THE LONGEST BRIDGE ON THE WIDEST RIVER—INDIA'S LONGEST RIVER BRIDGE

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POST-TENSIONING INSTITUTE ®

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INTRODUCTION

The Dholla–Sadiya Bridge is a major bridge project in Northeast India across the Brahmaputra River that originates in Tibet and is roughly 3800 km (2400 miles) long. Several tributaries join with Brahmaputra including Dibang, Lohit, Dhansri, and Kollong rivers. During the rainy season, the river reaches its maximum width of 20 km (12.4 miles) at the river delta.

The Ministry of Road Transport and Highways (MoRTH) performed a feasibility study of the project in 2003 after a request from local constituents and in 2009, the bridge construction was approved by the MoRTH with funding from the Government of India as part of the Arunachal Pradesh Package of Roads and Highways.

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This bridge has a superstructure of 9.15 km (5.7 miles) and an approach road of 19.35 km (12.0 miles) built on the south and north sides of the bridge (Fig. 1). The changes in water levels cause the river to flood excessively in low-lying areas, including the area surrounding the Dholla–Sadiya Bridge that was renamed at the inauguration by the Prime Minister of India, Mr. Narendra Modi, as the "Bhupen Hazarika Setu."

The bridge was designed with the precast segmental span-by-span method of construction (Fig. 2 and 3). It has two lanes of traffic plus one emergency lane to divert traffic when needed.

Segments were cast near Pier 13; a casting yard was set up with three long-line beds and one curved-span bed.

The average amount of segment production was 69 per month out of the total scope of 2745 segments over the period of nearly 5 years.

During the construction, the river flooded to its peak nearly three times, halting the construction work. As a result, the overall time for construction was extended by

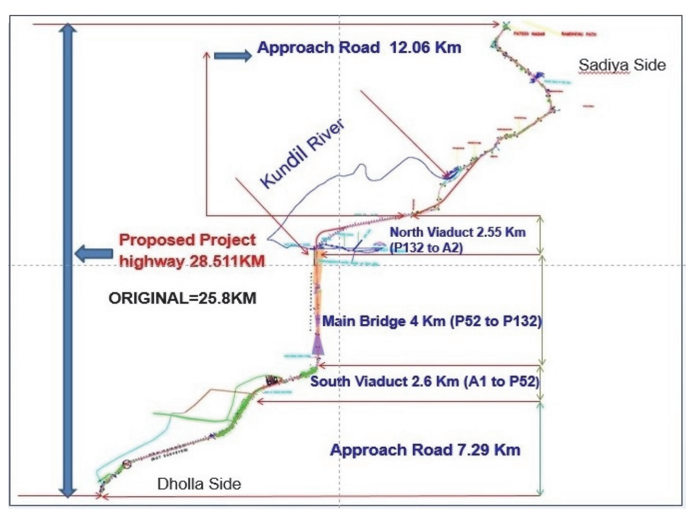


Fig. 1—Project scope.

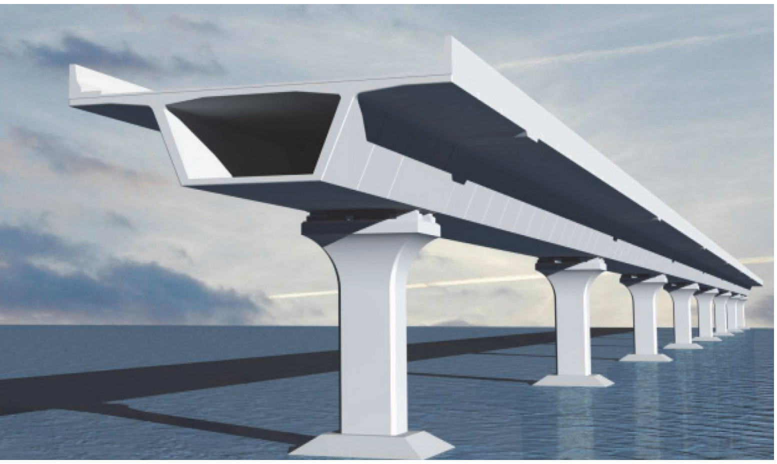


Fig. 2—Precast segmental span-by-span bridge

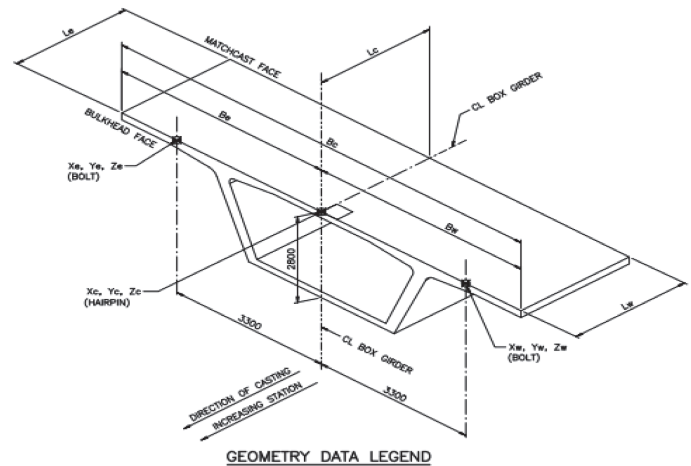


Fig. 3—Typical bridge cross section.

