Bangladesh Group of IABSE

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

IABSE-JSCE Joint Conference on

Advances in Bridge Engineering-III

Towards Owning a Resilient Infrastructure

21 - 22 August, 2015
Dhaka, Bangladesh

VENUE
Pan Pacific Sonargaon Hotel
Dhaka, Bangladesh

www.iabse-bd.org

Centennial Celebration of HARDINGE BRIDGE

Background

Flood plains of the Ganges, the Brahmaputra-Jamuna, and the Meghna rivers in the basin south to the Himalaya are the home of more than 600 million people of South Asia . In this alluvial deltaic formation, numerous short-medium and a few remarkable long bridges are recognized to be the important fixed links for offering an uninterrupted surface communication infrastructure. All the major cities of this region are to own a planned flyover and expressway networks to further improve the efficiency of countrywide surface corridors. Apart from design, construction and operation aspects; strengthening, repair and maintenance of all these large hardware are coming up as mammoth challenges of time to keep the lifeline resilient against service deterioration and natural calamities.

The 17th century 52.7m Masonry Bridge built over the Mir Kadim Canal , Munshigonj , Bangladesh still remains in service for pedestrian and small vehicles. It also gets well recognition as a valuable archeological artifact. The 1.64 km Hardinge Bridge, one of the largest and oldest railway bridges in this region even of today built over the lower Ganges (now known as the Padma), opened in 4th March 1915 gave uninterrupted broad gauge rail connectivity between Darjeeling and Calcutta for the then Eastern Bengal State Railway. It will complete its 100 year of successful service history in 2015 but has to serve even beyond in future.

United Nations Economic and Social Commission for Asia and the Pacific (UN ESCAP) recognized the best possibility for Bangladesh to contribute in bridging the Asia with Europe through the proposed Asian Highway and Trans Asian Railway Network. AH1, AH2 and AH41 will be the three most important routes of Asian Highway passing through Bangladesh at the south of the Himalaya to facilitate farthest East (Japan) to farthest West (boarder to Europe) surface connectivity. A recent study financed by the Asian Development Bank (ADB) identifies the necessity to strengthen the bridge link over the Padma at Hardinge Point to facilitate heavy rail movements for future regional and sub-regional connectivity. The 4.8 km Bangabandhu Bridge (AH2) over the Jamuna is now under a large scale strengthening scheme as several studies reached a unified conclusion about the structural inadequacy of its as-built system under present traffic and environmental loads. The Meghna Bridge and the Meghna-Gumti Bridge on the N1 corridor (AH 41) underwent emergency repair works recently but can only be strengthened when the Japan International Cooperation Agency (JICA) financed second bridges on this corridor are built. Proposed Padma Bridge (AH1), Jamuna Rail Link (AH2), 2nd Meghna (AH41), 2nd Meghna-Gumti (AH41), 2nd Kanchpur Bridges (AH41), Bhairab Rail Link (AH41) and a large number of small-medium length bridges under JICA financed East Bangladesh and West Bangladesh Bridge Improvement Projects will largely improve future connectivity in this region if the present bridges also effectively remain in service. UN ESCAP recognized the massive demand for investment in the transport sector in Asian regions in terms of infrastructure and services as well as maintenance. Bangladesh is among the countries that are constrained by limited budgets and borrowing capacity. This certainly urges the need for a proper management capability of the existing infrastructure not only through time-bound repair and maintenance schemes but also to undertake strengthening schemes to coup with the next generation demands.

Organization and Objectives

Japan Society of Civil Engineers, represented by the Committee of Steel Structures well supported the activities in Bangladesh since 2005 to develop, nourish and culture the discipline of bridge engineering with a view to understanding this rapidly developing society that in the past has well demonstrated for many times the inherent capabilities to recover quickly from large natural disasters. Scholarly discussions were initiated to identify the areas where technical breakthroughs are very much required for future needs and also to identify the areas that can be focused for transfer of appropriate technology. A consensus was reached on the necessities of exchanging ideas through International Events at a regular interval for well founding the knowledgebase and transferring technologies. In this line, Advances in Bridge Engineering-I, the first ever conference in Bridge Engineering in Bangladesh was organized in 2005 with 14 contributions, 5 from Japan and the rest from Bangladesh. Steel and composite constructions were given the special theme for that event. In 2010, after a five year interval, the Advances in Bridge Engineering-II was organized in close collaboration with Committee of Steel Structures, JSCE. IABSE, Switzerland was the other key partner. Six keynote addresses supported by 56 technical papers (13 papers from Japan) from specialists working in 11 countries made the event successful. Bearings, expansion joints, base isolation system and shock transmission units were given the special attention in theme for that event.

The 2015 event, at the five year interval is the next proposed one. This time it falls with the Centennial Celebration of the Hardinge Bridge . This sprits the idea of giving special attention to strengthening, repair and maintenance of the bridge for a owning a resilient infrastructure in the Asian region. The experts from Japan , Europe, Oceania and the neighboring countries are expected to provide in-depth deliberations on bridge forms, architecture, aerodynamic design, vibration and serviceability requirements but giving some attention also to the conference theme. In order to enhance regional cooperation, the conference aims to generate further discussions on the necessity and format of a unified Bridge Code for the Asian countries. It is important to know each others, the technological know-hows, potentials and also the social needs!

Scope

History and Planning
Historic bridges
Architecture and aesthetics
Geometric design of bridge, approach roads and viaducts

Materials and Construction
Materials
Codes on bridge engineering
Methods for analysis
Composite bridges
Construction sequence, phases, technology

Design for Dynamic Forces
Protection from earthquake
Base Isolation Technique
Bearings and expansion joints
Bridge dynamics, vibration control, aerodynamics
Design of shock transmission units

Geo-environmental Issues
Geotechnical aspects
River training works
Bridge hydraulics
Environmental issues

Administration and Monitoring
Bridge Administration
Bridge health monitoring
Instrumentation and field observations
Serviceability issues

Repair, Renovation and Retrofitting
Repair, maintenance and retrofitting of bridge elements
Repair and replacement of bearings and expansion joints

IABSE

Message from the President of IABSE

On behalf of IABSE, the International Association for Bridge and Structural Engineering, I warmly welcome you to this, the 3rd Joint IABSE-JSCE conference on Advances in Bridge Engineering. In doing this I would also like to congratulate the Bangladesh Group of IABSE on this joint initiative with the Japan Society of Civil Engineers and our other organisers, co-organisers and sponsors.

We know that the Indian subcontinent has been connected to the rest of the world from time immemorial and that a major feature of this has been travel. Bridges facilitate travel and a particularly important aspect in this region was the construction of several important bridges starting in the 17th century. However, the construction of the steel truss Hardinge Bridge during the time of 'British India' exactly one hundred years ago marked a major shift in ambition. Now that bridge celebrates its centenary, standing as a testament to the skill of our predecessors, it exemplifies the concept of resilience in structures that has, very much, come to the fore of late. How do we design resilient structures? How do we build resilience into our structures? These are comments that are frequently heard nowadays. Well, one answer is to learn from the past, to look at what has survived and to adapt and develop these concepts with the materials, know-how and equipment available to us today.

Bangladesh is a country dominated by the flood plains of its three mythic rivers. Until 1998 the country was effectively divided in two by the Jamuna river. Thus bridges are particularly important to the people of Bangladesh since they open up all manner of new opportunities. The construction of the Padma Bridge will provide further connectivity to the region.

But designing and building bridges calls for skill, ingenuity and tenacity - even more so when conditions are harsh and the environment is difficult. Producing solutions that accord with the functional demands, the expectations for elegance and the realities of the political and economic climate necessitates a careful balancing of often conflicting constraints so that the most appropriate solution emerges. There is, thus, all the more reason to ensure that what is built is suitable - both now and going forward - and that it continues to function for at least its designated life. Maintenance and durability are, therefore, just as important as strength and the initial construction programme and should feature in the thinking from the outset.

The aims of this conference accord very closely with the objectives of IABSE to promote a worldwide exchange of structural engineering knowledge, to identify present and future needs and to work towards meeting these, to encourage innovation and progress within structural engineering and to celebrate major achievements worldwide.

I wish every one of you a wonderful conference, with interesting and informative technical sessions, plentiful opportunities to meet with old friends and to make new friendships and that 'je ne sais quoi' feeling that results from a few days immersed in a technical gathering that is also an enjoyable experience. I am sure that you will find this here in Dhaka over the next few days.

David Nethercot
President of IABSE

Bangladesh Group of IABSE

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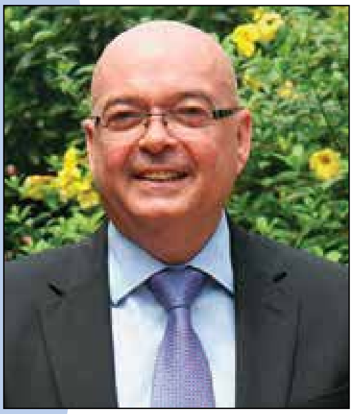
Message from the President of Japan Society of Civil Engineers

On behalf of Japan Society of Civil Engineers, it is my pleasure to welcome you at the third IABSE-JSCE Joint Conference on Advances in Bridge Engineering (ABE-III). The main theme of this conference is "Towards owing a resilient infrastructure". "Resilience" that is the ability to recover immediately from a disaster, such as an earthquake and flood, becomes more important for sustainable development for not only Bangladesh but also for the Asia-Pacific region. It is very clear that bridges are the vital key infrastructures to communicate and also to feed necessary information and commodities for post-disaster recovery.

