should be anticipated for a project of this nature that design adaptations would be required during construction. These adaptations could be, among other things, due to one or more of the following circumstances:

- Erosion of river banks resulting in changed bank lines and another site configuration
- Major shifting of river channels
- Increased flow through secondary creeks and floodways
- Discovery during construction of sub-soil condition not known at the time of design (despite extensive site investigation)
- Delays in the start of the construction period.

In practice, nearly all the above circumstances were occurred during the construction period. This means that the design of both guide bunds and the Bhuapur hard point had to be adapted with regard to location, plan-form and cross-section. The change in location and plan-form was on the one hand due to shifting of channel and on the other to land acquisition constraints. The change in cross-section in the first instance was due to difficulties encountered during construction of the west guide bund. It becomes evident that the soil during and after dredging was very sensitive to slight dynamic disturbances. It was therefore decided to provide a more gentle gradient below PWD-3m.

Bridge Construction

Foundations and substructure

Following determination of the location of the west guide bund on 15 October 1995, the bridge length and bridge alignment could be fixed thus allowing piling to commence.

Over the period mid-October 1995 to June 1996, the 121 main works piles plus two full-scale trial piles of 2.5m and 3.15m diameter and up to 82m length were driven. It was critical that the pile-driving barge HD 1000 and other heavy equipment be demobilized by August 1996 when the water level was appropriate to provide the draft for the piling barge to navigate to the Bay of Bengal and to pass under the power inter-connector.

Failure to meet this programme would have resulted in the barge demobilization being delayed by a season and thus potentially adding major cost to the project.

The pile fabrication using Japanese-supplied plate steel took place at Ulsan, Korea. Installation of the piles was primarily by Menk MHU 1700T hydraulic hammer. The follow-on operation after the driving involved airlifting concrete infill of the pile tube and grouting of the infill concrete base to restore any disturbed material at the pile toe.

Pile Driving

Driven Steel Piles

Installation of Pile Caps

During the piling process, up to 1700 KNm of energy was imparted by the hammer to the pile causing considerable disturbance to the surrounding material. The risk of a potential failure of the recently completed west guide bund by the final piles, due to piling vibrations, had to be minimized. This was done by temporary backfilling of the trench in front of the guide bund. Prior to this piling in guide bund itself, detailed monitoring of ground movements and attenuation characteristics was made by geophones during the piling of the preceding pile bents to ensure containment of these motions.

Following the installation of each pile group, a pre-cast concrete shell weighing approximately 300t was installed at each pier. The shell provides long-term protection against abrasion and boat impact and served as permanent formwork for the construction of concrete pile caps. This was achieved by plugging the shell base with tremie concrete followed by de-watering and the casting of structural concrete in the dry. The construction of the pier stems was done in situ by conventional methods.

Superstructure

The superstructure of the bridge is a variable depth single cell box girder comprising 50 No. pre-cast concrete pier head units 2m long and weighing 186t; 1152 No. 4m long standard segments of variable depth; and six sets of special hinge segments. The main bridge consists of 49 No. spans in which 47 spans each 99.375m and 2 No. end spans each 64.6875m giving a total length of 4800m. The length of viaduct is 128m at each side of the bridge.

The pre-casting yard was built on the east side of the river from where the erection would start and proceed to the west. The steel forms, comprising seven standard and two special forms for the hinge segments and the pier head units, were fabricated in Singapore.