STRUCTURAL DETAILS

Substructure:

- Pile depth river: 39 m (128 ft)
- Pile cap volume of concrete: 92.16 m^3 (3250 ft^3) (Viaducts) and 135.88 m^3 (4800 ft^3) (Main Bridge)
- Pier size, pier cap size once section: 4.7 x 3.5 m (15.4 x 11.5 ft)

Bearing type:

- Elastomeric, approximately 750 x 750 x 125 mm (2.5 x 2.5 x 0.4 ft)

Superstructure:

- Pier end segment height: 2.80 m (9.2 ft)
- Width of segment: 12.90 m (42.3 ft)
- Standard and deviator segment height: 2.80 m (9.2 ft)
- Pier end segment length: 2.255 m (7.4 ft) × two segments/span
- Typical segment: 3.500 m (11.5 ft) × 13 segments/span
- Typical segment weight: 65 tonnes (72 tons)

Loading class and service:

- Bridge loading according to Class 70R and Class A as per IRC-6 2014 (Indian standard)
- Approximate amount of river water discharged in peak through bridge: 850 m^3/s is (30,000 ft^3/s)

Total quantities:

- Total substructure concrete volume: 6795 m^3 (240,000 ft^3)
- Total superstructure concrete volume: 70,172 m^3 (2.5 million ft^3)
- Total structure reinforcing bar quantity: 21,308 tonnes (23,500 tons)
- Total Post-tensioning quantity: 2956 tonnes (3260 tons)

over 1.5 years. It is usually impossible to predict the impact of the flow of water due to natural and artificial conditions.

POST-TENSIONING FEATURES OF THE PROJECT

- Each span 16.158 tonnes (18 tons)
- Prestressing work tonnage: total bridge 2956 tonnes (3260 tons)
- Total number of spans: 183
- Span length: 50 m (164 ft)
- Segments: 15 segments per span
- Length of external PT HDPE duct used: 107,604 m (353,000 ft)
- Length of transverse tendon flat GI duct used: 164,700 m (540,000 ft)
- Seismic buffer PT bars: 364

Longitudinal post-tensioning tendons anchored in pier segments (refer to Fig. 4 through 6)

- Multistrand tendons with nineteen 15.2 mm (0.60 in.) strands
- Twelve tendons in each span with two future tendons
- Stressing force: 3700 kN (830 k) per tendon with multistrand jacks.

Transverse tendons: SF 506 type with four 15.20 mm (0.60 in.) strands.

Each strand was stressed individually to 195 kN (43 k) with a monostrand jack. Figure 7 shows the typical transverse tendon profile in the top deck of the segment.

Seismic buffer tendons: Longitudinal PT bars in all pier caps, Fig. 8

- PT bar diameter: 26.50 mm (1 in.)
- Length of PT bar: 2.19 m (7.2 ft)
- Stressing force: 500 kN (112 k)

QUALITY CONTROL OF POST-TENSIONING MATERIAL AND EQUIPMENT

Post-tensioning material quality control followed the project specifications:

- IS 14268 Clause II or equivalent to ASTM A416, "Standard Specifications for Low Relaxation PC Strand"
- IS 1343, Prestressed Concrete-Code of Practice
- MoRTH: For prestressing work (installation, stressing, and grouting); material acceptance criteria included corrugated steel ducts
- BS 4447/FIP-1993, Recommendations for Prestressing Anchorage Performance and Acceptance
- IS 4984: For plain HDPE pipes used for external post-tensioning work

Longitudinal post-tensioning (External tendons)

Anchorage Type M 1906 with nineteen 15.2 mm (0.6 in.) diameter strands (Fig. 9 and 10).

Transverse post-tensioning

Anchorage Type SF 506 with four 15.2 mm (0.60 in.) diameter strands is shown in Fig. 11 and 12.

Castings Type M 1906, M 706, and SF 505 are made as per Grade IS 210 Standard FG 20. Traceability of raw material was maintained for each batch. For every batch of castings sent to the site, random samples were selected and sent to a third-party laboratory.

The Anchorage Efficiency system tests were done at the Structural Engineering Laboratory at the Indian Institute of Technology (IIT), Madras. Load transfer and static tests were performed in accordance with FIP recommendations.