The first joint conference on bridge engineering was held in 2005 by the Committee of Steel Structures, JSCE and the associated stakeholders in Bangladesh. Furthermore, the second conference ABE-II convened in 2010 in close association with Bangladesh Group of IABSE and JSCE. And now the third conference ABE-III will be held in a more international context. I sincerely hope that this joint conference will serve as a platform for improving relationships and cooperation among the individuals and organizations from Bangladesh, Japan and all other participating countries.

Finally, I want to thank all local organizers together with JICA Bangladesh Office for their dedication and support towards ABE-III.

Noriaki Hirose
President
Japan Society of Civil Engineers



British
High Commission
Dhaka

Message from the British High Commissioner Dhaka

It is my pleasure to offer my best wishes to the International Conference on Advance in Bridge Engineering-III, jointly organised by International Association of Bridge and Structural Engineering (IABSE), Japan Society of Civil Engineers (JSCE). The Institution of Civil Engineers (UK) is supporting the event as the first Co-organiser.

This year the conference celebrates the centennial of the Hardinge Railway Bridge. It is one of the largest and oldest railway bridges in this region built over the lower Ganges (now known as the Padma). Opened in 4th March 1915 it gave uninterrupted broad gauge rail connectivity between Darjeeling and Calcutta for the then Eastern Bengal State Railway. Designed by British Consultants- Rendel Palmer and Tritton and named after Lord Hardinge the then Viceroy of India, the 1.8 kilometre steel structure was innovative in its design and even today after been badly damaged during the Liberation War, it is still the main railway artery to this part of Bangladesh.

Over the years support from Britain and many other countries have been instrumental in developing infrastructure which is so vital to Bangladesh. That's why I applaud the initiative to consider a unifying Bridge Code for all Asian countries. With an interconnected Asian region, bridges such as these become ever more important for trade, as well as connecting countries. This conference is not only an opportunity to celebrate the past but exchange ideas and expertise for what is being planned for the future in this region.

I warmly congratulate everyone associated with the conference and wish you every success of the event.

Robert W Gibson
HE Mr Robert Winnington Gibson CMG
British High Commissioner to the People's Republic of Bangladesh

Message of Chief Representative

On behalf of JICA Bangladesh Office, I warmly congratulate the Bangladesh Group of International Association for Bridge and Structural Engineering (IABSE) and Japan Society of Civil Engineers (JSCE) for organizing Joint IABSE-JSCE conference on Advances in Bridge Engineering-III. In doing this I would also like to congratulate other organisers, co-organisers and sponsors. JICA is very much happy to be with this event that also marks the Centennial Celebration of Hardinge Bridge (1915-2015), one of the most historic bridges in South Asia.

As I have known, the IABSE is the largest professional body of bridge and structural engineers in the world with members in 100 countries and 48 National Groups worldwide. Since 2005, the JSCE is also actively supporting the nourishment of Bridge Engineering Discipline in Bangladesh at a regular interval of five years.

As the largest bi-lateral development partner of Bangladesh, Japan has been providing official development assistance to Bangladesh for economic growth and poverty reduction since the establishment of diplomatic relations between the two countries in 1972. JICA has long been assisting Bangladesh by connecting the national road transportation network by constructing five large bridges, namely Jamuna, Paksey, Rupsha, Meghna and Gumti, as well as about five hundred of medium and small bridges across the country. These Bridges have enormous impacts on the overall economic development and reducing poverties for the people of Bangladesh. JICA has also been providing technical cooperation to enhance the technical capacity of Roads and Highways Department for bridge construction and maintenance.

As I have learnt, the conference focuses its attention on strengthening, repair and maintenance of bridges leading to a resilient infrastructure in the Asian region. The concept coincides very well with the objectives of JICA to help development of sustainable infrastructure in the partner countries.

As a co-organizer of the conference, I welcome all the participants of Bangladesh and abroad to this conference. We hope, this conference will be a landmark event in Bangladesh towards stepping up of nourishment, culture and transfer of appropriate technology in Bridge Engineering.

Mikio Hataeda
Chief Representative
JICA Bangladesh Office

ice
Institution of Civil Engineer

Message from the ICE President

I am delighted to know that Bangladesh is hosting yet another international conference – this time on ' Advances in Bridge Engineering'. The ICE is pleased to be associated with this event as one of its sponsors. I note that the timing of the conference coincides with the centenary of the completion of the Hardinge Bridge which is one of the lasting contributions made by British engineers in Bangladesh.

The subject of the conference could not be more relevant considering that Bangladesh with its numerous rivers and drainage channels in low lying deltaic region has a huge need for bridges. I am proud and happy to note that members of the ICE have and continue to make significant contribution in development of the country's bridge stock including construction supervision of the longest bridge - the Jamuna Multi-purpose Bridge.

The organisers must be very pleased that so many technical papers have been received from around the world including the key note paper written from the UK. I am sure the participants stand to gain a great deal during the deliberations of the conference. On behalf of the ICE I congratulate the organisers for this undertaking and wish them every success.

Bangladesh Group of IABSE

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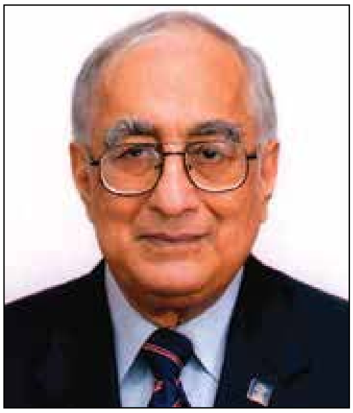


Bangladesh Group of IABSE

Message for Souvenir

I am very happy to note that the IABSE Bangladesh Chapter and Japan Society of Civil Engineers are jointly organizing an International Conference on Advances in Bridge Engineering in Dhaka from 21-23 August, 2015. The support of the Institution of Engineers, Bangladesh, Institution of Civil Engineers (UK) ICE Centre Bangladesh, American Society of Civil Engineers (Bangladesh International Section), Japan Concrete Institute and Japan Prestressed Concrete Institute, who are the Co-organizers of this conference, has helped in making this conference truly "International".

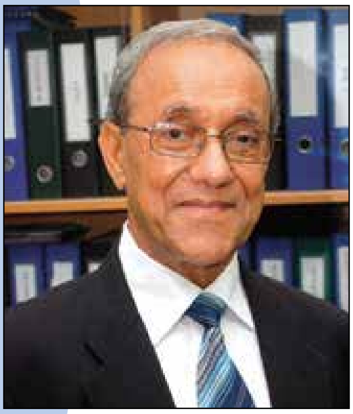
We are grateful for the support from Japan International Cooperation Agency, all the major departments and agencies of the Government of Bangladesh involved in bridge-building, viz. Roads and Highways Department, Bangladesh Railway, Bangladesh Bridge Authority and Local Government Engineering Department as well from Bangladesh University of Engineering and Technology and University of Asia Pacific. Without the financial support from various sponsors, it would not have been possible to organize this conference – we are grateful to them.

This conference, the third in the series of conferences on bridge engineering being held every five years starting from 2005, coincides with the centenary of the Hardinge Bridge. When the 1.64 km long bridge over Padma (Lower Ganges) carrying dual track broad gauge railway line was commissioned in 1915, it was considered to be one of the greatest engineering achievements. New solutions in the form of guide bunds were developed for river training works. The bridge has performed remarkably well over the last one hundred years and continues to provide a vital railway link connecting south western part of the country with northern and eastern part. We are happy that a number of papers dealing with the design and construction of this historic bridge and the restoration after it was damaged during the War of Liberation of Bangladesh in 1971 are being presented in this conference.

Building a surface communication infrastructure in Bangladesh, a country criss-crossed by hundreds of rivers, some of which are up to ten kilometres in width carrying vary large flows, poses a big challenge for engineers. The problem is exacerbated by soft alluvial soils which erode very easily. However, over the last few decades hundreds of bridges have been constructed with only a few major rivers left to be bridged. Hopefully, when these missing links are constructed eliminating the need for traditional dependence on ferries, Bangladesh will emerge as a major regional hub of the Asian Highway and Trans-Asian Railway network connecting South Asia with South East Asia and East Asia. The large number of papers which are going to be presented and discussed in the conference dealing with some of the latest advances in design, construction, repair and maintenance of bridges will contribute significantly in improving the knowledge base of engineers not only from Bangladesh, but also from other countries.

On behalf of the Steering Committee, it is my pleasure to welcome all the participants to the conference. 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 among engineers from different countries interested in bridge engineering.

Professor (Dr. Engr.) Jamilur Reza Choudhury
Convener, Steering Committee of the Conference



Bangladesh Group of IABSE

Message from the Bangladesh Group of IABSE

It is our immense pleasure and great honour for arranging and host the IABSE-JSCE conference on Advances in Bridge Engineering is being organized jointly by Bangladesh Group of International Association of Bridge IABSE and Japan Society of Civil Engineers JSCE on 21-22 August, 2015 at Pan Pacific Sonargaon Hotel, Dhaka, Bangladesh. The event is linked with the centenary celebration of the Hardinge Bridge over the river Ganges at Paksey, Bangladesh (1915-2015). The received papers on the conference theme are written by the international and national authors and those are overwhelmingly rich.

