Career Profile of

Mr. Dindayal Sharma
D2S Infrastructures Pvt Ltd, New Delhi

Recipient of S.B. Joshi Memorial Award for Excellence in Bridge & Structural Engineering for the year 2012, cited by Alumni Association of College of Engineering, Pune

Date of Birth:

- 08th May 1945

Educational Qualification and Training:

- B.I.T. Sindri, B.Sc. Engg. – 1967

Professional Experience and Training:

- Involved in execution of construction of Bridges since 1967 and undertaken contract for construction of Bridges , Rehabilitation of Bridges, Road Works , Building Works and Consultancy Services at his own capacity since 1973, till date completed 220 major bridges spread over the North Eastern States and Northern States of India like Arunachal Pradesh, Tripura, Mizoram, Manipur, Meghalya, Nagaland, Sikkim, West Bengal , Bihar and Jammu & Kashmir, Himachal Pradesh, including in the Royal Kindgom of Bhutan.
- Introduced the PSC Box type Superstructures was for the first time in the North Eastern Region (in Arunachal Pradesh) in the year 1986.

- Introduced the concept of prestressed steel bridges for structural design and/or to avoid premature rusting of the bottom chord member.

- Completed work of Construction of 220 nos major bridges and ROB for a length of 9563 mtrs, out of which PSC Superstructure 8316 mtrs (maximum span 160mtrs) steel and BUG Steel Superstructures 1247 mtrs (maximum span 90m) and 20 Nos. Rehabilitation of Bridges, Road Works of 112 Km in the state of Assam and Meghalya and completed Building Works like construction of 200 bedded Hospital Building both OPD and IPD at Nalbari, Assam. Engineering College Hostel at Jalukbari, Administrative Block of Cotton College at Guwahati.

- Completed Design and construction of 637.60m long bridge in the year 2002 over river Noadhing on NH-52 under the C.E. Project, Udayak which is longest Bridge under BRO.
- Completed Design and Construction of 280 Mtr long Permanent Bridge over River Chenab on road Jammu-Akhnoor under the C.E. Project Sampark in J&K state. The intermediate span 160m is longest balance Cantilever span in India. The bridge was dedicated to the Nation by the Honorable Prime Minister on 28the April 2008.

•Completed the Rehabilitation of Painthal bridge on NH-IA near Jawahar Tunnel in J&K on Jammu-Srinagar Highway, under the C.E. Project Beacon, BRO. The work was completed under the guidance of Dr. T.N. Subba Rao.

•Completed the Rehabilitation of Dawki Bridge, including Design, under Meghalaya P.W.D. The bridge is a cable suspension bridge with a span of 102.412 M and carriage way of 4.115 M. The bridge was constructed in the year 1932.

•Completed the most unbalanced cantilever Bridge over river Munwar Tawi at KM 13.795 on road Sundarbani-Beripattan-Naushera under Project Sampark in Jammu & Kashmir State. 124M Length (Span 14M + 96M + 14M).

Honors & Awards:

A- <u>By The Indian Roads Congress (IRC)</u>

- 1999 - Medal for Best Paper on Maintenance titled ' Rehabilitation of A Permanent Bridge Over Painthal Nallah in J&K State in KM 168.400 on Jammu-Srinagar Route (NH-A).

- 2000 - Commendation Certificate for Champa Bridge titled 'Rehabilitation of Damaged Bridge Over River Champa on NH-31 in Assam.

- 2005 - Medal Instituted by Maharashtra PWD for the Best Paper on Construction titled 'Construction of 637.6 Metres Bridge Over River Naodhing on NH-52 in Arunachal Pradesh : A Challenge Accomplished"

B - <u>Association of Consulting Civil Engineers (Acce) Som Datt Award</u>

- 1996 - For Construction of 55 m PSC Girder Bridge at Chungthang over River Teesta in Sikkim under C.E. Project Setuk BRO.

- 1998 - For Repair and Rehabilitation of Painthal Bridge on NH-1A in J&K under C.E. Project Becon,BRO.

- 1999 - For Excellence in Repair and Rehabilitation of Dawki Bridge on NH-40 in Meghalaya under State PWD.

C - <u>The Maharashtra India Chapter of American Concrete Institute</u>

- 1998 - First Prize - Category – I For Most Outstanding Repair & Rehabilitation of Painthal Bridge in J&K under BRO.

D-<u>INDIAN INSTITUTION OF BRIDGE ENGINEERS (I.I.B.E)</u>

- 1995 - Second Prize - Category – II Ishnu & Bonday Bridges in Royal Kindom of Bhutan under Border Roads Organisation.

- 1996 - Third Prize - Category – I Chungthang Bridge over River Teesta in Sikkim under BRO.

- 1997 - First Prize - Category – IV Rehabilitation of Painthal Bridge on NH-1A in J&K under

BRO.

- 1998 - Second Prize- Category – IV Rehabilitation of Dawki Bridge in Meghalaya under State, PWD

- 1999 - Third Prize - Category – II Rehabilitation of Champamati Bridge in Assam under State PWD

- 2001- Third Prize - Category – II Manas Bridge in Royal Kindom of Bhutan under BRO

- 2004 - Third Prize - Category – I Naodhing Bridge in Arunachal Pradesh under BRO.

By other Agencies: ICI-MC-Bauchemie Award for Outstanding Concrete Structure for the year 2007-2008 for Akhnoor Bridge over River Chenab.

Affiliation with Professional Bodies:

- Fellow – Institution of Engineers (INDIA)
- Indian Road Congress.
- Member of Indian Building Congress.
- Member of Indian Concrete Institute.
- Member of Indian Institute of Public Administration.
- Steel Bridge Committee I.R.C. 1996, 2000.
- Member of Association of consulting Civil Engineers, Bangalore.
- Member of International Association for Bridge & Structure Engineering.
- Member of International Council of Consultants.
- Member of Indian Institution of Bridge Engineers.
- Member of Indian Society of Earthquake Technology.
- Member of International Tunneling Association of India.

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New Delhi – 110019.

18 CHENAB BRIDGE – A CANVAS IN CONCRETE

INDIA'S LONGEST CONTINOUS 60+160+60=280MTR. SPAN BRIDGE CONSTRUCTED THROUGH CANTILEVER GONSTRUCTION TECHNOLOGY

Mr. Dindayal D. Sharma
Chairman, D2S Infrastructures Pvt Ltd

18.1 Introduction

The bridge over river Chenab on road Jammu Akhnoor - Poonch in J&K State was lying incomplete for more than three decades. The decision was necessary to find ways and means to complete the permanent bridge to meet the strategic needs of the Nation and to overcome the traffic bottlenecks. The tremendous pressure from the political leadership and the Army authorities for the completion of the bridge had forced the BRO to decide and take many bold, dynamic, brilliant and viable administrative and technical decisions. The proposal, made by the ground executives and examined by the technical and the administrative wings of the department was accepted. This resulted in the construction of 280m long (longest mid span in the country of 160m + 2x 60M approach spans) PSC cantilever single span bridge.