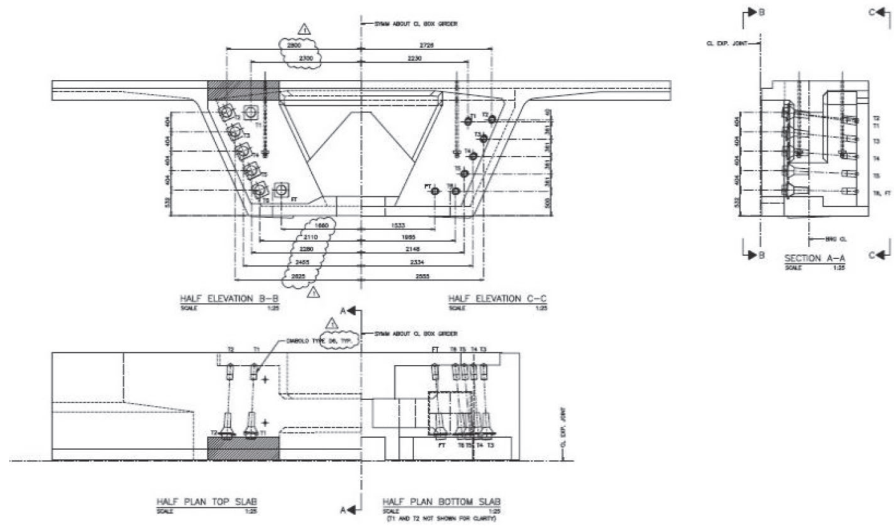


Fig. 4— Longitudinal post-tensioning anchorage in pier segments.

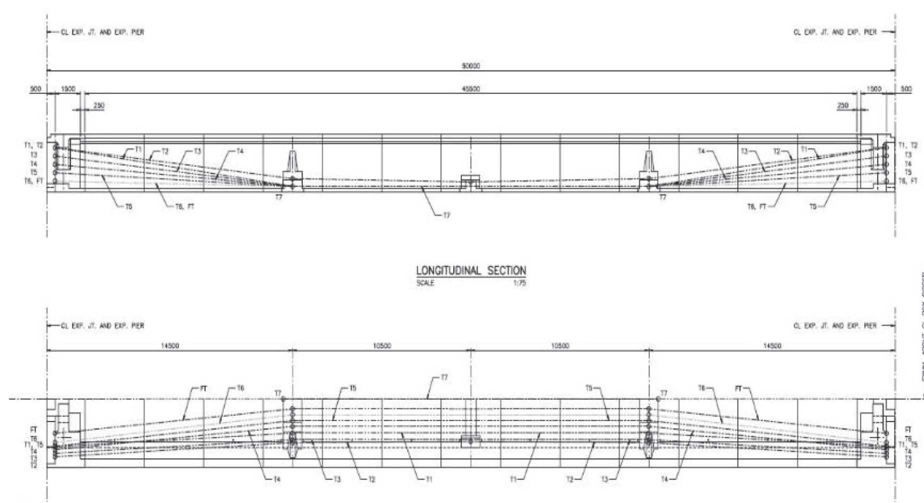


Fig. 5—Longitudinal post-tensioning anchorage in pier segments.

Fig. 6—Pier segment with view of longitudinal tendon anchorages.

Fig. 7—Typical transverse tendon profile in top deck of segment.

Fig. 8—Seismic buffer tendons.

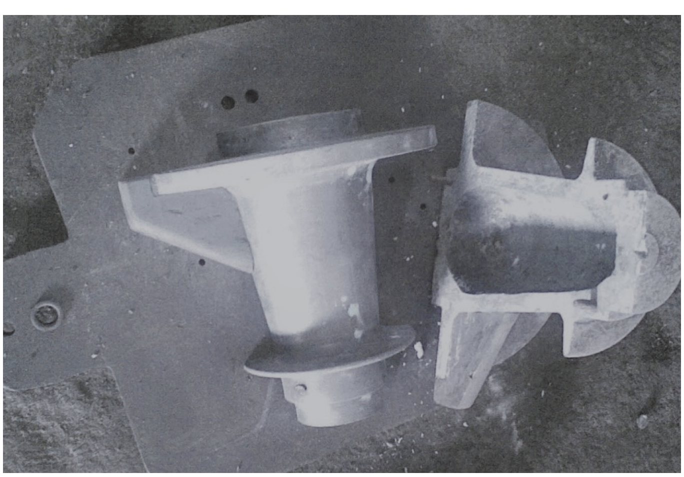


Fig. 9—Special bearing plate 1906: Inspection of mold and core box.

Fig. 10—Wedge plate 1906: Inspection of wedge cavity taper.