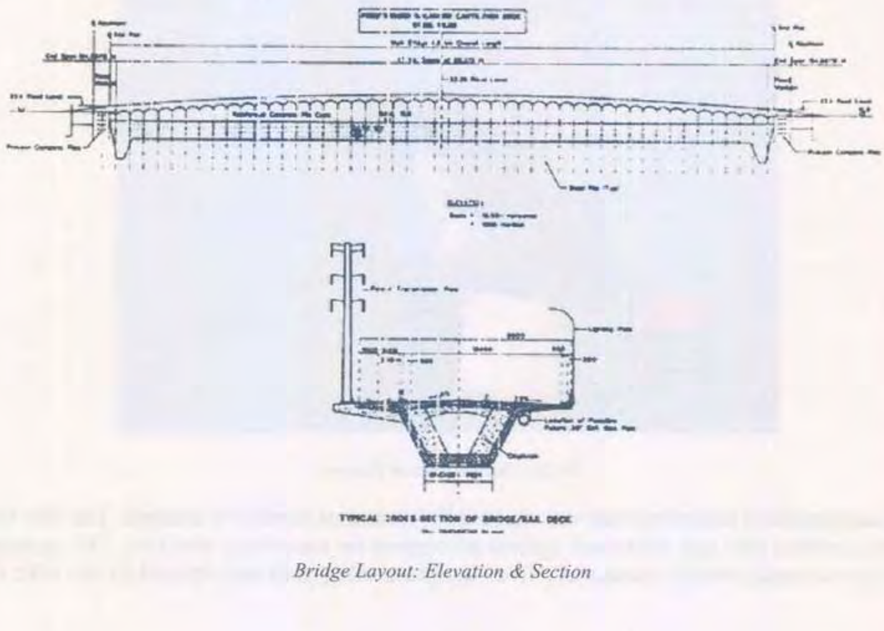
Bridge Construction in Progress

The precast segmental superstructure was erected by balanced cantilever method. The pier head units (PHU) was erected first and restrained against movement by temporary restrains. The segments were supplied by two multi-wheel transporters from the pre-casting yard and erected by the 600t two-span gantry. The erection procedure ensured that the out-of-balance moment did not exceed the weight of one segment. The out-of-balance moment was taken by the pier up to the erection of segments 2 east and west. The out -of -balance effects beyond this point were transferred into the erection gantry by means of supports 1 and 2. The span was completed by casting an in situ concrete stitch at mid span.

Erection of Deck

The erection cycle time improved dramatically as the operatives gained experience and cycle times of under seven days per span were achieved.

Elevation on Erection Gantry



Bridge Layout: Elevation & Section

Key Facts of Bridge

- Designer: Hyundai + TY Lin
- Engineer: RPT ~ NEDECO ~ BCL
- Builder: Hyundai Engineering and Construction Joint Venture
- Contract: FIDIC3
- Cost: US$ 269 million
- Duration: 49 months
- Completion: June 1998
- Bridge Length: 4800 m
- Viaduct length: 2 x 128 m
- Piling:
- Total Tonnage: 34,000 Tonnes
- Total Number: 121 (2.5m Dia piles: 63 3.15m Dia piles: 58)
- Pile caps & Pier stems:
- Total Number: 50 each
- Deck Segments:
- Total weight 176,000 Tonnes
- Total Number: 1257
- Concrete:
- In - situ: 66,000 cu m
- Precast: 118,000 cu m
- Average Workforce No.: 2,250

Construction of River Training Works

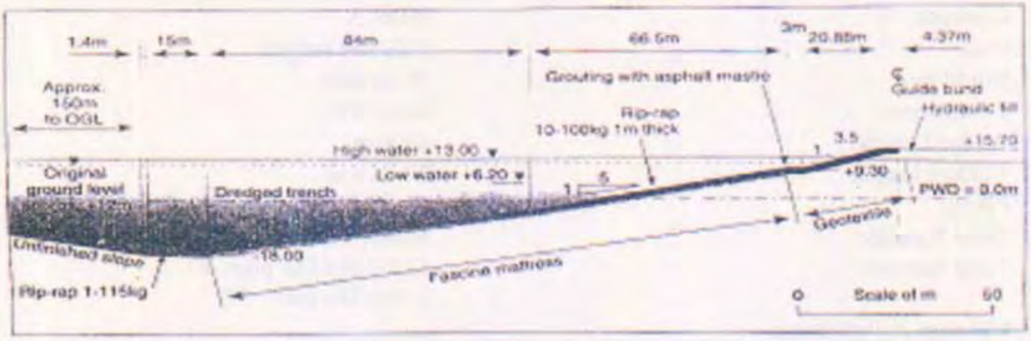
Construction of the river training works, commencing with the east guide bund, started on 15 October 1994 in accordance with the revised works programme. During this period it was necessary to dredge the work harbour and to reclaim areas in the flood plain using the sand dredged from the harbour basin. These areas were required by the two major contracts (bridge and river training works) for offices, workshops, working areas and residential areas for the site staff.

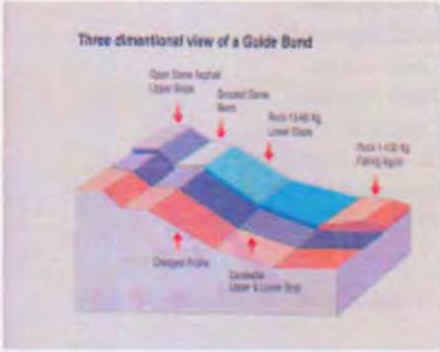
One year after start of construction, the location of the west guide bund was fixed. It was the intention to complete this guide bund, including all reclamation and closure of the western river channel as well as some secondary channels, in a period of 6 $^1/_2$ months. This became impossible, mainly due to the unforeseen behavior of the sub-soil. In November-December 1995 a number of minor and major slips occurred in rapid succession in the dredged 1-in-3.5 slope. This prompted the consultant to change the slope gradient to 1-in-5/1-in-6 and to adjust the toe level of the protection works.