This acceptance of the proposal has culminated in the completion of an aesthetically beautiful, and structurally durable bridge over river Chenab at Akhnoor under Project Sampark of the Border Roads Organization under the technical supervision of D.G.B.R.

An attempt is made to put on record the historical, administrative, technical and the constructional aspects of the Chenab bridge which has also created many firsts in the Country.

18.2 History of Chenab Bridge

The River Chenab is one of the big rivers of Northern India. The origin of this river is from two streams Chandra and Bhaga on the opposite side of Baralacha Pass at an altitude of 5000 m in the Himalaya's which meet at Tanding at an elevation of 2300 m to form the river Chenab. The river enters the Pangi valley of Chamba district of Himachal Pradesh and further flows towards J&K and enters the Podar Valley. It flows further 1200 km fed by the Catchments area of 61000 sq km in the foothills of J&K and the province Punjab under Pakistan before joining the river Sutlej.

The road Jammu Akhnoor was constructed during the regime of MaharajaHari Singh in 1932 and a single lane steel Truss bridge over river Chenab was constructed in between1932-34AD with 3spans (lxI38m+2x35m) steel Girder through type bridge of total length of 208m at km 25.25to cross river Chenab. The areas of Akhnoor,Jouria, Palanwalla, Chamba etc. became accessible to Jammu. This bridge is single lane with restricted class loading vehicles. The Strategic needs necessitated the construction of a new double lane bridge with Class 70R loading as per current IRC Codes.

The Government of India desired to improve the road and bridge to improve accessibility upto the International Border/Line of Control, considering its strategic importance after of the famous battle of Chamb Jouria in 1965 and the Indo-Pak war in 1971. These strategic needs

prompted the J&K State Govt. to hand over this road to BRO in 1971 along with the Akhnoor steel bridge.

The road including the existing Akhnoor Bridge was taken over by the Border Roads Organization, the premier road construction wing of the Government of India in Sept 1971. Immediately, thereafter details of the ground Survey for improvement of the road to double lane and construction of permanent bridge over Chenab was carried out.

A suitable site for construction of permanent RCC Bridge was selected and sub-soil investigation on the ground was done. A bridge scheme for 231m length with 5 spans of (3x46+2x46.5) at 800m up stream of existing steel bridge was approved by the Competent authority, as shown in *Fig.18.1*.

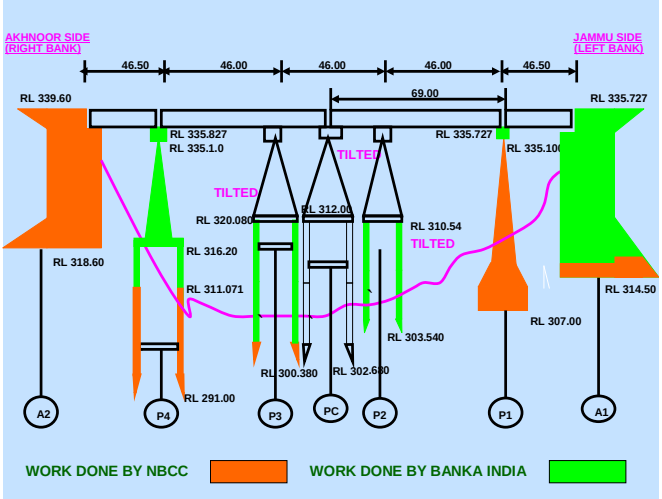


Fig 18.1 Bridge scheme for 3x46+2x46.5 m span (This scheme was abandoned later on)

The execution of the work commenced in 1978 on the ground but could not be completed even after deployment of two contractors till 1994. The contractors were unable to sink the well in the midstream due to various constraints of execution of foundation works among other problems. The position of the incomplete work executed after number of revisions of the scheme is shown in *Fig.18.2* and *Fig.18.3.*

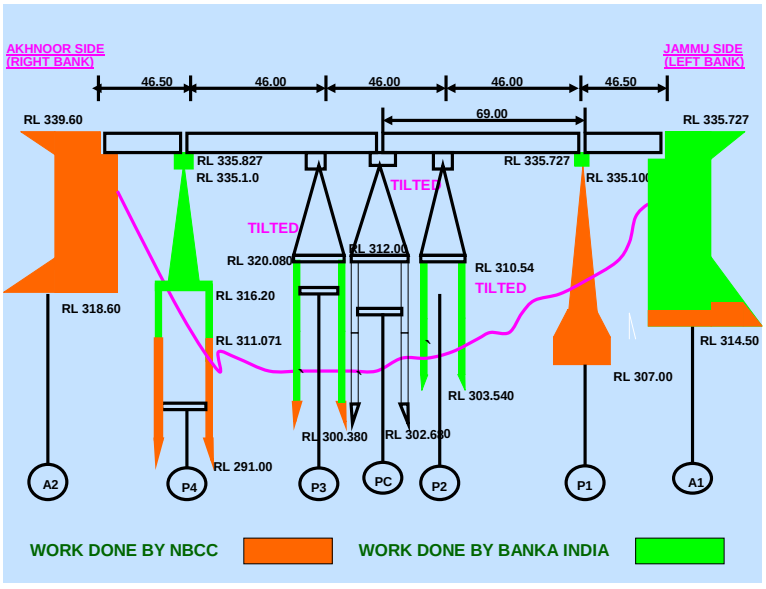


Fig 18.2 Work done by contractor Banka under revised bridge Scheme I

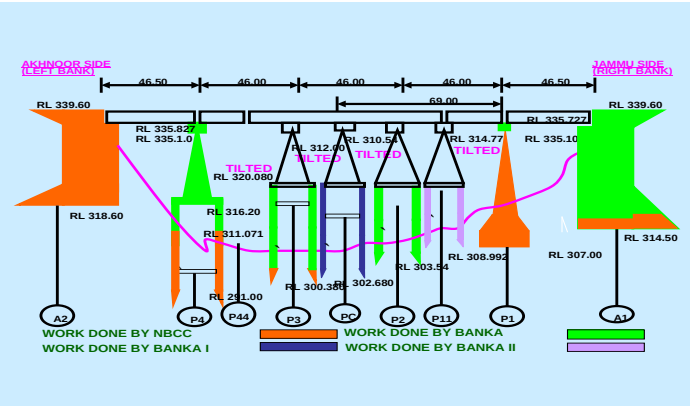


Fig 18.3 Work done by contractor Banka under revised bridge Scheme II

18.3 New Proposal

After detailed investigations of the behavior of this river and based on detailed examination of the past records a new proposal was conceptualized with cantilever PSC bridge, as shown in Fig.4. The proposal had been examined in detail by the competent authorities and finally a 280m long continuous cantilever bridge having a single main span of 160m necessitated by keeping the pier-wells inside the bank, well away from the water line, had been approved, shown in *Fig.18.4*.