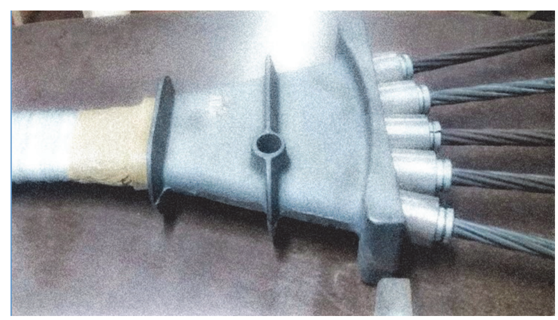


Fig. 11—Typical SF 506 flat anchorage.

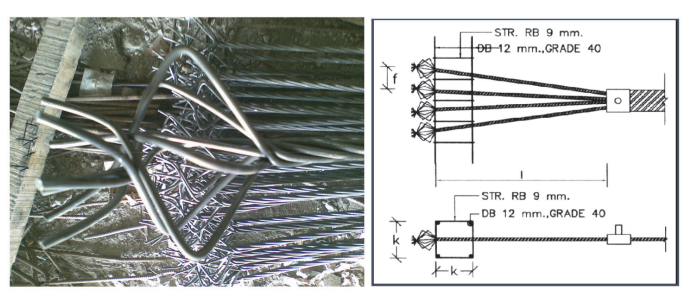


Fig. 12—The dead-end anchorage is a bulb-type with a bond length of 750 mm (30 in.).

QUALITY CONTROL TESTING

Corrugated ducts:

GI corrugated ducts used for transverse tendons were tested at the manufacturing facility in Hyderabad for the essential four tests in accordance with MoRTH specifications.

Workability test (Fig. 14 and 15)

- A test sample of 1100 mm (43 in.) length was fixed to a base plate and bent to a radius of 1800 mm (71 in.) for three cycles, and the joints were observed to ensure that no failure or opening took place.

Transverse load test:

- This test was done to determine if the stiffness of the duct is sufficient to prevent permanent distortion during site handling.

Tension load test:

- This test was done to ensure that the couplers and joints would hold the ducts under specified tension loads (refer to Fig. 16).

Water loss test:

- During the test, the 1100 mm (43 in.) length sample was sealed at both ends and subjected to a water pressure of 0.05 MPa (73 psi) for a period of 5 minutes, with the acceptable criteria of 1.50% loss of volume.
- A sample was provided with inlet and outlet as per Fig. 17 and water volume change before and after the pressure test was calculated to evaluate the loss to meet the specification criteria

HDPE pipes

The HDPE pipes are PE 100 PN6 DN 110, 110 mm (4.3 in.) OD for tendons T1 to T6 and 75 mm (3 in.) OD for tendon T7. They were tested in accordance with MoRTH specifications. The quality control tests covered dimensional, mechanical, and chemical properties at CIPET (Central Institute of Plastic Engineering and Technology, Hyderabad)

HDPE smooth pipe testing was done for every lot at CIPET in accordance to IS 4984.

Tests done at the laboratory:

- Hydrostatic characteristics as per IS 4984-1995 reaffirms the acceptance and type tests with sample subject to 80°C (176°F) and 5.7 MPa (830 psi) hydraulic pressure applied for a period of 48 hours and 165 hours, respectively. The samples should not develop any localized swelling, leakage, or weeping.
- Carbon black content test: IS 2530-1963, 2.50 ± 0.5%
- Carbon black dispersion: Shall be satisfactory
- Density test (kg/m^2): IS 7328-1992 940 to 958.4 kg/m^2

Equipment:

Post-tensioning jacks were manufactured at M/s Orione hydraulics, Belgaum Karnataka State, for the longitudinal and transverse Tech9 post-tensioning anchorage systems.

Before delivery to the project, calibration test (Fig. 18(a)) was conducted. Additionally, periodical efficiency tests (Fig. 18(b)) were conducted at the site in the presence of the consultant client engineer's team.

Fig. 13—15.2 mm (0.6 in.) three-piece wedge 45 mm (1.8 in.) length.

Periodic QA tests were conducted on PT materials at third-party laboratories for chemical and mechanical properties inspection.

All wedges on the project were three-piece, 15.2 mm (0.6 in.), 45 mm (1.8 in.) length (Fig. 13).

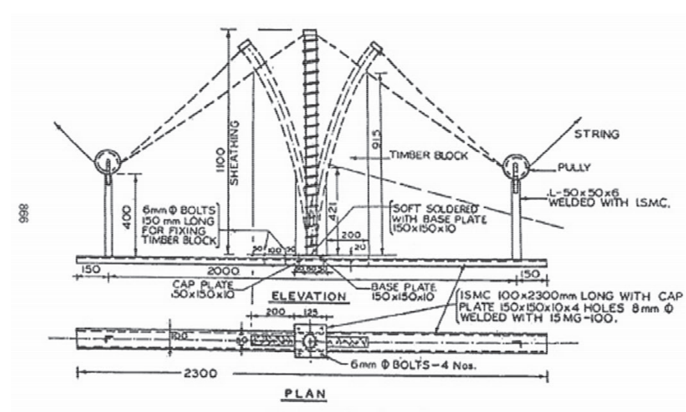


Fig. 14—Workability test setup.