We are also congratulate from the bottom of our heart to the co-organizers of the conference are the Institution of Civil Engineers ICE, UK, represented by ICE Centre Bangladesh, the American Society of Civil Engineers ASCE, represented by its Bangladesh International Section, the Institution of Engineers Bangladesh IEB, Japan Concrete Institute JCI, and Japan Prestressed Concrete Institute JPCI. Japan Cooperation Agency (JICA), Roads and Highways Department RHD of Bangladesh, Bangladesh Railway BR, Bangladesh Bridge Authority BBA, Local Government Engineering Department LGED, Bangladesh University of Engineering & Technology BUET, Bangladesh Association of Construction Industry BACI, Bangladesh Association of Consulting Engineers BACE, University of Asia Pacific UAP, Ahsanullah University of Science & Technology AUST, Military Institute of Science & Technology MIST, and the Construction Supervision Consultant CSC of Padma Multipurpose Bridge Project PMBP represented by its Chief Coordinator on behalf of Bangladesh Army. Their co-operation makes the conference a successful one and we express our deep gratitude to them. At the same time we also acknowledge and recognize the contributions of our sponsors, Host Sponsor, BSRM; two platinum sponsors, Seven Rings Cement; and Basundhara Cement. There are other sponsors and we are very much thankful to them all. In this conference we have subsidize the registration fee for the young professionals and member of IABSE Bangladesh Group and we are hope full that the objective of the conference could be achieved.

We are thankful to the Steering Committee, Organizing Committee, Scientific and Technical Committee and International Advisory Committee members, the valued participants, numerous volunteers, electronic and print media, the event management team of i-Creation, the Sonargaon Hotel management and others for their generous support in different forms. We will feel deep satisfaction if the conference is found beneficial to the delegates.

M. A. Sobhan, PEng CEng FICE
Chair, Bangladesh Group of IABSE &
Convener, Organizing Committee of the Conference

We were together in 2005

Advances in Bridge Engineering-I






YEAR 2004


We were together also in 2010

Advances in Bridge Engineering-II


RESERVED


Advances in Bridge Engineering-II


Advances in Bridge Engineering-II


Advances in Bridge Engineering-II


Advances in Bridge Engineering-II

Program at a Glance

21 August 2015, Friday

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<tr><td>Parallel Session 3</td><td>Design and Construction</td></tr>
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22 August 2015, Saturday

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Room: Ball Room I

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HARDINGE BRIDGE

Engineering Challenges & Success of 100 Years

Compiled by
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Inception

The East Indian Railway (EIR) and the Great Indian Peninsular Railway (GIPR) were founded in the mid 1840, with the object of building the first experimental railways in India, these to be based upon Calcutta and Bombay respectively. In 1862, the first railway link between Calcutta and Khustia was established in Bengal by East Bengal Railway EBR. It was extended from Poradaha, Khustia to Vheramara in 1878. The extension of railway link after Vheramara stopped due to the presence of mighty River, the Padma, the lower reach of the Ganges. The Padma is below the point of the off-take of the Bhagirathi River (India) while another Ganges River distributary is also known as the Hooghly River. Padma is a major river in Bangladesh. It is the main natural distributary of the Ganges, flowing generally southeast for 120 km to its confluence with the Meghna River near the Bay of Bengal. However, it was necessary to cross the river for transportation of agricultural products, goods and passengers. After the establishment of meter gauge railway link between North Bengal and Shiliguri by North Bengal Railway NBR in 1880 a ferry service was introduce at Damukdia-Rayta of Vheramara and Sara Ghat of Ishwardee to cross the river.

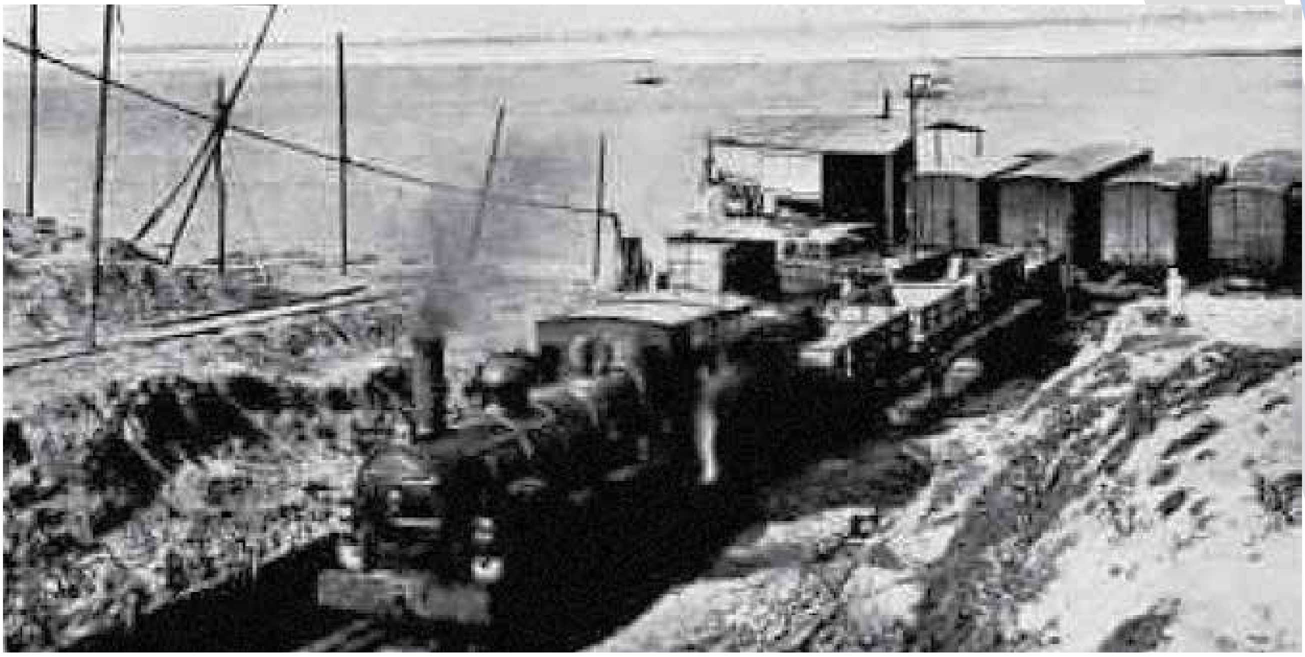

Photo 1. Pre-construction time photograph illustrating the loading of wagons on ferry to cross the river. Image from Internet.

Although it was possible to cross the river by ferry service but it was cumbersome and time consuming. So it was felt to build a railway bridge over the river Padma to provide a fixed link. It was also thought that if a bridge is built then both the railway company would be benefitted by carrying increased passenger, goods and as well as it would be financially feasible. Construction of a railway bridge over the mighty river Padma required huge amount of money and that was not possible to arrange by the two railway companies. By this time Government of British India was planning to build a bridge. Finally manager of EBR Major GF Boughe in 1889 had made a proposal to the Chief Engineer PWD for the construction of a bridge. In his proposal he explained the necessity of constructing a tunnel or bridge crossing between Damukdia and Sara across the Padma river but he did not recommend bridge or tunnel options. He mainly explained the economic and financial benefit of the project.

Planning, Design and Construction

The construction of the Hardinge Bridge was proposed and discussed for more than twenty years before it was finally get sanctioned for construction in 1908. Proposals put forward by the then Eastern Bengal Railway EBR in 1889, were investigated by a committee and reported that it would be feasible. There were many discussions as to the selecting site of the bridge. In 1907, a committee representing commercial interests recommended one of the 'Sara' sites which had been favored by Sir FJE Spring. A technical committee reported that a bridge could be constructed at Sara crossing the lower Ganges between the Paksey and Bheramara Upazila stations on the broad gauge railway from Khulna to Parbatipur Upazila. A detailed plan for the bridge was drawn up in 1902 by Sir FJE Spring, and once the permission was given for the construction of a railway bridge to be built and a committee was formed in 1908 to oversee the project. Sir Robert Gales from Britain joined the project as the Engineer-in-Chief. This proposal was passed in 1908. The commissioning of the Hardinge Bridge was authorized in 1908 and in 1910 construction of the bridge begun. In 1909 field survey started. The construction of the bridge started in 1910 and the bridge was opened in 1915. On the 1st of January 1915, the first trial train crossed the bridge down track and on 25 February of the same year the second trial train crossed the bridge on the up track. Finally on 4 March 1915 Lord Hardinge inaugurated the bridge. A total of 24,000 people were employed for constructing the bridge. The construction of the Hardinge Bridge also benefited the local population, as it provided jobs for twenty-four thousand people during the construction time.

The Bridge

Hardinge Bridge is the second longest, 1.64 km Railway Bridge in Bangladesh. It has additional 77 m long land spans at each of the ends giving a total length of 1.8 km. Each of its fifteen river spans are 109.5 m in length. Some Railway Bridges across the Upper Ganges River and Indus valley was constructed around 1900's did have longer river spans. However, in terms of total length, it was the second longest at the time of construction. At the time of conceiving the Hardinge Bridge project, the foundation on soft soil and meandering character of the Ganges in the construction location the recent past were of great concerns for the designers. Falling apron technique was used for river training.