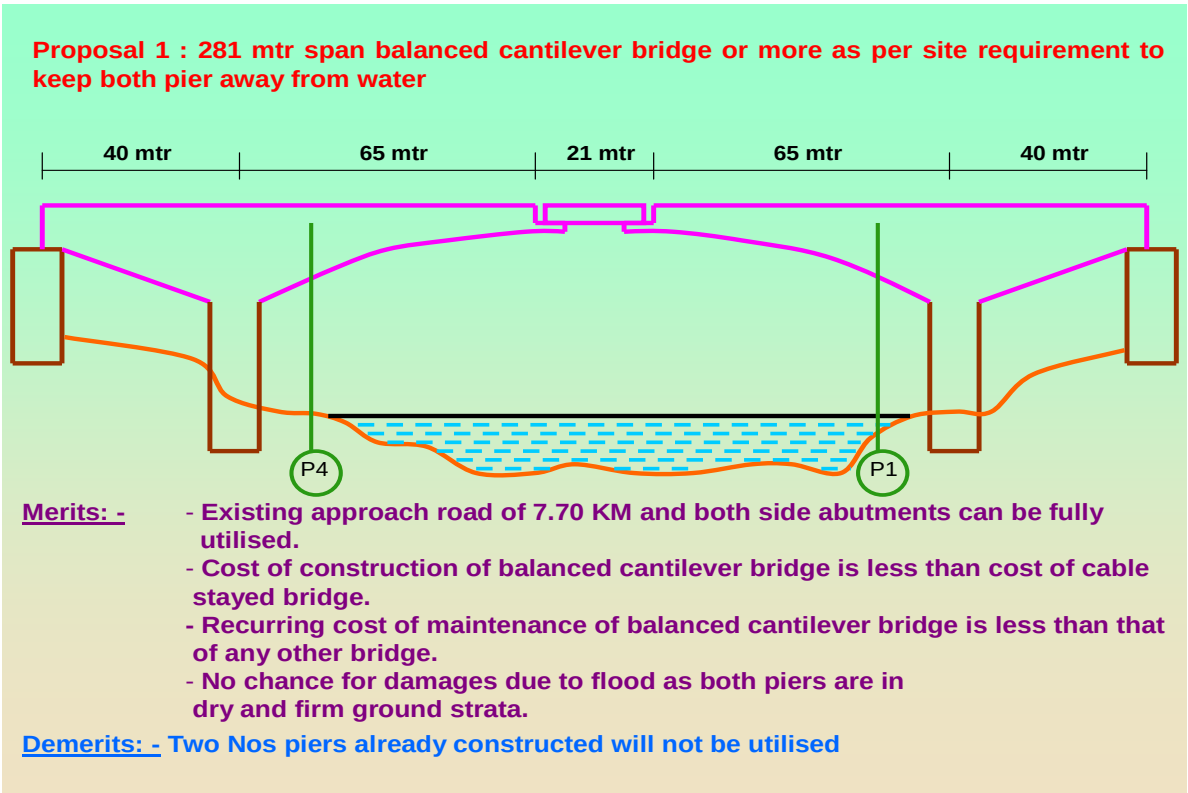


Fig 18.4 New proposal on the site (Actually executed)

All the constructed old structures whether complete or incomplete on the site had been abandoned. This kept the foundations away from the water edge and overlapping with the foundation of old existing piers P1 and P4 was also avoided. This proposal also facilitated the construction of the foundations on dry land and free from any obstruction.

Thus the proposal finally resulted in bold, dynamic brilliant, administrative and technical decision giving fillip to the hope for construction of the permanent bridge over river Chenab at Akhnoor.

18.4 Important Decisions

18.4.1 Technical Decisions

- Since all the earlier agencies had failed because of problems encountered in the construction of foundations having hard conglomerate soil strata due to difficulties faced in well sinking because of the high water current and conglomerate strata resulting in tilting of the wells, it was proposed to go for open foundation for the bridge and bridge the river gap of about 130m at LWL without any support. Thus a main span of 160 m single span with two end spans of 60 m each was selected to keep the foundation edge of the piers well away from the waterline.

- As a corollary to the above decision all the foundations remaining on the ground and in the river were abandoned. The PSC Girders lying on the ground towards the Jammu side embankment were also abandoned.

18.4.2 Administrative Decisions

- The recommendations by HQ DGBR stated above were accepted by the BRDB Secretariat of the GOI resulting in writing off of all past expenditures made in the construction of the bridge.

- It was also decided by the Government to call for Tenders by Invitation only and accordingly few pre-selected Firms approved by the Government were invited to bid for the work. Out of these pre-selected Firms only 3 Firms gave valid and responsive bids.

- Very stiff conditions of payment for executing the works were imposed in the NIT which were not negotiable.

- No Running or advance payment for materials or for machineries were allowed till the levels of the piers crossed the designed HFL. No advance against machineries & equipments was admissible as per CA.

- No running payments were admissible till the Piers P1 & P2 crossed the HFL. No payments for abutments were to be made until the both the piers crossed the HFL of 330.40 m.

- The time of completion of 20 months was kept SACROSANCT and liquated damages of 10% of the CA amount were leviable for any delay in the period of completion.

- The Interim payment schedule were fixed where 8% i.e. more than Rs. 160.00 lacs of the CA amount was kept for load Testing among others. The exact conditions of the NIT/Tender are reproduced below.

- Billing Schedule for Advance on account Payment was as per pages 61 and 62 of the Tender. As per Tender-Clause 25.1(a), the pricing for payments of advances on account of work done and of the materials delivered will be as per *Table No.1*.

S/No.	Item of work	Expected completion period/date from the date of commencement	Percentage payable
(i)	On submission and approval of detailed design and drawing	06^{th} month	2%
(ii)	On completion of pier marked P1	12^{th} month	8%

(iii)	On completion of pier marked P2	12^{th} month	8%
(iv)	On completion of abutment marked A1	10^{th} month	4%
(v)	On completion of abutment marked A2	10^{th} month	4%
(vi)	On installation of bearing	12^{th} month	1%
(vii)	On completion of super-structure	14^{th} month	
	Home bank span of 60M		11%
	Far bank spans of 60M		11%
(viii)	The centre span	16^{th} month	25%
(ix)	Casting of deck slab	17^{th} month	14%
(x)	Hand rails	18^{th} month	2%
(xi)	Completion of load testing	19^{th} month	8%
(xii)	Site clearance	During 20^{th} month	2%
	Total	20^{th} month	100%

Table 18.1: Billing schedule

- The contractor shall note that the compensation for delay, if any, in completion of work shall be levied at the rate of 1% per week of the amount of percentage indicated Table No.1 for the delayed items as a whole (including the completed portion also) of works against which separate completion period has been given. The maximum amount of compensation(LD) shall be limited to 10% of the amount of percentage payable indicated in Table No.18.1. However, the total of compensation shall be limited to 10% of the contract amount.

- In case the tenderer is submitting his own new proposal and the scheme other than the departmental proposal he shall submit the schedule for running payment also for approval of the Accepting Officer along with his tender.