Fig. 15—Workability test.

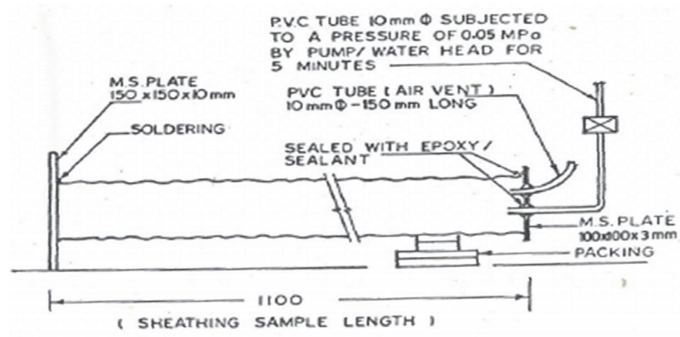


Fig. 17—Water loss test.

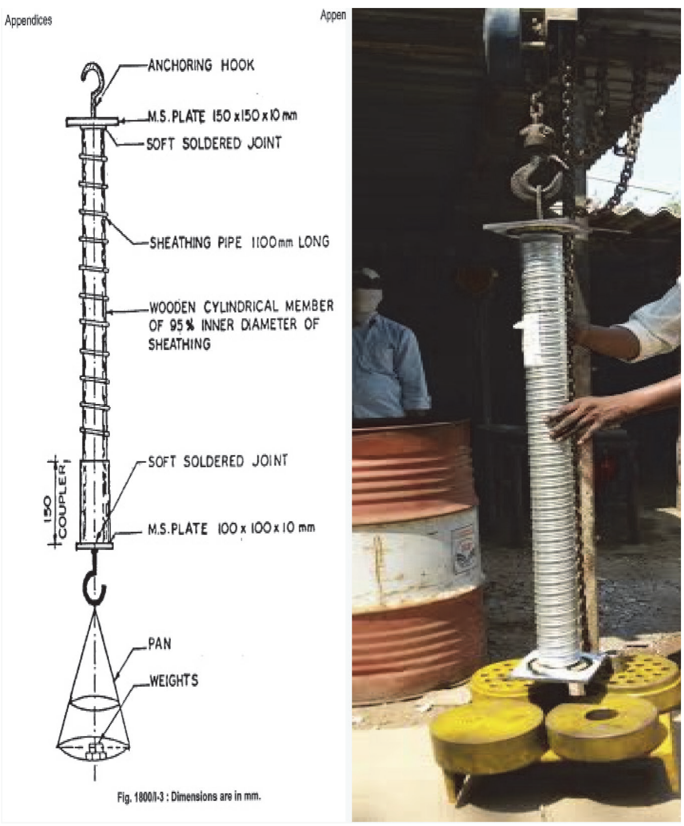


Fig. 16—Tension load test.

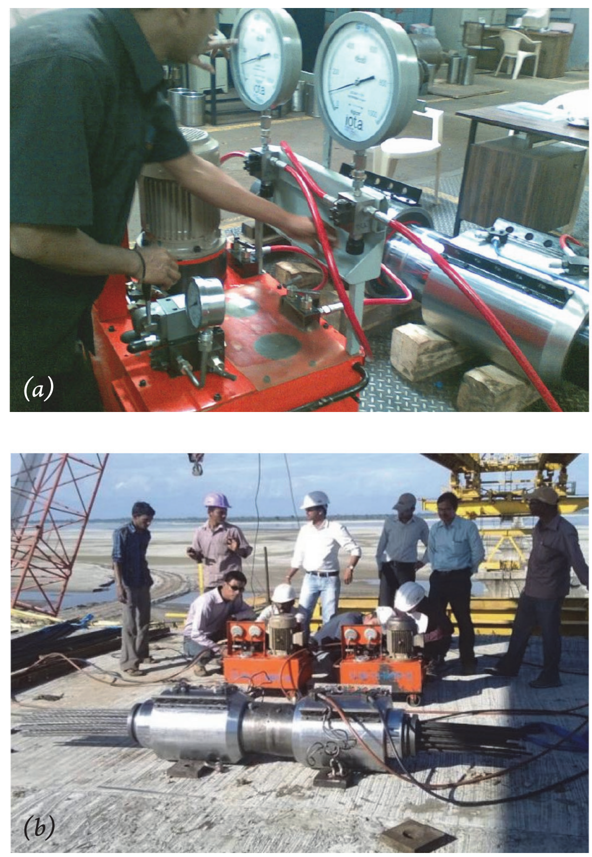


Fig. 18— (a) Jack calibration test; and (b) efficiency tests.