As the foundation was of concern, the river spans were founded on caissons that were the deepest at that time, 49 m below the lowest water level. All joints of the steel truss were riveted. 10.5 m high trestles were anchored on the pier top using anchor bolts. 1.7 m high steel bearings (fixed and expansion type) resting on the top of trestle platform supports the main truss girders. The bottom of the main truss was thus placed 12.2 m above the caisson top. It consists of sixteen piers and the piers are all on extreamly deep well foundation. Well foundations of this bridge are sunk at a depth of 150 to 160 ft (45.73 m – 48.78 m) below the low-water level. That was the deepest bridge foundation in that region, because of the deep scouring nature of the river bed in high discharge condition. The wells are of precast concrete block in a double D shaped 63 ft X 37ft (19.20 m X 11.28 m) overall size with two dredging holes of 18.5 ft (5.64 m) in diameter.

It took three yeras to complete the sinking of the wells. In the first season five wells, in the second seven and in the third four wells had been sunk.

In the evening of 7 April 1888, a devastating tornado hit Dhaka city causing great damage. Ahsan Manjil was severely damaged and abandoned. An English engineer from Kolkata arrived here to examine the palace. At the time of the reconstruction, the present beautiful dome was erected over the palace building. Again Ahsan Manzil was partly damaged by the earthquake of 12 June 1897 but the dome was not damaged. However, Nawab Ahsanullah had it repaired again. A wind storm of 17th October 1909 right at the bridge site, immediately before the start of construction work raised additional concerns for the designers. This finally led to realization of a double track steel truss rail bridge of Pensylvennia-Patit (pratt) form for the fifteen river spans. English Engineers were aware of this region that the wind force plays a significant role on structural design. So the designers changed the design of steel truss. They changed single lane railway bridge to double lane railway bridge in an immediate decision. To reduce wind effect, depth of truss was kept minimum and petit truss was used.

The Pennsylvania truss, like the Baltimore truss sometimes referred to as a "petit," was developed by engineers of the Pennsylvania Railroad in 1875. The Pennsylvania truss (along with the Baltimore truss) was the product of two of the early eastern trunk line railroads developed during the 1870s for heavy locomotives. This truss is similar to the Baltimore truss in that it has sub-divided panels, but it also has a polygonal or inclined top chord. As with the Baltimore truss, the Pennsylvania truss was originally developed for use in relatively long span railroad bridges, but became a common type for shorter span lengths. The truss was adapted for highway use as early as the 1880s. For economy the truss, depth is ideally set at a fixed proportion of the span. As the span increases the truss depth and bay width increase accordingly. The bay width is usually fixed by providing truss nodes on the centre lines of the deck cross beams, thus avoiding high local bending stress in the deck chord. For large-span bridges with an economical spacing for the deck cross-beams, the height of the truss may be as much as four times the bay width. In such a case, a subdivided form of truss will be required to avoid very long uneconomical compression web members, or tensile members subjected to load reversal due to moving live loads. The diamond and Petit trusses have the advantage of achieving shorter diagonals than the K-truss in design.

The bridge itself was constructed out of fifteen petit trusses that were prefabricated. Concrete was used to build the sixteen piers that keep the bridge above water, while the structures above water were constructed out of steel. The broad gauge lines are laid side by side with a separate footpath on the downstream side. Two high-tension electric lines at upstream and downstream sides of the bridge were erected later on, but not were in the original design. The headroom of the bridge is rested by the structural frame up giving a 4.45 m clear passage way from the floor level.


Photo 2. Hardinge Bridge today. Images by: A.F.M.S. Amin

The superstructure of Hardinge Bridge took a final shape using mild steel. The original steel of Hardinge Bridge is of mild steel type equivalent to grade 43 of BS 4360 having yield stress of 20.8 tons/sq inch; ultimate tensile strength of 30.6 tons/sq inch at an elongation of 23%. The original design loading for the girders was Indian Railway broad gauge B of 1903+33% with an impact allowance giving a total live load of 1927 tons on two tracks. Weight of each petit truss is 1250 ton. The design was as the then standard laid down by in the Government of India Bridges Rule 1903. With these design loads the stresses allowed on the members were 125 MPa (8 ton/sq in) in tension and 105 MPa (6.8 ton/sq in) in compression in main members with l/r up to 26.8. The impacted live load values adopted in the original design compare favorably with similar value used in the latest BG ML standard of loading now in use in sub-continent. The changes are more in the horizontal forces. The complete steel work of the original construction was fabricated in the workshops of Cleveland Bridge and Engineering Co. Limited and Braithwaite & Kirk Co. Ltd in United Kingdom.

Challenges from Nature

The Bridge, built with extreme caution against any breach by the turbulent flows of the river in those days, met with a serious threat on its existence during the late floods on 25th September, 1933. A breach of 120 m occurred first in the right guide bank at the Bheramara end. The breach eventually extended to 480 m on 7th October, despite day and night work by engineers and workmen, whose services were requisitioned as an emergency measure. Rehabilitation work required 2 years of intense activity.

Photo 3. Bherama end of the Hardinge Bridge today showing siltation but no erosion. Images by: A.F.M.S. Amin

Damage in the Liberation War of Bangladesh in 1971

During the war of liberation the twelfth span of the Hardinge Bridge broke down into the river by shelling. One end of the span was hanging dangerously with the base and a 12.2 m part from the other end collapsed. Down stream side bottom chord at the mid span of Span 9 was partially blown off. Pier 2 was also damaged. After the liberation, the bridge was reopened on 12 October 1972, after salvaging the fallen Span 12 and emergency repair for Span 9 and 12. The repair and restoration works were conducted jointly by Bangladesh Railway and the Eastern India Railway of India. The Span 12 fallen in the river was salvaged by Selco, a company from Singapore engaged by United Kingdom. Span 9 was lifted and bottom chord and adjoining damaged members were repaired and replaced. Span 12 was temporarily replaced by a single track span. In the second phase, the bridge was brought back to its original shape of petit truss and was reopened on 4th August 1975. The work was conducted by the Bangladesh Railway and Eastern India Railway of India. The new double track truss for Span 12 was manufactured in Kolkata.

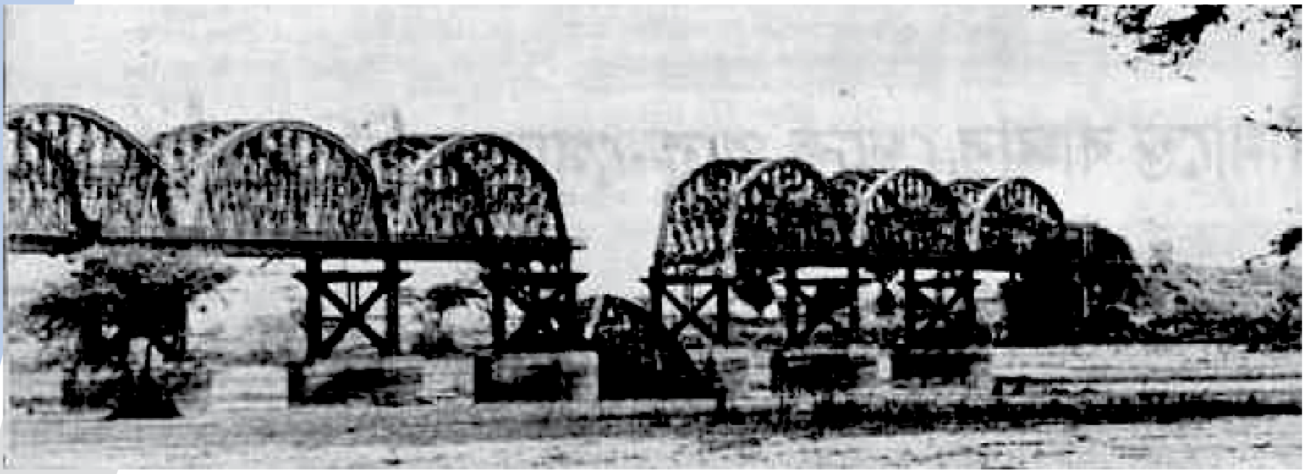

Photo 4. The photograph of Hardinge Bridge showing the fallen Span 12. Image from Internet

Photos 5-10. The photographs depict the repair work of Span 9 and Span 12 after 1971 war damage. Images by A.F.M.S. Amin.

Diversified Use

A high-tension electric line is passed over upstream side of the bridge. It was 132 kV double circuit transmission line added in in 1960s. It was bracketed of from the upstream trusses. For this addition Rendel Palmer and Tritton, London the consulting Engineers made a detail analysis of stress condition of the broad gauge train line with standard loading. This showed that the axial and combined stresses were within the original permissible stresses. The permissible stresses meanwhile had been increased in BS 153 to 140 MPa (9.0 ton/in^2). Another transmission line was also installed in the downstream side of the bridge later on.