- Advance on payment schedule as given will be governed by the order of priority of construction as indicated and the contractors will complete both the piers up to HFL level before undertaking construction of abutments. In case, however, the contractor desires to undertake the work of abutments prior to that of piers or simultaneously he shall be at liberty to do so with expressed condition that any advance payment on account of any of the abutment works will be released as per above percentage only, when progress of works on both the piers has reached at least up to HFL. No advance on payment for material at site for superstructure work will be made till the piers are completed up to at least HFL.

- Once the construction of piers (abutments in case of single span cantilever construction) reaches HFL , advance on account payment as per clause may be claimed by the contractor as per work done and material brought at site at Pro-rata to the percentage indicated against each individual item(s) of works.

- In case of single span cantilever construction from both ends, no advance on account payment, either for abutments or for materials brought at site will be made till construction of both the abutments reach up to HFL. Thereafter, the advance on account payment shall be governed by the clause of the tender.

- No payment shall be made against the perishable material. The decision of Engineer in charge, as to the perish ability of any item shall be final and binding.

- The advance payments against the material shall be adjusted fully from the next payment of advance against the works executed. If, however, the entire advance is not adjusted in the first RAR, it will be adjusted in the next RAR.

Bids were received accordingly and the work was awarded to the lowest Bidders M/s D2S Infrastructures Pvt. Ltd. at their quoted rates of Rs.21.06 Crores as per proposal shown in *Fig.18.6.*

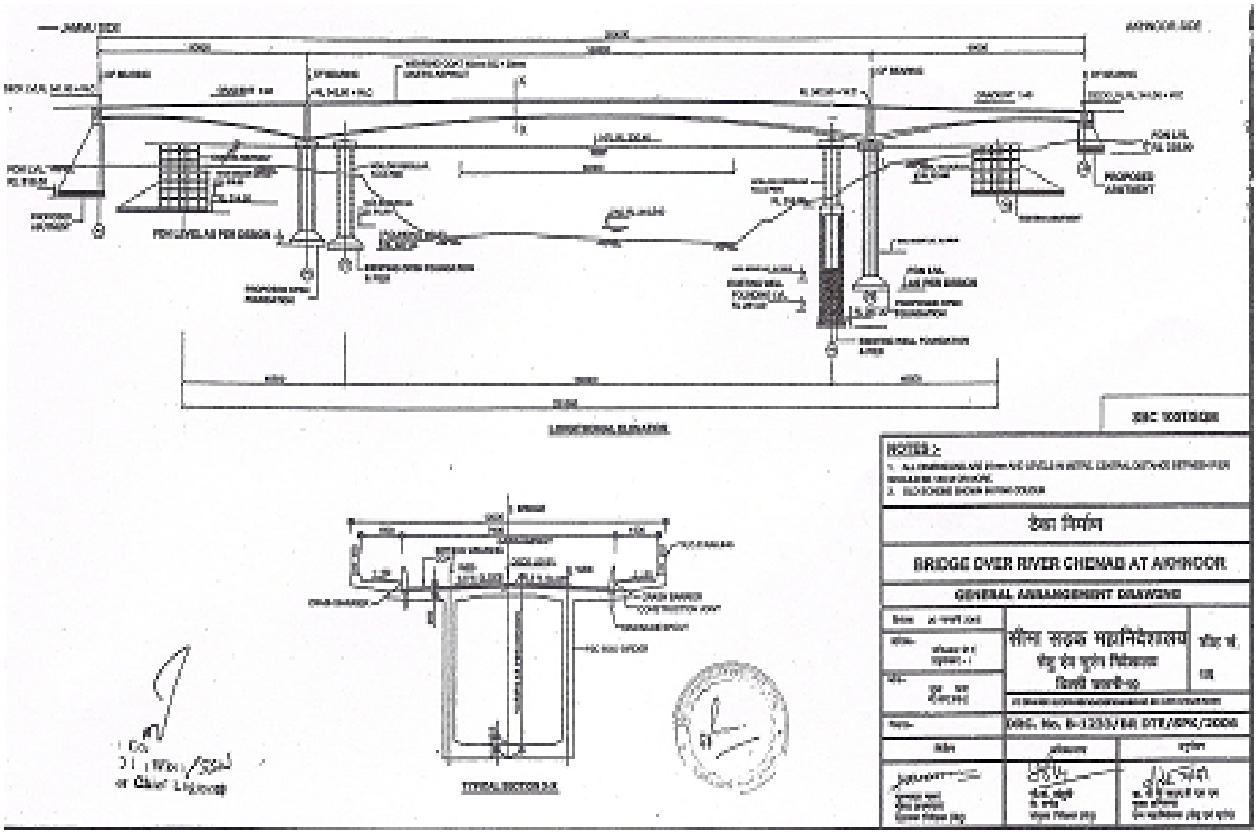


Fig 18.6 View of approved Scheme

18.5 Design Philosophy of the Bridge

18.5.1 Design Concept

As per the Contract Agreement, the design of the bridge had to confirm to the relevant IRC standards applicable and as revised from time to time on the date of tender.

The existing structure and landscapes of the site has been fully taken care of so that obstruction due to the Piers would be negligible. The fixing of the foundation size had also been given due weightage so that the edge on the water side was maintained. All the components of the bridge were designed to work together and compliment each other aesthetically. It had further been ensured that the Substructure and the Superstructure box have the same width i.e. 5.00 m in Cross Section so that the slenderness and sleekness of the structure is maintained. This was done to enhance its aesthetics, which in fact is a visual delight as actually seen.

Superstructure has been given parabolic profile in elevation. Soffit Slab thickness also varies parabolically, from300 mm to 1250 mm. Pier Head segment has been provided with suitably designed diaphragm block. Soffit has been thickened at junction with diaphragm block to take care of large compressive forces.

18.5.2 Loads

For pre-stressing, characteristic values Pm (x,t) have been used. For erection stages, relevant values of t have been used. For the finished structure, values of t just after completion and after 70 years.

The variable loads considered are:

(a) Traffic Load

1 lane of class 70R or 2 lanes of class A according to IRC:6-2000, clause 207.1.

(b) Footway Loading

According to IRC:6-2000, clause 209.4:

$P = (P´-260+4800/L)\ (16.5-W)/15$

$P´= 500\ kg/m^2$

L = Length in m of relevant part(s) of influence lines

W = Width of footway

(c) Braking Force

20% of the first train load and 10% of the load of succeeding trains, train loads in one lane only being considered.

(d) Water Current

Horizontal forces from water current are based on mean velocity of 3.5m/s.

(e) Temperature

Concrete structures: Uniform temperature change in the structure: $\pm 25^0C$ Non uniform temperature distribution in as per positive and reverse temperature differences as per clause 218.3 of IRC:6-2000.

(f) Erection Loads

Traveler type top truss

Weight- 650 kN

Point of application from support - Tip of Cantilever

Imbalance due to selfweight

Dimensional tolerance - 5%

Random Loading

Equipment and Personnel -0.5 kN/m2

Vertical Wind pressure 0.55 kN/m2

Concentrated load attip of Cantilever - 50kN

(g) Bearing Friction

Sliding bearings (Teflon on stainless steel) 5% of the actual characteristic bearing load.