CASTING YARD WORKS

The casting yard setup started in 2010 and work on the first segment started in July 2011. There were 2745 segments in 183 spans in total; the main river bridge with 83 spans and the north and south viaducts having 50 spans each. All spans consisted of ten typical segments, one Type 1 deviator segment, two Type 2 deviator segments, and two pier segments (Fig. 19).

The casting yard work started by casting the Span-1 south viaduct. At the same time, construction of the main bridge segments occurred in another casting bed. Work in the yard was done day and night with four shifts maximum. The batching plant was set up close to the yard to achieve uninterrupted concrete supply and quality.

The precasting work occurred during the dry season because the bridge is in a valley between the upper Assam and Arunachal hilly terrain, making work during the rainy season difficult due to flooding. During the rainy season, rains were thunderous and continued for weeks once started. The weather at times was so unpredictable that for a few months, construction was halted.

Figure 20 shows the long-line setup for the casting of the first span segments.

Three 100 tonne (110 ton) capacity gantry cranes were used to move the segments from the casting bed to the stacking yard.

Average segment production was 69 segments per month with the casting yards operating from July 2011 to March 2016.

Prefabricated reinforcing steel cages were placed with lifting frames and positioned in the segment forms, with post-tensioning transverse tendons placed in advance to save installation time.

The first stage stressing of the transverse tendons was performed after the concreted reached 20 MPa (2900 psi). At this stage, the segments were moved from the casting bed to the designated yard locations per span sequence with gantry cranes (Fig. 21). The second stage stressing of the transverse tendons was done at 28 MPa (4100 psi) concrete strength. Segments were ready for erection after the concrete had reached 50 MPa (7300 psi)strength.

Duct production: Innovative concept implemented for duct production at site

HDPE duct

During the initial stage of the project for the first few spans, the HDPE plain ducts were produced and transported from the southern city of Visakhapatnam to the jobsite with a transporting on-road distance of approximately 2500 km (1550 miles). It had taken a time of approximately 28 days for the ducts with standard lengths of 9 m (30 ft) to reach the site.

The HDPE duct was transported in coils instead of cut lengths and this reduced high transport costs.

Later, the HDPE producer M/s Rupak plastics Vizag installed the HDPE plant directly at the bridge site, saving time and costs. Also, the same HDPE extrusion plant was further used for other bridges in adjacent states, thus resulting in further economy.

Thus, for all the spans, the HDPE duct was rolled to the required full length of tendons of 46.8 m (154 ft) (inside to inside of pier segments) and shifted to the site along with segment shifting trailers.

Steel corrugated duct

A steel corrugated pipe rolling machine and a flattening machine were also installed on site and took care of flat duct requirements for the project, saving time and costs.

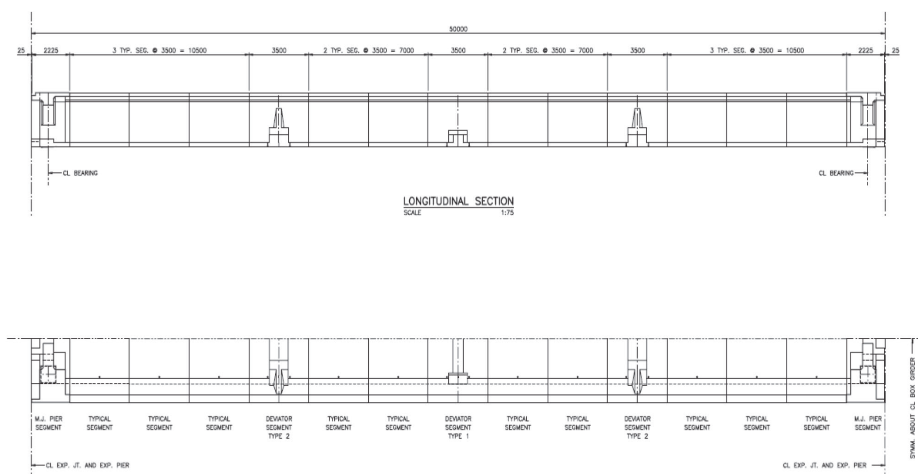


Fig. 19—Segment layout.

Fig. 20—Casting of first span segments.

Fig. 21—Segments moved by gantry crane.

Fig. 22—Bridge launching with trestles.

Fig. 23—Bridge launching with gantry system.