Photos 11-12. Hardinge Bridge with High Tension Transmission Line. The repair of Pier 2 by confining is also visible in left figure. Top chord bracing of the repaired span 12 is seen in the left with electric transmission lines both upstream and down stream are seen. Images by: A.F.M.S. Amin

With the help of Asian Development Bank ADB and United Nations Development Program UNDP Roads and Highways Department RHD has made First Road Master Plan in 1991. In this master plan there was a proposal to convert Hardinge Rail Bridge in to rail cum Road Bridge by renovating the deck so that light and heavy vehicles can also use it. This master plan was supposed to be implemented by 2001. In reality a four separate lane road bridge (Lalon Shah Bridge) was completed and opened for traffic in 2004 with financial assistance from Japan.

Concluding Remarks

The Hardinge Bridge is now a part of the society. The river and the bridge attract people from home and abroad. Due to the change of geo-political boundary of the country after independence from Great Britain in 1947, the bridge lost its importance as the transit route to Kolkata for which it was initially designed. Thus, in 100 years, the bridge was not subjected to the projected traffic needs. The absence of rail link over the Jamuna effectively divided the country for a long time. This also decreased its importance. However, rail traffic on the bridge is now steadily increasing after the opening of Bangabandhu Jamuna Bridge and train connectivity with Kolkata. At this moment, a separate rail link over the Jamuna is under evaluation. Once completed, the train speed will gradually increase. This may need further evaluation of the capacity of the Hardinge bridge to fit for meeting the demand of the next generation. In the present Bangladesh Inland Water Transport Authority (BIWTA) classification, the bridge falls in Class II for its vertical navigational clearance. This may also bring some hinders in future. The Padma river at Hardinge point now also flows not like that were in the past. Thus the threat for bank erosion and scour no longer exist. No study has yet been conducted against its earthquake protection as it was not considered in the original design.

However, even after realizing any rail link alternate to Hardinge Bridge, the bridge shall remain at the center of the society for its historical importance, aesthetic look and the service it provided to the people of this land over a period of over 10 decades equating to 100 years!

Comparison of Static and Dynamic Load Analysis*

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INTRODUCTION

In the last half of the '90s, pile integrity test was introduced in Bangladesh to test the piles. The test is based on the Stress Wave Theory. At the beginning, it was termed as Sonic Integrity Test (SIT), as a parameter for control quality of foundations. Afterwards, it was improved to emerge as Dynamic Load Test (DLT) in order to measure the pile-soil behavior. However, up to then, the bearing capacity of a piled foundation was determined with a Static Load Test (SLT, ASTM D 1143-81). As we all know, in spite the familiarity SLT is costly in respect of time, space and money. During these years, where Quality Assurance (QA) started to play an important role in the Bangladeshi construction market, as well as the increment in service loads, an increase in the demand for verifying piling works was felt in the construction industry. As well, the availability of new technology in construction methods, tighter schedules for finishing site works and limited space, inspired the DLT to be introduced as an alternative to the cumbersome static test.

In this write-up, correlations between Dynamic and Static Load Tests performed on the same pile are shown. To do this, relevant geotechnical information as available in a project was used to derive the conclusions.

SOIL PROFILE AND TEST PILE

Figure 1 shows the soil profile of the test site as found in a Standard Penetration Test. Pilcon Rotary Machine and the ground conditions are described in the following geotechnical profile (Figure 1). The Energy of SPT Hammer was calibrated. To derive the comparisons of Static and Dynamic Load Analysis, two test piles located in Bangladesh Road Research Laboratory were used. Each of the piles were cast-in-situ bored pile of 1 m diameter and 30 m in length. Bentonite mud was used to protect the bore hole. Pile construction was done by Conventional Boring Machine. During Construction of Pile Crosshole Sonic logging pipe were installed from top of the pile to the bottom.

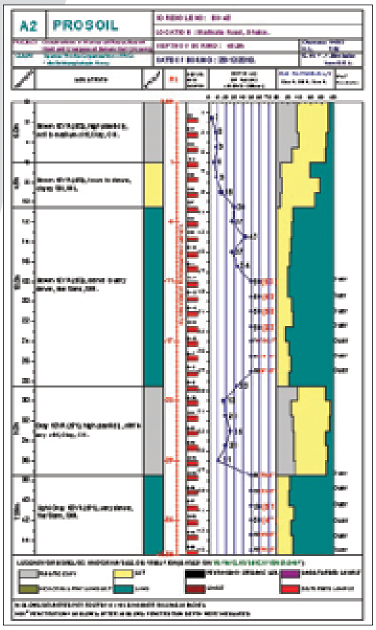


Fig 1. Geotechnical Profile

Fig 2. Advancing of Boring

* A sponsored publication

VERIFICATION OF CONCRETE QUALITY

Figures 4 and 5 show the response from pile integrity test (PIT) for the test piles. The cross hole sonic logging test results are shown in Figures 6 and 7 for Pile # 1 and 2, respectively.

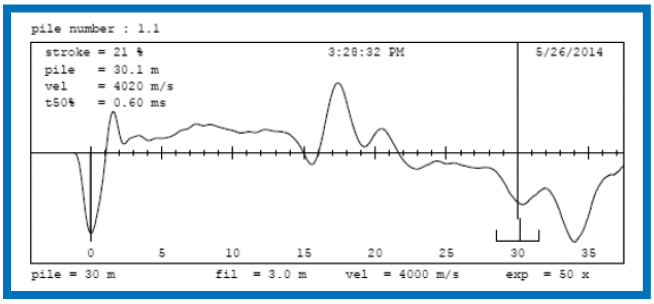


Fig 3. PIT of Pile#1

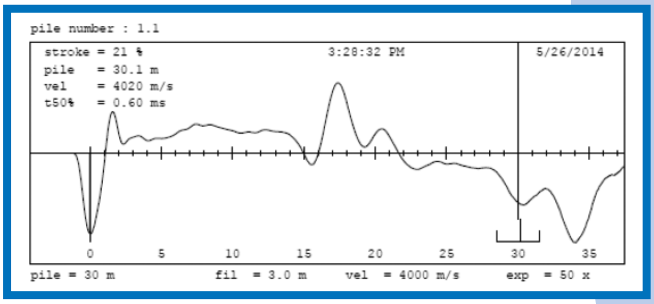


Fig 4. PIT of Pile#2

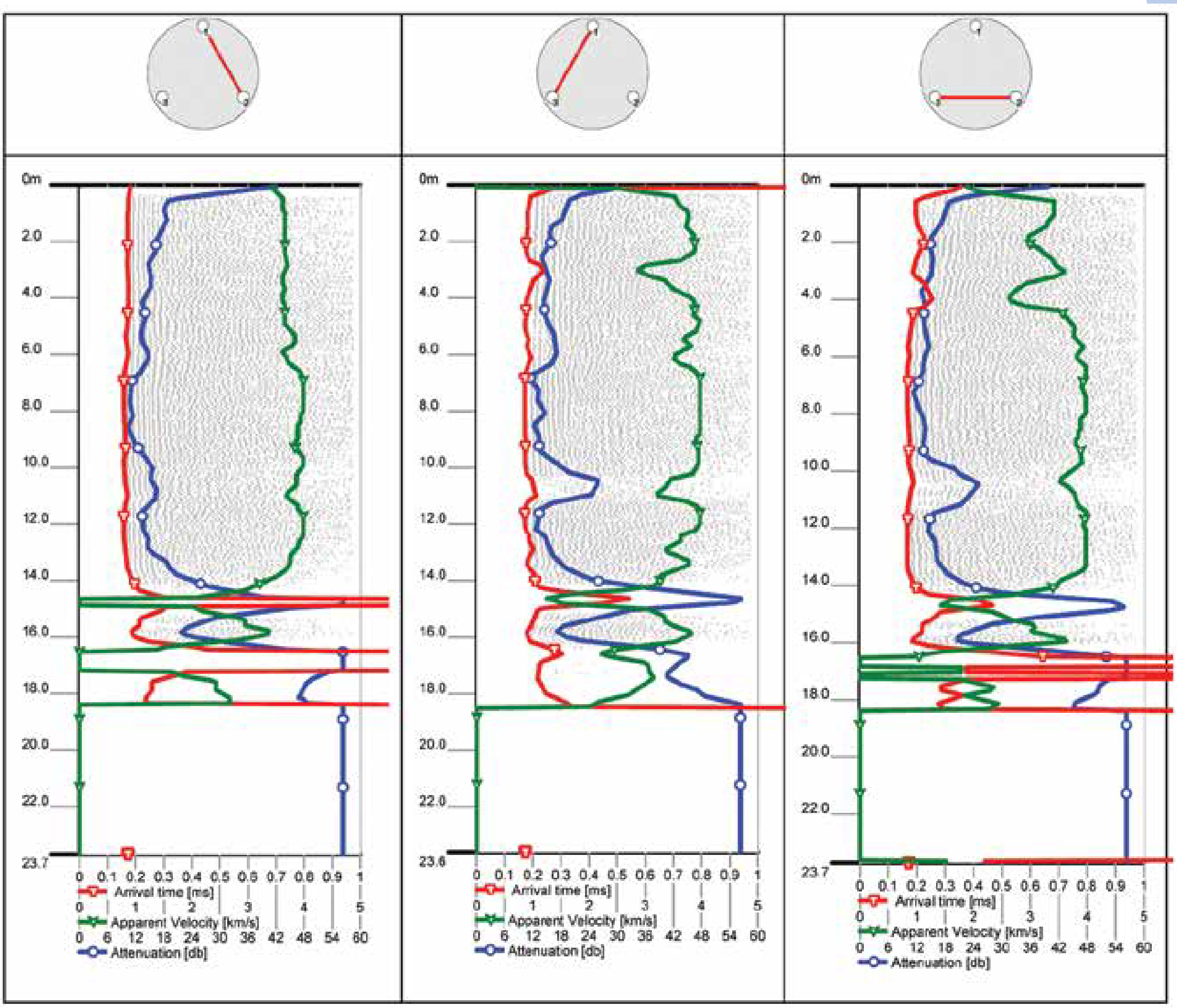


Fig 5. CSL of Pile#1

PIT test for pile #1: The Pile has anomaly at 14.0 m (from the pile top). The actual length of the pile may be around 22.5m. PIT test for pile #2: Because of the variability of the wave speed in concrete, the small change in pile length cannot be detected with the low-strain test method.