(h) Accidental Loads from Earthquake

The site is in zone V

Zone factor 0, 36

18.5.3 Superstructures

The superstructure has been constructed progressively from the piers. The PSC box depth varies from 9.75 m at root to 3.4 m at the center of span 2. The Span-depth ratio for mid span at root is 16.4 m and at mid span it is 47 m. The out to out width of the box is 12 m and carriageway width caters to two lane traffic with 1.5 m footpath on either side separated by crash barrier. The soffit profile of the box varies parabolically. The pier-head segment was 5.0 m wide. First 5 segments have been proposed to be constructed on the staging as firm ground for staging was available. Also at 11m distance from pier location, a pier on the central span side was available to be used as temporary support for ensuring stability during construction. The segment-width varies from 2.25 m to 4.5 m. The weight of each segment has been restricted to 130 t owing to requirements of bridge traveler unit. In span 1

and 3, the box has been filled up with PCC to a length of 14.5 m to ensure stability during service and to prevent uplift on abutment bearings. Access opening has been provided through the diaphragms and fill-portion.

18.5.4 Pre-stressing Cables

For pre-stressing, 62 no. of cables, at junction of web and deck slab have been used. For cantilever erection of the bridge. 31 no. of pre-stressing cables on either side of the box have been concentrated at the junction of web and deck slab. The provision for future pre-stressing has been kept by providing 5 no. of 110 mm diameter holes in the diaphragm.

18.5.5 Blisters

The blisters have been used either in the web or essentially at junction of web with deck or soffit slab. As an exception, near the abutment, the blisters have been provided in the soffit of deck slab to take care of forces due to temperature variation.

At pier locations, the diaphragm wall is 1200 mm thick and bottom part has been provided as solid block of size 4m x 4 m , considering temporary fixing for stability.

18.5.6 Substructure and Foundation

The abutments consist of hollow box and piers consist of hollow rectangular section on raft foundations. The pier section is tapered near foundation for a height of 4.5 m for effective dispersion of the load on the foundation area.

(a) **Abutments:** The box size of A1 is 12 m x 10.5 m. It is divided into 9 cells. The box size of A2 is 12 m x 7.6 m. It is divided into 6 cells. The wall thickness is 750 mm on front and back and 500 mm for side walls. Internal walls are 450 thick.

(b) **Piers P1 & P2**: The hollow section size is 6.6 m x 5.0 m (outer dimensions). The raft foundation size for piers is 14.25 m x 17.0 m.

18.5.7 Articulation Design

Articulation arrangement is as per following criteria:

- Transfer of Vertical loads by POT/PTFE bearings.
- Horizontal longitudinal forces under normal conditions are transferred through pin bearing to Pier P1.
- Horizontal transverse forces are transferred through elastomeric stoppers at A1 and A2 and through pin bearing on P1 and guided pin bearing on P2.
- STUs on P2 permit movement under normal conditions but get locked during seismic forces. Thus horizontal longitudinal seismic forces are shared between piers P1 and P2.
- Uplift on abutment during service is taken care of by providing mortise-and-tenon joint between abutment and superstructure.
- Expansion joints are provided at A1 and A2.

18.5.8 Stability during Construction

During construction, stability cables, 4 no. of 19 T 15 have been provided to prevent uplift at abutment which have been used to anchor the superstructure to abutment while span 1 has

been completed and superstructure has been made to rest on bearings on Abutment in order to progress the construction on central part of 40 m of span 2 of 160 m. The Stability Cables had been stressed to 60% of UTS value.

These cables are proposed to be removed after stressing of 2 no. of continuity cables. Remaining continuity cables shall be stressed only after de-stressing of continuity cables. A beam has been provided on top to prevent upward thrust due to live load during service.

- **Construction Methodology**

Stage 0: Dismantling of top portion existing abutment & existing piers EP1 & EP2.

(a)	Compressor 300 cfm width Jack Hammers and all accessories	- 4 Nos
(b)	Pocklain	- 2 Nos
(c)	Drilling accessories	-12 sets
(d)	Vehicles for site movement	- 2 Nos
(e)	Water pump 10 H P	- 6 Nos
(f)	Hydraulic Excavators (JCB)	- 2 Nos
(g)	Tata Tippers 8 cum capacity	- 4 Nos
(h)	Gen Set 15 KV A 125 KVA	- 2 sets - 2 sets
(i)	Concrete mini batch plant	- 1 set
(j)	Welding Set	- 8 Nos

Stage 1: Cast pier head segment 1 on bearings & temporary blocks for stability (supported on pier cap)

Stage 1a: Erect staging on either side

Stage 2-5: Cast segments 2 to 5 simultaneously on either side of pier head accounting for camber and pre-stress progressively

Stage 5a: Provide support on elastomeric bearing on temporary bent1 & bent2 at 11 m from pier centre in span 1 & span 3 and on existing piers EP1 & EP2, 11m from pier centre in span 2. Contact of super structure with bearing on temporary support (bent/existing pier) shall be ensured after pre-stressing through jacking or otherwise.

Stage 5b: Erect traveler on river side & equivalent weight (by trolley on rail/ on land side).

Stage 6-18: Cast segment 6 to 18 simultaneously on either side of pier head, accounting for camber and pre-stress progressively (segments to be cast on staging in span1&3 by shifting staging progressively and by traveler in span 2)

Stage 18a: Cast abutment diaphragm and box projections.

Stage 18b: Place temporary supports on abutment & pre-stress stability cables for holding down (provision to be kept in abutment wall, rotation and movement at abutment on long

axis not to be restrained) by providing sleeve around cable to allow flexibility. Remove trolley on land side.

Stage 18c: Remove support on existing pier EP1 and EP2

Stage 18d: Remove temporary bent 1 & bent 2

Stage 18e: Pre-stress continuity cables no. 201-203, 205-207 in span 1 & span 3. Fill with pcc in segments near abutment, stress cable no. 204, cast u box at diaphragm & fill with pcc.

Stage 19-22: Casting and pre-stress of segments 19 to 22 in span 2 progresses with camber correction.

Stage 22a: Move traveler systematically close to centre line of pier & dismantle.

Stage 22b: Suspend form for closure segment for mid span (central span) and erect formwork for closure span.

Stage 23: Cast closure segment & stress cable no. 101,103.

Stage 23a: De-stress stability cables & stress the remaining bottom continuity cables in span 2. Cast balance abutment part, deck slab & side walls and installation of top & bottom bearings of abutment.

Stage 23b: Complete construction-crash barrier, railing, expansion joint, footway & wearing coat.

18.5.9 Execution Methodology

The contract for the design and execution had been accepted after completing all formalities with M/s D2S Infrastructures Pvt. Ltd. on 27 April 2006. The foundation stone had been laid by Hon'ble Chief Minister Ghulam Nabi Azad on 28 April 2006.

To ensure timely completion of the Project, a detailed programme had been prepared with the department and D2S Infrastructure Pvt. Ltd. (author as Commander TF) along with the contractor, project manager and designer on the 3rd of May 2006. Important decisions as mentioned below had also been taken so that the work could be completed with acceptable quality and timely based on the tender, stipulations and the site conditions.