SEQUENCE OF WORK

Segment erection and stressing of longitudinal tendons (Fig. 24)

1. Segments moved from casting yard
2. Segment lifting, placing, and alignment started from the pier segment of each span
3. Temporary PT of segments
   3.1 Temporary PT done to the minimum force of 45 tonnes (50 tons) on each of the 26.5 mm (1 in.) diameter PT bars to get each segment aligned with the other continuous match-cast segments.
4. Once the temporary PT was completed and survey checks were done, the HDPE post-tensioning ducts were installed followed by threading of PC strands in each duct
5. Anchor head wedge installation on live and dead-end side
6. Stressing up to a force of 3700 kN (830 k) in the sequence T1, T2, T3, T4 as part of first stage to get the launcher suspension PT bars released
7. When the Stage-1 stressing was complete, the spans were jacked up by four span jacks, each 500 tonne (550 ton) capacity, and then the Stage-2 stressing was carried out. This jacking up further clears any overloading of suspension PT bars from the launching gantry
8. Once the Stage-2 stressing was done, further kinematic steps were performed until the next span segments were erected and aligned to get ready for stressing works
9. Stressing record form as per MoRTH is filled at every span
10. Grouting of longitudinal tendons
    10.1. Grouting works followed the erection LG sequence of work
    10.2. An average of three spans grouting planned at each time and the average cement consumption, field tests, and compressive strength of the 100 mm (4 in.) cubes were recorded in prescribed formats.

Safety:

A qualified safety engineer was on site for day and night shifts during the bridge erection works.

It is indeed a great achievement for the entire team that the total bridge work was completed without a noticeable accident.

BRIDGE LAUNCHING

The bridge erection took place as follows: South viaduct—ground launching system with truss (Fig. 22); the main and north viaduct—overhead gantry system (Fig. 23).

The first span segments were installed in March 2012 and continued until Span 49-50. At the same time, the LG assembly works at Pier 50 began.

The average speed of construction with the ground system was 6 days per span, and 2.5 days per span with LG.

The post-tensioning work was performed by teams working day and night shifts.

Erection schedule and post-tensioning

The span erection and post-tensioning works were well controlled, since both activities were done by Tech9.

The average span erection and stressing work together took 5 days per span, with the shortest and fastest one taking 2.5 days/span. On average, the duct and manual strand installation took 6 hours and the 12 longitudinal tendon stressing took also 6 hours. This time cycle was possible only after close supervision and effective training of the local workers.

A progress of up to nine spans per month was achieved with close monitoring of span erection kinematics.

Small team, big achievement

A team size of 12 skilled staff members and 60 workers was maintained for 'round-the-clock work and completed the construction work on time.

Zero accidents

Due to close supervision of span erection, the project was able to be completed with a safe working environment, free of accidents.

Technical issues and troubleshooting

During the project period, technical and general weather challenges were encountered.

Technical challenges

Interference of T1 and T2 tendon with LG

It was found that the T1 and T2 tendon anchorage line had an interference with the LG legs. Coordination with the LG designer and revision of the leg position accommodated the tendon stressing jack working area.

Curve kinematics

A curve with a radius of 1000 m (3280 ft) on the north viaduct had to be negotiated with the LG. With a

Launcher assembly.

Load test of launcher.

Erection of segments.

HDPE and strands installation.

complete step by step analysis, preparation was made at the site and made it successful till the final curve span was completed.

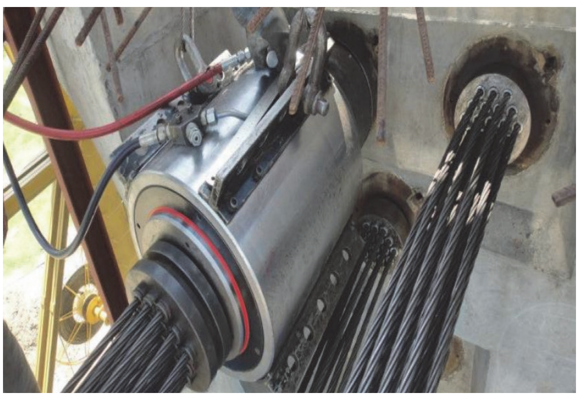
Curve kinematics of LG was negotiated by adding a supplemental support bracket to the false segment. Revised kinematic steps resulted in successful implementation.