Despite the slips at the west guide bund, the slope protection works in general were carried out as planned. This was due to the application of a modernized version of the old
Dutch fascine mattress. A Dutch fascine mattress historically was of 0.5m thick brushwood construction in units of 1000 to 2000 m^2 which, after fabrication during low tide, were floated to the site.

After positioning, they would be ballasted and sunk at the turn of the tide and a final ballast layer placed by dumping stones from flat top barges.

The fascines had a triple function. They acted as a filter layer, provided a rigid framework to the mattress and provided buoyancy. With current designs, the filter function has been taken over by a composite geotextile. In Bangladesh, this geotextile is attached to a rigid framework of split bamboos, which also provided buoyancy. For the Jamuna river training works, the largest mattress dimensions were 30 m by 155 m(4650 m^2) . After positioning, the floating mattress was gradually sunk by ballasting with boulders. Final ballasting, by placing rock up to 100 kg, was effected by means of a side stone-dumping vessel. This vessel, with capacity of up to 1300 t of rock, was positioned by means of satellites (GPS) and its combined movements and dumping rate controlled by computers.





Typical X-section of Guide Bund in Bridge Corridor Showing Fascine Mattress

Fascine Mattress for Guide Bunds

At the west guide bund, 141 mattresses having an overall area of 480,000 m^2 were placed in a period of 146 days. At the east guide bund 93 mattresses measuring 400,000 m^2 were placed in 121 days. The side stone-dumping vessel was operated 24h a day and reached dumping productions of 10,000t a day.

Completed Part of West Guide Bund

Completed Part of East Guide Bund

The length of east guide bund and west guide bund are 3.07 km and 3.26 km respectively. The length of hard point at Bhuapur side 1.7km. The guide bunds, which were constructed in ternches, required a total of 26 M m^3 of dredging.

Rail Track Bed

Key Facts of River Training Works

• Designer:	RPT ~ NEDECO ~ BCL
• Engineer:	RPT ~ NEDECO ~ BCL
• Builder:	HAM- VOA JV
• Contract:	FIDIC3
• Cost:	US$ 323 million
• Duration:	37 months
• Completion:	June 1997
• Vol of dredging:	26,5000,000 m3
• Area of reclamation:	486 ha
• Tonnage of rock:	1,500,000 Tonnes
• Length of Guide Bunds:	
❍ East Guide Bund:	3.07 km
❍ West Guide Bund:	3.26 km
❍ Bhuapur hard point:	1.7 km
• Average Workforce No.:	2,050

Resettlement Action Plan

The Jamuna Multipurpose Bridge Authority (JMBA) has acquired 7316 acres of land on both sides of the Jamuna river for construction of various components and facilities, including the East and West guide bunds for river training and protection. As a result of land aquisition, about 16000 households have lost their agricultural land; homestead and/or other properties while indirectly affected households have lost their sources of income like farm/non-farm workers, tenants cultivators, squatters and uthulis.

In accordance with the world Bank Operating directive 4.30, a resettlement plan called RRAP (Revised Resettlement Action Plan) was prepared to mitigate the adverse impacts of land acquisition and displacement. The primary objective of the RRAP has been to restore and where possible to improve the income and living standards of the affected persons within a short period of time after resettlement with as little disruption as possible in their own economic and social environment. Of the 16000 households, 3600 households needed to be resettled; the rest losts are agricultural land only. All affected households, irrespective of ownership titles, were eligible for compensation as defined by the Entitlement Matrix, which recognizes 14 categories. Affected households/persons have been provided with replacement farm land, compensation for houses, house plots at the resettlement sites and improved infrastructure facilities. Nearly two-thirds of those requiring resettlement have resettled in the pre-existing villages, where additional infrastructure have been provided by JMBA for the host villages. In addition to replacement farmland, a training and income-generation program is conducted for the persons for alternative sources of income and livelihood programs. The poor and female-headed households receive special attention in the training and income generating programs.

Environmental Management Action Plan

An Environmental Impact Assessment (EIA) of the project was an integral part of the project feasibility study. The EIA covered the entire project area as well as its likely environment impact areas. The following special studies were also undertaken to fully understand the environmental impacts of the project:

i) Dhaleswari Mitigation Plan (January 1992)- it is a branch of Jamuna originating near the bridge site.
ii) Land Use Master Plan (January 1992)
iii) Fisheries Impact and Mitigation Study (January 1992)
iv) Wildlife Study (1990-92)
v) Bridge End Planning Integration Study (July 1992)

On the basis of these studies and other exploratory works a framework Environmental Management Action Plan (EMAP) was prepared for the major functional components of which are as follows:

i) Elimination or reduction of adverse impacts.
ii) Off-setting or compensating irreversible and residual adverse impacts.
iii) Maximization of positive impacts.
iv) Monitoring the implementation process.