18.6 Execution Decisions

18.6.1 Construction on both banks had to be mechanized and synchronized properly and main pier P1 and P2 to be started simultaneously alongwith A1 & A2.

18.6.2 To achieve the above progress and target as per the CA all necessary equipments, tools, plants, machineries and vehicles, as given in Table2, were to be deployed and provided at site within 30 days.

18.6.3 All other vehicles/Plants/Equipments were needed after completion of excavation. Hence, it was decided to place the order and ensure that the following items should be placed at site on or before 30th August 2006.

- Concrete batch mix plant 30 cum/hrs capacity – 2 Sets

- Concrete pump 30Cum/hrs - 2 Sets
- Gen set 125 KVA – 2 Sets
- Mobile crane 20 T Capacity – 2 Sets
- Tractor cum loader – 2 Sets
- Power press for steel bar cutting - 2 Sets

18.6.4 Site laboratory had been set up so that all required test for the work could be carried out simultaneously to ensure proper quality by 30th June 2006.

18.6.5 Proper labour camp and the office had to be established by 30th June 2006. However with the existing accommodation the, site office had started functioning immediately after the acceptance of the CA.

18.6.6 Total required quantities of major construction materials like cement, steel and aggregates were to be identified and orders to the concerned manufacturers had to be placed in a phased manner to avoid any slippage of delivery dates. It had been ensured by the contractor that every 15 days position will be reviewed and advance & corrective action taken up. The quantities of materials required were shown in Table 3.

18.6.7 The required quantity of shuttering materials had to be brought at site before 30th June 2006 and shuttering to be fabricated at site only except Cantilever Construction Shuttering Equipments which was outsourced.

18.6.8 It was also decided that order of bearings will be placed before Nov 2006 with delivery by Feb 07 and order for cantilever construction shuttering equipment two sets also to be placed with the date of delivery at site before 31 March 2007.

18.6.9 The issue of payment of running bills had also been raised by contractor. The author the then Commander had assured him of disbursing payments within 24 hours on receipt of correct running bill as per CA conditions. Also the TF had assured that the approval of the founding level will be given immediately on reaching designed RL.

18.6.10 The bridge had to be treated as 2 bridges on each bank to be linked finally. Hence all equipments, plants, vehicles, cranes and gantries etc. had to be doubled and procured accordingly.

18.7 Important Phases of Project

18.7.1 Foundations

The work of the execution of the foundation of PI and P2 had been physically started on the ground by 5th Jun & 15th Jun 2006 respectively and plants & equipments placed as per the original schedule. The excavation was only possible by drilling and blasting as very hard conglomerate strata in both the foundations of piers P1 & P2 was encountered after the removal of the initial overburden of Earth upto a depth of about 3 m. The foundation of pier P1 & P2 had been completed and lean concrete laid after conducting plate load bearing test were carried out on 01 Sept 2006 at RL 311 for P1 and at RL 309.5 for P2. Simultaneously execution of abutments were also progressed.

The work had been taken up in full swing. Due to heavy rains and high floods after placing the reinforcement in both the Piers there was a set back due to High water level because of floods and the pits were filled with mud debris etc. However the surface were cleaned by deploying adequate people round the clock and concreting of the foundation of both piers

completed by 14 Oct 2006. Further work also continued simultaneously. The pier P1 and P2 had crossed HFL (at RL330.40M) on 11 Dec 06 and 14 Dec 06 respectively and further works were not possible for want of bearing whose Anchor bars were to have been embedded in the Pier cap.

Simultaneously execution of abutments were also progressed and lean concrete in Al and A2 were completed by 15 Dec 06 as well as concreting work in foundation on 23 Dec 06 and further work were continued.

18.7.2 Bearings

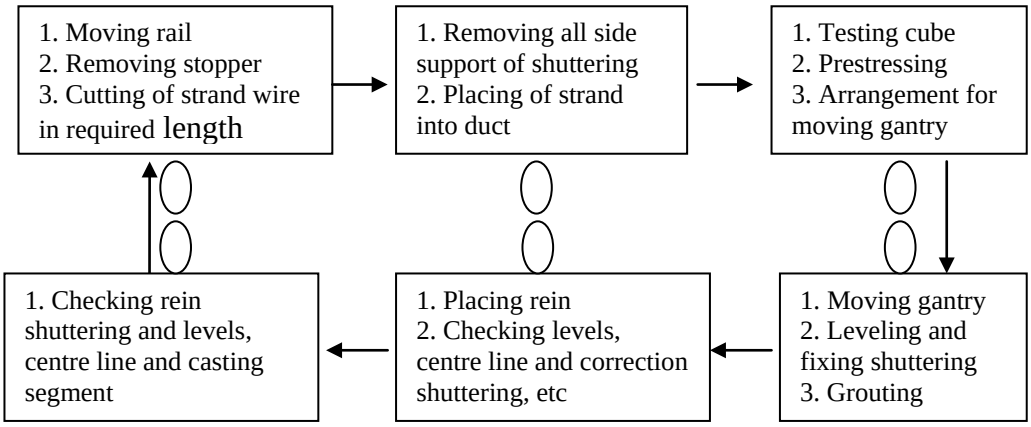
The bearings 4000 MT capacity were special type and extremely heavy, causing delay in its manufacture vis-à-vis the time committed for delivery. The author had himself contacted the Managing Director of MAGEBA, the manufacturers for the supply of the bearings and came to know that they had some problems in machining the huge area of 1m x 1.10 m resulting in delay of 3 months which delayed the assessed time for completing the bridge from 20th Dec 2007 to beyond March 2007. The 1st consignment of bearing had reached the site on 05 Mar 07 and the bearing of P1 laid on 20th 2007 and unto base of bearing of Pier P1 completed on 25 April 07 and pier head completed on 6th May 2007.

18.7.3 Piers and Super Structure

The work of pier P2 was also started and bearing laid on 19 May 07 and pier head was completed on 09 June 07. Delay was compounded in the delivery of CCSE hence after completing the pier-head it was decided to continue segmental construction of super structure by staging shuttering on both the piers by supporting from the ground casting up to 5th segment was completed by this process. The CCSE equipments had reached site after a 4 month delay. Therefore the entire project had been delayed due to the delay in manufacture of bearings & CCSE equipment by four months. However on receipt of all the bearings & CCSE equipment the planning for linking the bridge had been reviewed by expediting the construction of each segment where some margin for reduction was squeezed in.

18.7.4 Segmental Construction

On receipt of CCSE, the segmental construction was further speeded up. The testing of concrete Cubes were done after 3 days, 7 days and 28 days. It was observed that the 3 days result was more than 67% i.e. catering to the 7 days strength. Hence, it was decided to carry out the stressing after 3 days. Attempt was made to complete the casting of each set of segment on both piers within 6 days after getting 67% strength after 3 days. This plan accelerated the progress of the work and 75 days delay had been up. The various activities involved and action taken to complete the construction cycle every 6 days are shown in the flow diagram as shown in *Fig.18.7*.