The CSL test results of Pile #1: First Arrival Time data indicate that satisfactory concrete is up to the depth of 14.0m and the concrete below 14.0 m to 23.7m isn't satisfactory. Apparent velocity up to 14.0 m (from the pile top) is in between 3.5-4 km/sec, consistent with good quality concrete.

The CSL test results of Pile #2: This shaft had what is often called a "soft toe" condition, where a small amount, typically less than 300mm vertically, of soil is present at the bottom of the shaft. CSL testing can clearly show a soft toe condition as long as the access tubes are close enough to the bottom of the shaft. The soft toe effectively reduces the shaft length by a small amount. Apparent velocity up to 26.4 m (from the pile top) is above 3.6km/sec, consistent with good quality concrete. The actual length of the pile may be around 29.0 m.

From the CSL and PIT Results the lengths of Pile#1 and Pile#2 can be approximated to be 22.5 m and 29.1 m, respectively.

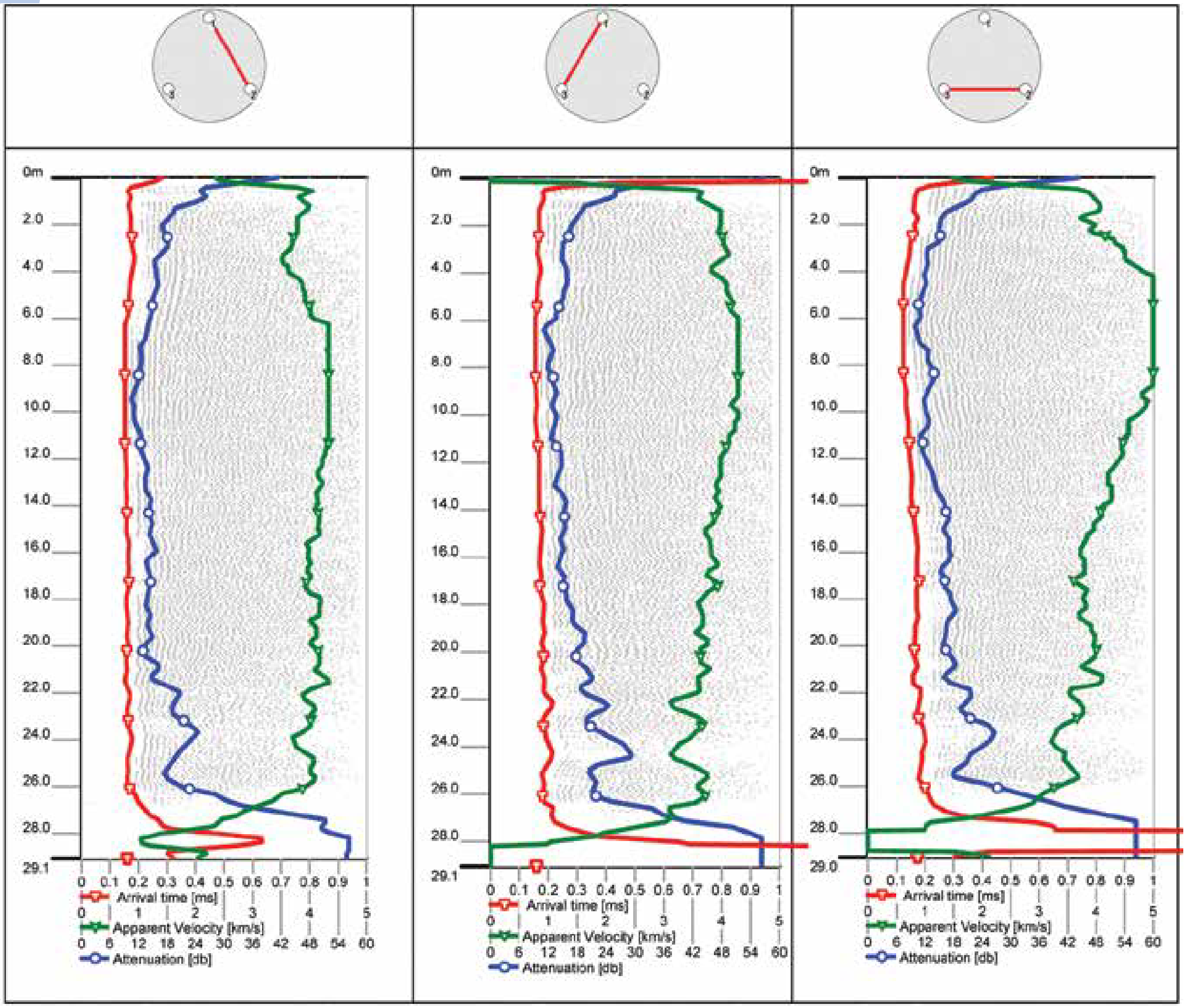


Fig 6. CSL of Pile#2

PILE CAPACITY CALCULATION

Pile capacity was calculated through Spread Sheet based on the above length. Calibrated hammer transfer 60% energy to the SPT Sampler. Following table shows capacity of pile by Calibrated Hammer. For the estimated pile lengths, the Service Load and Maximum Test Load appears for Pile#1 and Pile#2 appears to be 1.21 MN, 2.20 MN & 2.42 MN and 4.40 MN, respectively.

STATIC LOAD TEST AND DYNAMIC LOAD TEST

To understand the real behavior of the pile-soil interaction as defined by a Load-Displacement Curve, static load test (SLT) was performed on both the piles (Figures 7 and 8).

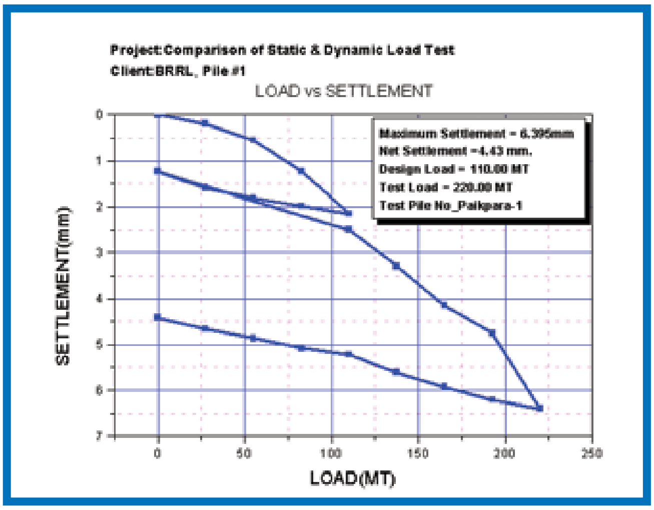


Fig 7. SLT of Pile#1

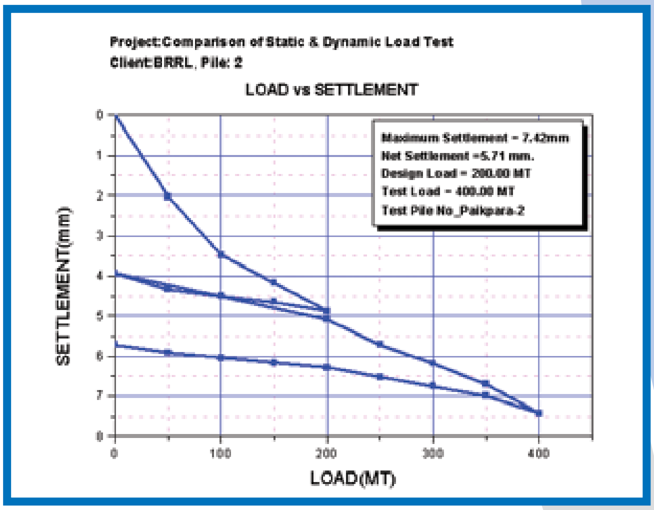


Fig 7. SLT of Pile#1

For DLT strain and acceleration transducers were also mounted on the pile shaft near the pile head. The load displacement behavior is calculated by signal matching (Figures 10 and 11).

Fig 10. Preparation of combined acceleration and strain sensor

Fig 11. Final setup of combined acceleration and strain sensor

The dynamic loading methods are dynamic load testing (DLT) by an impact hammer by launching a reaction mass from the pile head. The generated compression wave travels down the pile and reflects upward. This reflected wave contains information about the shaft friction, toe resistance and possible pile defects. DLT introduces a short duration shock pulse into the pile. So for DLT the pile load calculation depends strongly on pile material and cross section properties. Figures 13 and 14 show the force and displacement responses measured in DLT.