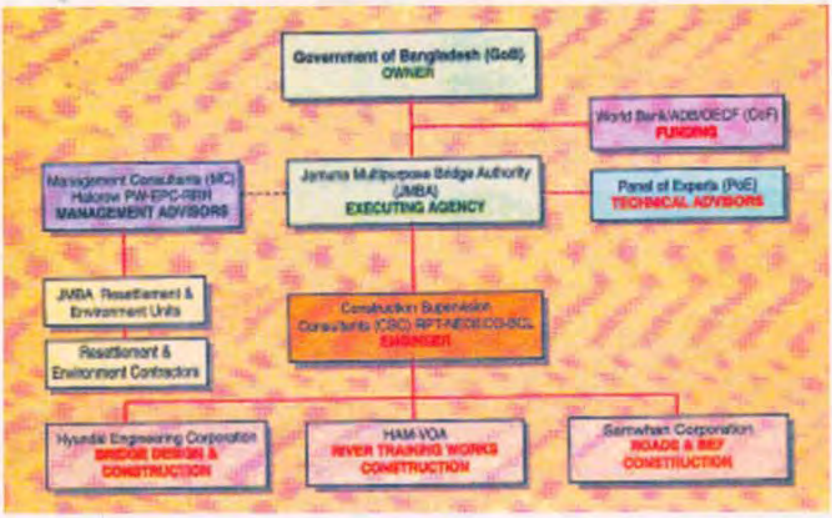
To facilitate implementation and monitoring of EMAP a separate wing called the Environmental Unit (JMBA-EU) was created. Some of the construction related environmental impacts were:

- Dredging and disposal of dredged fill
- Surface drainage disruption
- Water quality deterioration
- Air and noise pollution
- Waste disposal
- Disturbance to wild life
- Health and sanitation hazards
- Destruction of plant and vegetation

These issues were successfully addressed through appropriate components of EMAP. It is mentioned here that NGO's, which include BRAC and Grameen Bank, have played an important role in implementation of EMAP.

Project Implementation

The Jamuna Multipurpose Bridge Project (JMBP) was implemented by the following organogram



Total Project Cost and Funding Arrangements

Project Cost	
Bridge	US$269 million
RTW	US$ 323 million
Roads etc	US$ 71 million
Consultants	US$ 33 million
Land etc	US$ 67 million
Others	US$ 186 million
JMBA	US$ 13 million
Total Project Cost: US$ 962 million	

Funding Arrangement		
GOB	:	US$ 362 million
IDA	:	US$ 200 million
ADB	:	US$200 million
OEFC	:	US$200 million

Conclusion

A long cherished dream of the people of Bangladesh has been achieved through opening of the bridge for traffic on 23 June 1998, when facilities for road, rail and electricity transfer are available. The quality of construction, the programme achieved and budget met give satisfaction to the owner and the co-financiers.

PARTICULARS OF BRIDGES OF LENGTH 300 METER AND ABOVE IN BANGLADESH

Sl. No.	Nmae	Length (m)	Particulars	Cost (Approx.)	Road No.	Chainage	# LRP Name
01.	Jamuna Multipurpose Bridge	4800	Prestressed concrete box girder 47 spans, 99.375m each 2 spans, 64.6875m each	USD 962 million	N405	105	-
02.	Lalon Shah Bridge at Paksey	1786	Prestressed concrete box girder 15 spans, 109.5m each 2 spans, 71.75m each	BDT 106453 lakhs*	N404	70.656	LRP072a
03.	Meghna-Gumti Bridge	1410	Prestressed concrete box girder 15 spans, 87m each 2 spans, 52.5m each	BDT 31300 lakhs*	N1	37.01	LRP037a
04.	Khan Jahan Ali Bridge at Khulna	1360	Prestressed concrete box girder 5 spans, 100m each 2 spans, 70m each and Prestressed concrete girder 24 spans, 30m each	BDT 72415 lakhs*	N709	2.34	LRP002a
05.	Bangladesh-UK Friendship Bridge	1191	7 sspans, 110m each 2 spans, 79.5m each and viaduct 122m at Ashuganj side and 140m at Bhairab side	BDT 80929 lakhs*	N2	71.834	LRP072c
06.	2nd Buriganga Bridge at Babu Bazar	1016	Prestressed concrete girder, Main bridge 304m Flyover 712m	BDT 14861 lakhs*	R820	1.015	LRP001a