Note: Independent activity for cutting, bending, binding, reinforcement, repair and cleaning shuttering and other processing works continue.

Fig.18.7 Sequence of 6 Days Cycle for Segmental Construction

18.7.5 Major precautions taken during execution

- The conglomerate strata encountered during excavation of foundation was excavated with the help of drilling and controlled blasting to avoid threat to life and properties, the site being very near to the residential area of the Army units (P_1) and the Buddhist ruins (P_2).

- The bearings were placed at pier head with due care and reinforcement were simultaneously placed with the bearings reinforcements were extremely congested and there was very limited space for placing the anchors of the bearings.

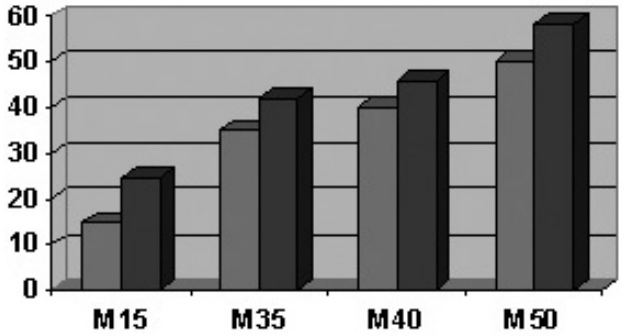
- To avoid excessive deflection due to unbalanced load during the construction a properly designed (total load - 600 M.T.) bent on both sides of the piers had been erected. Neoprene pad were placed at the point of load transfer.

- The CCSE equipment had been placed safely and before use load testing of the same up to designed load of 130 M.T had been done to avoid excessive deflection during the execution of the work. Load testing was done by placing saturated sand with water corresponding to the weight of 13MT. the end stoppers were increased to 5.00M.

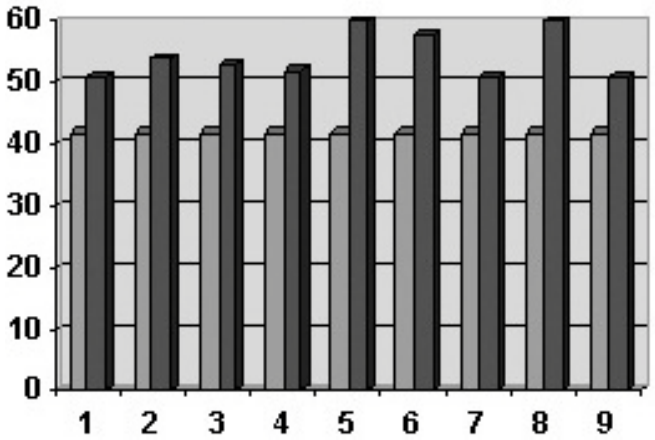
18.7.6 Sequence of load testing

- CCSE was erected on superstructure for start of construction of segment.
- It was felt necessary to do load testing before actual execution.
- The empty box of shuttering fully suspended with CCSE was filled up with sand up to a load of 130MT.
- The deflection of CCSE was found 19mm on full load against allowable 25mm.
- No fault noticed during load testing at any joints of CCSE
- Actual deflection of CCSE is around 10mm during concreting
- To ascertain the actual strength sufficient concrete cubes were left on the surface of the concrete casted and curing was carried out with the main structure and these cubes were tested after 3 days & 7 days.
- Cube Test Results of strength achieved with 400 kg cement, OPC 43 Grade, are shown in the *Graph No.1*, wherein the Grade of Concrete is shown as Faint and strength achieved is shown as Dark.

- Target vs Achieved strength results of Mix Design are shown in the *Graph No.2*, wherein the Target Compressive Strength is shown as Faint and Achieved Compressive Strength is shown as Dark.



Graph No.1: Details of strength achieved with 400 kg cement OPC 43 grade cube test results



Graph No.2: Mix Design: Target vs Achievement

- Proper grouting after pre cambering had been ensured. The grouted duct had been tested with pressure flow of water to ascertain possible leakage in the concrete.
- The quality control was strictly adhered to and cubes were kept on the structure only and curing was carried with the structure to ascertain the actual result. the strength achieved after 3 days and 28 days have been tabulated here in *Table No.2* which clearly indicated the quality control on the work.

Item of work	**Grade of concrete**	**Average of strength (mpa) Pier P1**			**Average of strength (mpa) Pier P2**		
		3 days	**7days**	**28 days**	**3 days**	**7days**	**28 days**
Pier head segment 1	M50	39.90	50.80	58.92	40.84	44.84	56.54
segment 2	M50	42.39	47.60	57.40	39.32	46.76	57.78
segment 3	M50	42.00	48.96	56.52	50.43	54.43	59.98
segment 4	M50	42.00	48.90	57.33	41.48	50.82	58.81
segment 5	M50	48.00	49.93	57.63	47.18	46.81	56.70
segment 6	M50	53.18	53.71	59.83	41.48	52.37	56.30
segment 7	M50	40.59	54.00	57.33	43.66	47.77	58.00
segment 8	M50	43.78	45.6	54.59	45.11	48.30	58.98
segment 9	M50	43.33	47.53	55.00	39.93	45.63	56.58
segment 10	M50	38.56	48.07	56.16	39.93	47.93	59.56
Segment 11	M50	43.70	47.53	56.00	39.79	45.37	54.96
Segment 12	M50	40.00	49.55	57.78	37.33	47.48	55.41
Segment 13	M50	46.15	48.52	58.74	38.15	46.22	55.48
Segment 14	M50	40.59	46.82	55.56	36.59	46.44	54.96
Segment 15	M50	38.48	46.74	54.67	39.03	44.50	54.52
Segment 16	M50	38.22	46.61	54.67	40.44	46.96	55.11

Segment 17	M50	37.93	46.54	57.48	38.80	45.85	57.37
Segment 18	M50	37.48	45.33	55.04	43.55	44.74	57.44
Segment 19	M50	40.44	45.13	54.37	41.85	46.61	57.79
Segment 20	M50	37.48	41.70	54.44	44.11	48.78	59.78
Segment 21	M50	42.18	44.88	56.36	39.70	46.96	56.95
Segment 22	M50	40.78	53.55	57.22	39.00	47.93	58.11
Segment 23	M50	37.33	42.00	56.67	37.33	42.00	56.67

Table No. 2 Cube Strength Achieved in 3 & 28 Days

18.7.7 Final Phase of Construction

The segmental construction beyond 5th segments o P1 and P2 were started upon receipt of CCSE by 18 July and 15th Aug 07 respectively and 6 days cycle maintained. The 22nd segment of P1 and P2 were completed on 09th Dec 07 and 19th Dec 07 respectively and finally the 23rd segment was cast on 31st Dec 07 which linked the bridge. The fixing of railing, crash barrier and other activities were executed simultaneously including removal of CCSE equipments. The load testing had also been completed where deflection had been observed at 2.19 mm against permissible limit of 6.6 mm. the bridge was taken over by the department after clearing the site by 10th Feb 08.