Local challenges:

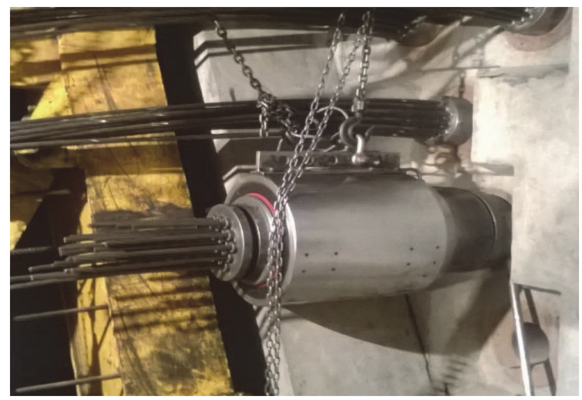
The Brahmaputra River was hit by the worst floods in the summer of 2012 and flooded twice more in 2014. In 2012, while the crew was industriously working on site, sudden flash floods resulted in submerging the single-span segments that were kept near the P50-P51 span and a new crane with a capacity of 60 tonnes (66 tons). Several smaller items of equipment were also washed away in the floods.

During this time, the virtual river width extended beyond 20 km (12.4 miles). The site personnel were rescued by military teams by boats.

It was challenging to rebuild the teams that got separated during floods and get back the working momentum.



Stressing of tendons Stages 1 and 2.



Stressing of tendons Stages 1 and 2.

Grouting of tendons.

Grout quality tests.

Grouting in progress.

Seismic PT bar stressing.

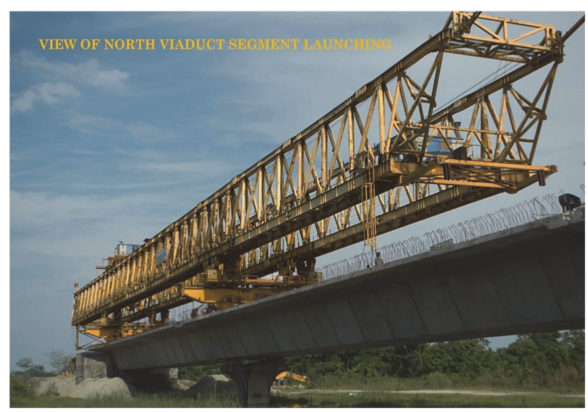
The construction journey started in July 2011 and was completed by June 2016, spanning 5 years of numerous struggles and challenges. The team feels proud to be part of India's longest bridge, which is earning several awards at reputable institutes.

PROJECT TEAM:

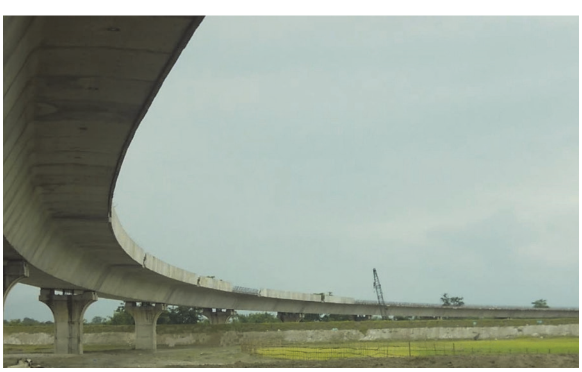
- Owner: MoRTH Ministry of Road Transport and Highways, New Delhi
- Concessionaire: Navayuga Dholla Infra Private Limited, Hyderabad
- EPC contractor: Navayuga Engineering Company Ltd, Hyderabad
- Project design consultant: Precast Bridge Tech, Bangkok
- Independent engineer: SN Bhobhe Associates & Voyants Solutions JV
- Post-tensioning and bridge erection subcontractor: Tech9 Engineering Solutions Pvt Ltd, Hyderabad
- Ground erection scheme designed by: Wiecon, Taiwan
- Overhead gantry design by: Comtec, Italy

South viaduct nearing completion.

Main bridge completion.



Final erection complete: May 16, 2016.



North viaduct nearing completion.

The post-tensioning and erection team.

Fig. 24—Sequence of work in pictures.

Flood during LG installation.

Segment erection on hold due to flood.

Cranes that got submerged in flood.

Site evacuated two to three times fully and camps rebuilt.

Fig. 25—Floods delaying construction.

ACKNOWLEDGMENTS:

Special thanks to:

- The Ministry of Road Transport and Highways, New Delhi
- M/s SN Bhobhe Associates, Mumbai
- Mr. C. Sridhar, Managing Director, Navayuga Engineering Co Ltd
- Mr. Sirajuddin, Regional Director, Navayuga Engineering Co Ltd
- Mr. B Diwakar Rao Sr., President, Navayuga Engineering Co Ltd
- Mr. B. Surya Raju, Chief Project Manager, Navayuga Engineering Co Ltd
- Mr. V. Shekar, Managing Director, Tech9 Engineering Solutions Pvt Ltd
- Courtesy: Reference to MoRTH specifications

INAUGURATION

On May 26, 2017, the Prime Minister of India, Mr. Narendra Modi, inaugurated the Dholla–Sadiya Bridge and named it after the prominent singer and musician of Assam state, Bhupen Hazarika.

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