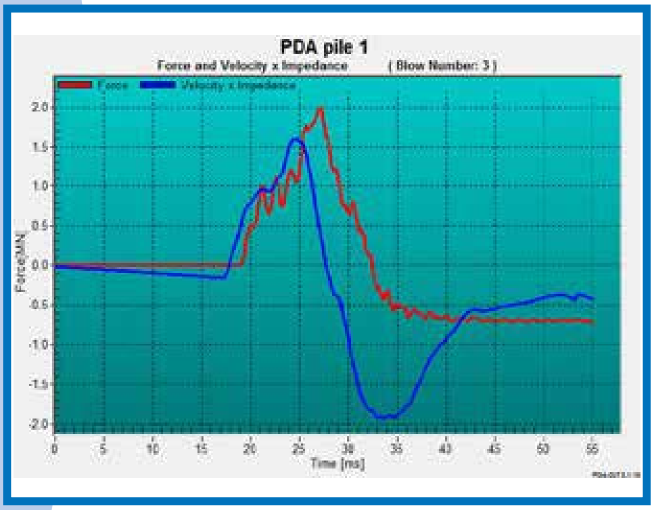


Fig 13. Load vs. Time of Pile#1

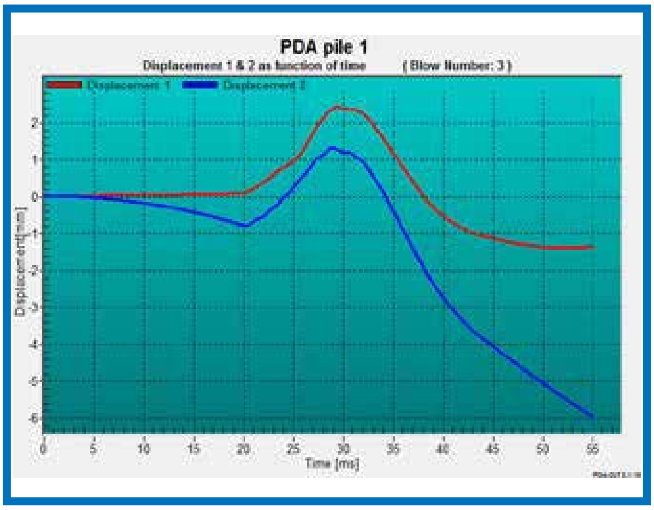
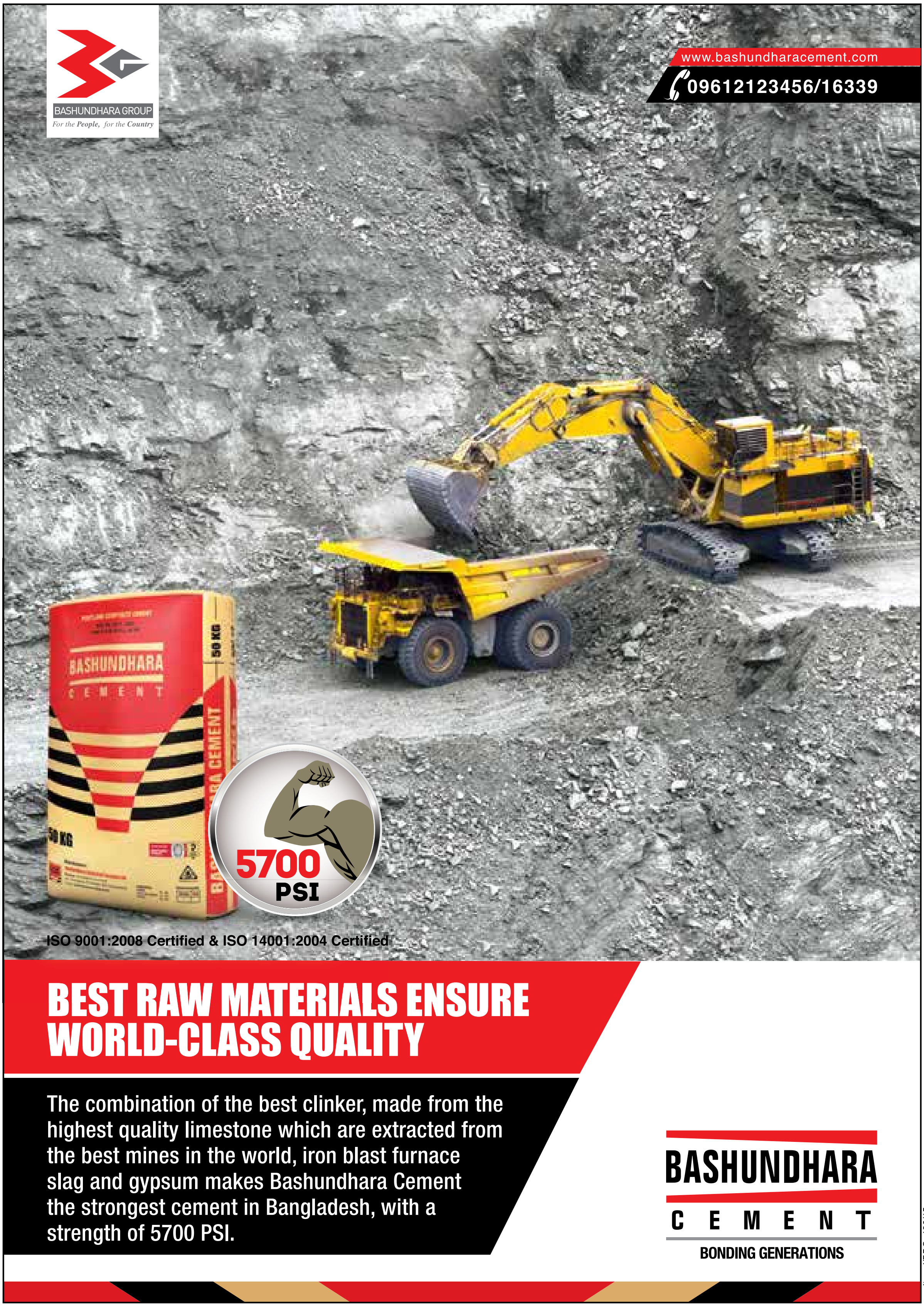


Fig 14. Load vs. Time of Pile#1

OBSERVATIONS & CONCLUSIONS

The results obtained from the analysis enables a platform for comparison between static load test results and that of dynamic test results. Based on the output, the following conclusions can be derived:

- At test load, dynamic load test predicted settlement is smaller compared to that of settlement measured under static load. This shows a reasonable agreement between the two test results as SLT was done before DLT.
- Easy placement of DLT loading device in center of the pile is noteworthy.
- Pile and soil responses obtained in DLT are closer to those obtained under static load.
- DLT is cheaper and quicker method than Static Load Test for larger diameter bored pile and small bridges as compare to Static load test. Also in DLT, required less space than Static Load Test.
- SLT were found to be comparable to that of DLTWAVE analysis for both Static and Dynamic test.