18.8 Lessons Learnt

There are numbers of lessons learnt from the construction of this bridge, as follows:

- In retrospect repeated changes of the GAD by changing locations of the foundations should have been avoided. Proper analysis was required when the tilting of wells was occurring repeatedly in the stream, rather than putting more wells in the flowing zone ofthe river.

- As per the site conditions and ground strata the best suited foundation was open which had been taken care of while the new concept for cantilever construction was proposed.

- For the completion of the bridge it was essential to complete the foundation first rather than casting of super structure elements. This was ensured in the New CA.

- Constructional stores and resources management should be critically examined, maintained, planned and all precautions & remedial measures needed to be taken to avoid critical loss of time.

- To ensure timely completion of the project, approval of different stages of works by competent authority was to be monitored apart from payment of running bills. Bills were paid within 24 hours of receipt. The progress was monitored by both HQDGBR and BRDB Secretariat weekly. The period of completion was sacrosanct as the Honourable Defence Minister had announced the same on the floor of the Lok Sabha.

- Heavy flood on 03 Aug 06 and 02 Sept 06 caused damages to the coffer dam and the entire excavated foundation was filled with mud and debris twice, causing a delay in the completion of the foundation. Hence it is essential to take proper care of such foundations from flash floods by having suitable coffer dams.

- Concept to use more cement for achieving higher strength should be reviewed. Higher strength is possible by proper control of cement water cement ratio and use of nominal and requisite quantity of admixture to increase the workability and use of proper grade of aggregates as per the Mixed Design.

18.9 Innovations

During the Design and construction of this bridge, a number of innovations/firsts have been achieved. The list of innovations/firsts is as under:

- The Heaviest bearings ever used in any bridge in India. Total weight of bearings is 42.0 MT and maximum capacity 4000 MT. Physical Weight of bearings is shown Table 4.
- Longest span Pre-stressed Concrete bridge (160m) in India.
- The fastest construction of any P.S.C structure in India for a bridge of 280 m length.
- The shortest time cycle consistently achieved for the construction of each pair of segments (06 days).10.13
- Concrete Mix with minimum cement content of 400 Kg for M 50/43 grade used in India along with Admixture (cement used O.P.C 43 Grade).

  Fe 500 steel for Reinforced bars used for thefirst time in India in a cantilever construction bridge.
- Pre-stressing being done after only 60 hours of casting of each segment.
- The concrete below bearings done by Conbextra grout for the first time. Self Compacting Concrete (S.C.C) used for the first time for concrete below the bearings.
- The depth of Girder in the Central Portion is 3.40M for 160 m span. This has a high span depth ratio of more than 47.
- Total concreting with automatic batching concrete plant and concrete pump. Concrete mixed transported and placed untouched by hand for a cantilever construction river bridge in India.
- Use of Electrical Passenger Hoist for Inspection used first time in India for river bridge.
- Use of surface retarder & curing compound for cantilever bridge.
- 43 Grade Cement used for 50 MPa concrete for the first time.
- Fastest Approval of Founding levels for execution.
- Segments on both sides of the Pier concreted simultaneously balancing the weights by doing synchronized casting for the first time.

Conclusions and Recommendations

Technical and administrative decisions should be taken on merit and based on the available technology after proper analysis. By taking bold decisions not based on hiding or camouflaging the acts of the past mistakes this bridge has seen the light of the day. Our felicitation to all concerned. Conclusions are as follows:

1. Sites where the velocity of the flow of water is high i.e. more than 4M m/s and where the bed is conglomerate, soft stone, bouldary etc. (in short difficult to penetrate) such type of construction of continuous long span bridges are recommended.

2. Other countries are achieving construction of spans of around 200 m. We should also explore constructing such large spans.

3. The grade of concrete designed for used in this bridge for superstructure was M50. It is recommended that for such large spans grade of around M80 and above should be targeted. This will reduce the cost of construction as well as the dead load of the superstructure. Incidentally, in this Bridge M50 was achieved in the first trial mix with minimum cement of 400 kg/m^3 content and normal admixtures.

4. Continuous survey of the levels and centre line with the help of total station is a must for these type of structures. In this bridge continuous checking of deflections and the centre line as per the approved drawings as conceived by the design consultant and as per the approved drawings and as actually observed matched like a 'T' and there were no variations. Thus the linking segment was cast at the same level on both ends in elevation with a matching centre line.

5. Time is the essence of the contract and 'Money is the cause of it'. The department by its action in this bridge has shown that in spite of stiff financial conditions there were no conflicts and Perfect Harmony was maintained during execution.

6. For time bound important projects, team of Officers who start the project should be made to complete the same to ensure continuity of command, accountability, efficiency and satisfaction of the team.

7. When the 22nd segments were facing each other and the shuttering of the 23rd segment i.e. the linking segment was to have been placed there was no level difference and the levels matched on both tips to the nearest millimeter both in plan (centre line) as well as in elevation. This was possible because every day the levels were maintained by a team of surveyors with the help of total station. These levels were sent to the Design consultant who monitored these personally. In fact after the concreting of each segment the levels actually measured and as envisaged by the designer fitted almost like a 'T'. This proves that the parameters fixed by the Design consultant and the parameters as actually achieved during execution were complimenting each other. The cables were so placed that almost all the cables were straight and without any kink. Thus pre-stressing results were exactly as shown in approved drawings both in terms of extension and gauge pressure.

8. The area where the bridge is located experiences extreme weather i.e. extreme cold and extreme hot weather temperature vary from 5^0 C to 46^0 C. Concreting in this extreme temperature becomes risky as extreme heat results in microscopic cracking as the steel shuttering becomes very hot. However, it is during the extreme cold (temperature below 10^0 C when the cube results drastically fall from their targeted strengths). In this bridge while doing concrete during the Hot weather, concreting was avoided during the mid day and concreting completed by 11:00 AM by starting it early in the morning or starting it in the evening and completing the same in the night. During cold weather, the water was heated with electrical Heating Immersion Rods and Heating the same in preheated water tank by burning fire wood below dams. By this action the cube results were achieved.

9. On the advise of the Proof Consultants the reinforcements as required as per detailed design in this bridge was increased substantially in the Blisters. This led to early stressing without any problems/distress. It is recommended that reinforcements in blisters should be increased.

10. The bridge scheme was unequal, the river side span (half) was 80 m and the earth side was 60 m. Thus unbalanced moments had to accommodate in the Earth side by additional dead load. The difficulty in construction, and the risk of unequal moments could have been avoided if the land side span was made equal i.e. increased from 60 m to 80 m. This action would have reduced the risk without any increase in costs as executed structure has costed more.

11. The designer of this bridge has scrupulously followed the use of Tapering Sections, Haunches, and Chamfers for better and smoother flow of forces to avoid stress concentration and/or cracking. This method although required as per code has almost been forgotten. It is recommended that wherever force transfer is taking place, the old, tried and tested methods of easing of stress should be scrupulously followed. 12. During the last decade technology has advanced exponentially. Hence for all problematic bridges lying incomplete elsewhere adoption and adaption of the latest technology will definitely expedite completion as has been achieved in Chenab bridge if problems are reviewed afresh.