** Cost indicates contribution from GOB, # LRP - Location Referencing Point*

PARTICULARS OF BRIDGES OF LENGTH 300 METER AND ABOVE IN BANGLADESH

Sl. No.	Nmae	Length (m)	Particulars	Cost (Approx.)	Road No.	Chainage	# LRP Name
07.	Meghna Bridge	930	Prestressed concrete box girder 9 spans, 87m each 2 spans, 48.5m each 2 spans, 25m each	7387000000 Yen	N1	24.393	LRP024a
08	5th Bangladesh-Chaina Friendship Bridge at Gabkhan	918	Prestressed concrete box girder and prefabricated hollow slab beam	BDT 8196 lakhs	R870	19.917	LRP020c
09.	Hajrath Shah Amanat Bridge at Chittagong	914	Truss with timber deck	BDT 14153 lakhs	N1	238.467	LRP241a
10.	1st Bangladesh-China Friendship Bridge at Postagola	847	Prestressed concrete girder	-	N8	-	-
11.	Dharala Bridge at Kurigram	648	Prestressed concrete girder 15 spans, 43m each	BDT 9750 lakhs	Z5622	3.178	LRP004a
12.	Tora Bridge	646	RCC girder	-	N5	55.866	LRP056c
13.	Doratana Bridge at Begerhat	630.5	Prestressed concrete girder 13 spans, 48.5m each	BDT 3331 lakhs	R770	18.965	LRP019b
14.	Garai Bridge at Kamarkhali	622	Calendar Hamilton Truss with RCC Decking, 7 spans	BDT 2513 lakhs	N7	65.221	LRP064b
15.	Baral Bridge at Baghabari	571.5	Prestressed concrete girder 15 spans, 38.1m each	-	N5	129.616	LRP131a
16.	Dhaleshari Bridge	492.45	Prestressed concrete girder	-	N5	48	LRP049a
17.	4th Bangladesh-China Friendship Bridge at Debiganj	477	Prestressed concrete girder	-	Z5003	-	-
18.	Hazi Shariatullah Bridge	450	Prestressed concrete girder 10 spans, 45m each	BDT 8700 lakhs	N8	-	-
19.	2nd Bangladesh-China Friendship Bridge at Shambuganj	447.19	Prestressed concrete girder	BDT 7864 lakhs	R370	1.433	LRP001c
20.	Old Brammaputra Bridge	428.91	Prestressed concrete girder	-	N2	68.42	LRP069a
21.	Shahid Captain Mohiuddin Jahangir Birsrestha Bridge at Nawabganj	410	Prestressed concrete girder	BDT 4637 lakhs	Z6801	3.066	LRP003b

** Cost indicates contribution from GOB, # LRP - Location Referencing Point*

PARTICULARS OF BRIDGES OF LENGTH 300 METER AND ABOVE IN BANGLADESH

Sl. No.	Nmae	Length (m)	Particulars	Cost (Approx.)	Road No.	Chainage	# LRP Name
22.	Kanchpur Bridge	397	Prestressed concrete girder	-	N1	8.976	LRP008b
23.	Dhalashari Bridge (2)	395.3	Prestressed concrete girder 6 spans, 33.5m each Truss with RCC slab 2 spans. 88m each and 2 end spans, 9.15m each	BDT 3316 lakhs	N8	13.834	LRP013c
24.	Birsrestha Mohiuddin Jahangir Bridge at Doarika	388	Prestressed concrete girder 8 spans, 48.5m each	-	N8	147.561	LRP0148a
25.	Keen Bridge at Sylhet	387	Truss with RCC slab	-	N208	58.496	LRP058b
26.	Subopur Bridge	375	Truss with RCC slab	-	Z1031	32.151	LRP032b
27.	Shahajadpur Bridge	372.84	Prestressed concrete girder 10 spans, 36.6m each	-	Z5410	13.584	LRP013b
28.	Thakurakona Bridge	372	RCC girder	-	R370	50.492	LRP050a
29.	Boleshwar Bridge	336.84	Prestressed concrete girder	BDT 1321 lakhs	Z7709	39.642	LRP039a
30.	Mollahat Bridge	303.21	Prestressed concrete girder 7 spans, 42.67m each	BDT 2355 lakhs	N805	79.403	LRP079a
31.	Shahid Rafiq Bridge	303	Prestressed concrete girder	-	R504	3.165	LRP003a

** Cost indicates contribution from GOB, # LRP - Location Referencing Point*