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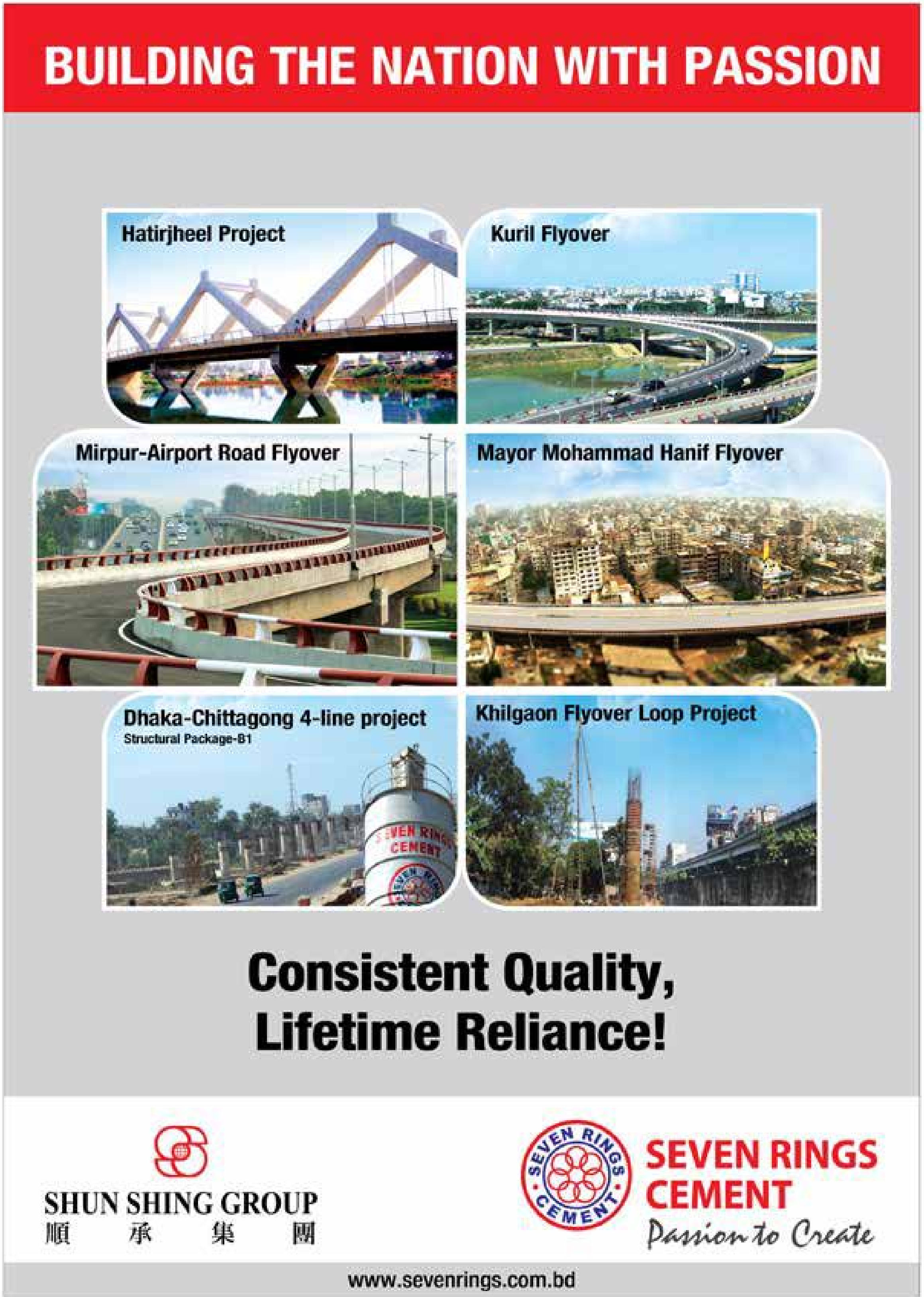
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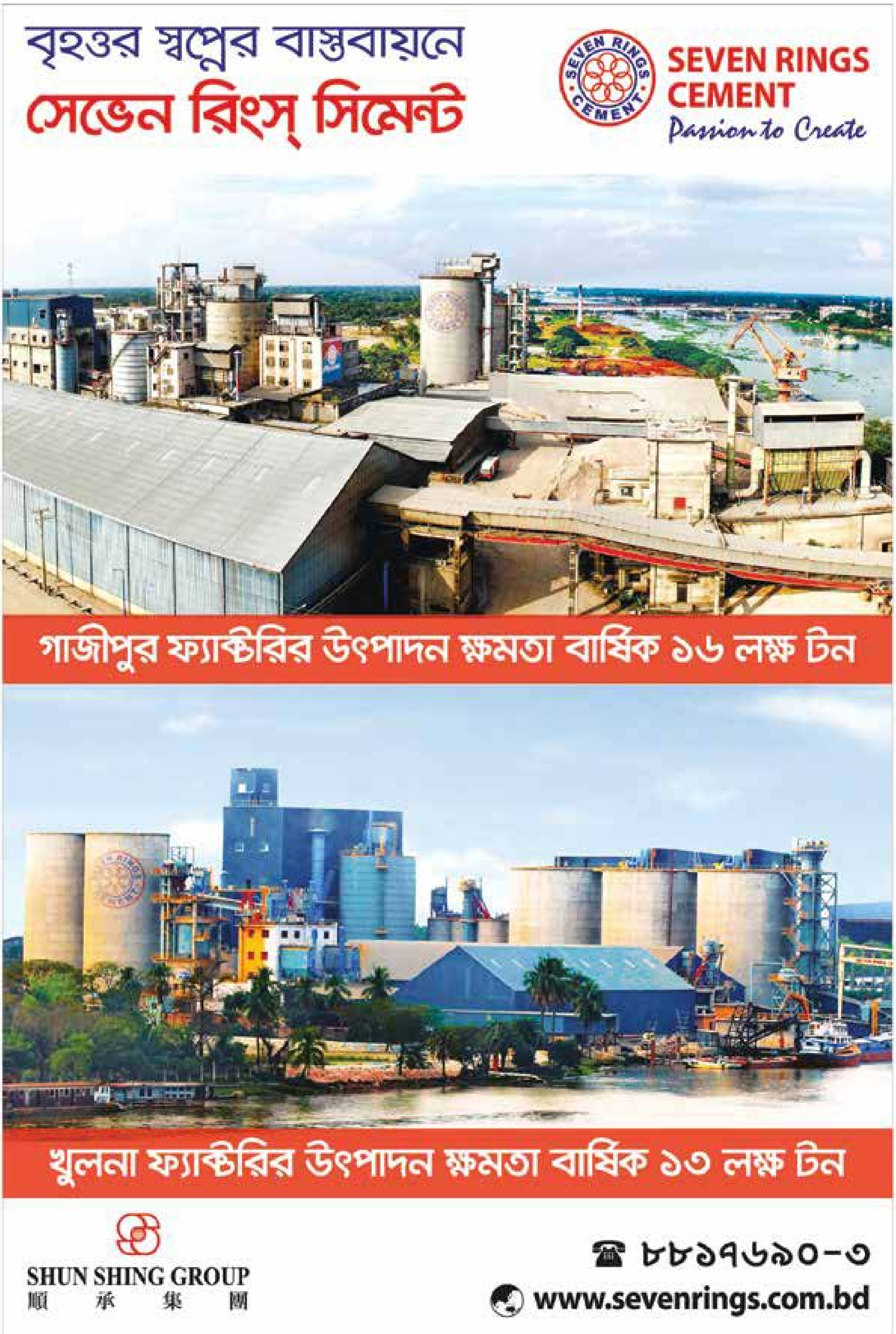
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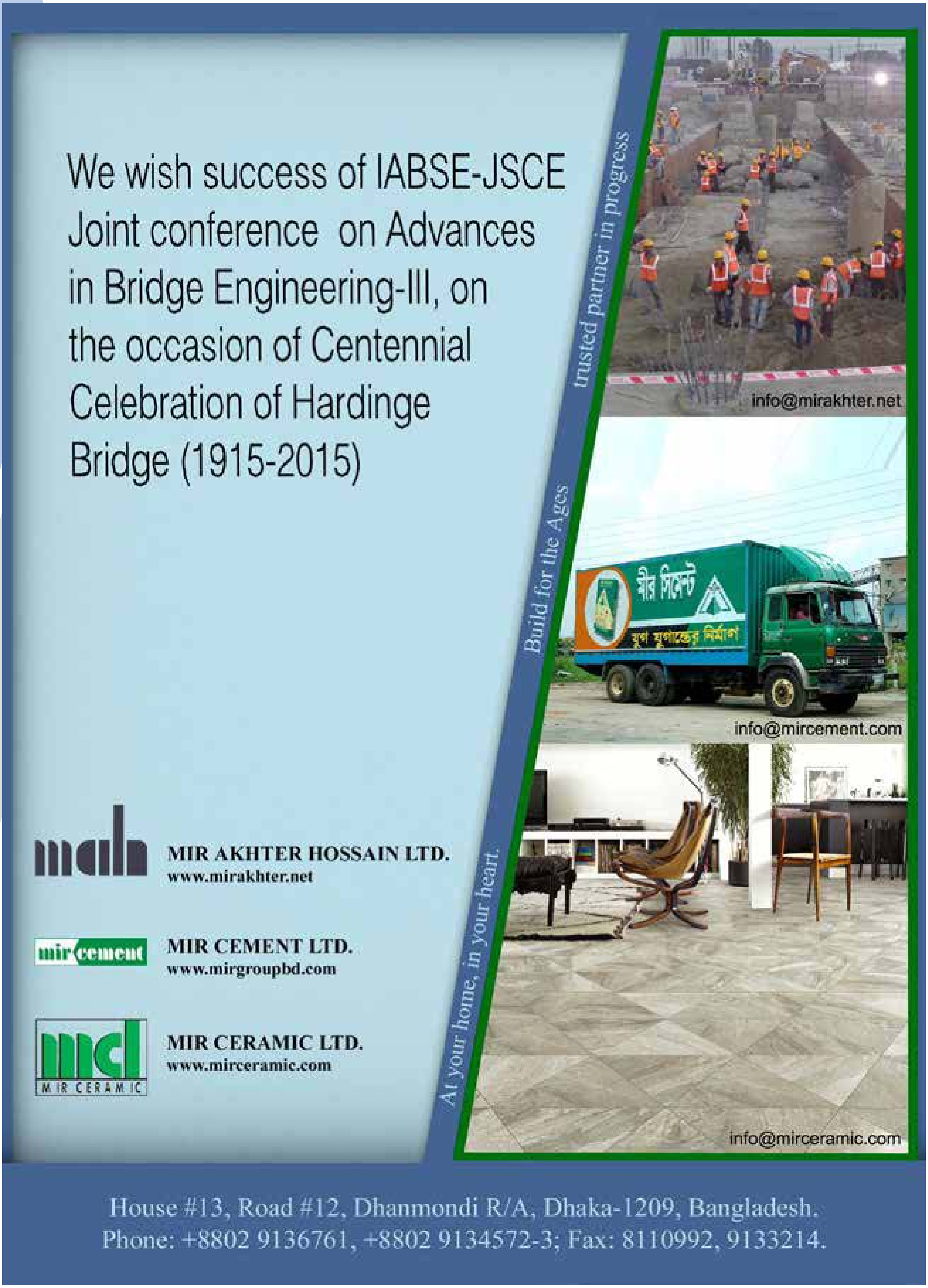
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