# Poira bridge : Construction of India's first horizontal swing bridge

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*The paper covers the details of the Poira horizontal swing bridge, the first of its kind to be completed in India. There are a number of bridges with vertical opening of the superstructure for facilitating movement of ships / barges in the river / canal / sea but in this case horizontal opening of a super structure for navigation purpose has been provided. The paper gives full details of the salient features, design, construction testing, operation and maintenance of the bridges.*

***Keywords:*** *Poira bridge, horizontal swing bridge, rotation system, RCC counterweight span, bridge construction.*

Goa is a small, beautiful state on the west coast of India having numerous beaches and tiny islands of tourist interest. Hence, it is essential to reach all the places in a short time without hindrances and increase connectivity. The state of Goa is bifurcated by river Zuari into two parts – South Goa and North Goa.

Corjuem is one of the many islands of Goa and attracts many tourists to its historical old fort. The island is in Bardez taluka in North Goa. It is sandwiched between two streams of river Mapusa, a tributary of river Mandovi. Therefore, there was a need of two bridges to be constructed on these two streams – one in between village Aldona and village Corjuem and another one between village Corjuem and village Poira.

Both these streams are navigational channels and hence minimum vertical clearance is essential below the bridge superstructure for the barges / ships to pass without any difficulty. Aldona has a signature bridge with cable stays. With this bridge, Corjuem is connected with the rest of Bardez and the required vertical clearance is maintained on account of adjustment in obligatory span and positioning of the pylon.

In the case of this bridge (the horizontal swing bridge), 11 kva HT grid line passes over the location of the bridge. This grid supplies electricity to the states of Goa, Maharashtra and Karnataka. Due to the requirement of navigation, the superstructure must have minimum vertical clearance (2.64 m) above high flood level. Further, 7.20 m minimum vertical clearance is required between road top level over the bridge and electric grid. It was found that neither the location of the bridge could be changed nor the grid level could be raised to get required minimum vertical clearance.

Under the circumstances, it was mandatory to have horizontal swing of the superstructure to facilitate movement of the ships / barges. Taking into consideration these constraints, it was decided to have horizontal opening superstructure for this bridge. The layout of the Poira bridge is shown in Figure 1.

## Salient features of the bridge

1. Total length of bridge: 54.09 m with a movable central span of 37 m.
2. Length of approaches: 300 m on Corjuem side and 200 m on Poira side.
3. Loadings: Two lanes - class AA / One lane of class 70R as per IRC
4. Width of bridge: 12 m. with a carriageway of 10 m and footpath of 1 m on either side.
5. Width of approaches: 12 m with bituminous carriageway of 7.50 m wide and side drain with footpath and kerb of 2.25 m on either side.
6. Wearing course: 75 mm thick dense bituminous macadam with 50 mm thick bituminous macadam. 25 mm thick bituminous concrete with 12 mm mastic on bridge portion only.
7. Foundations: Open foundations for abutments and cast-

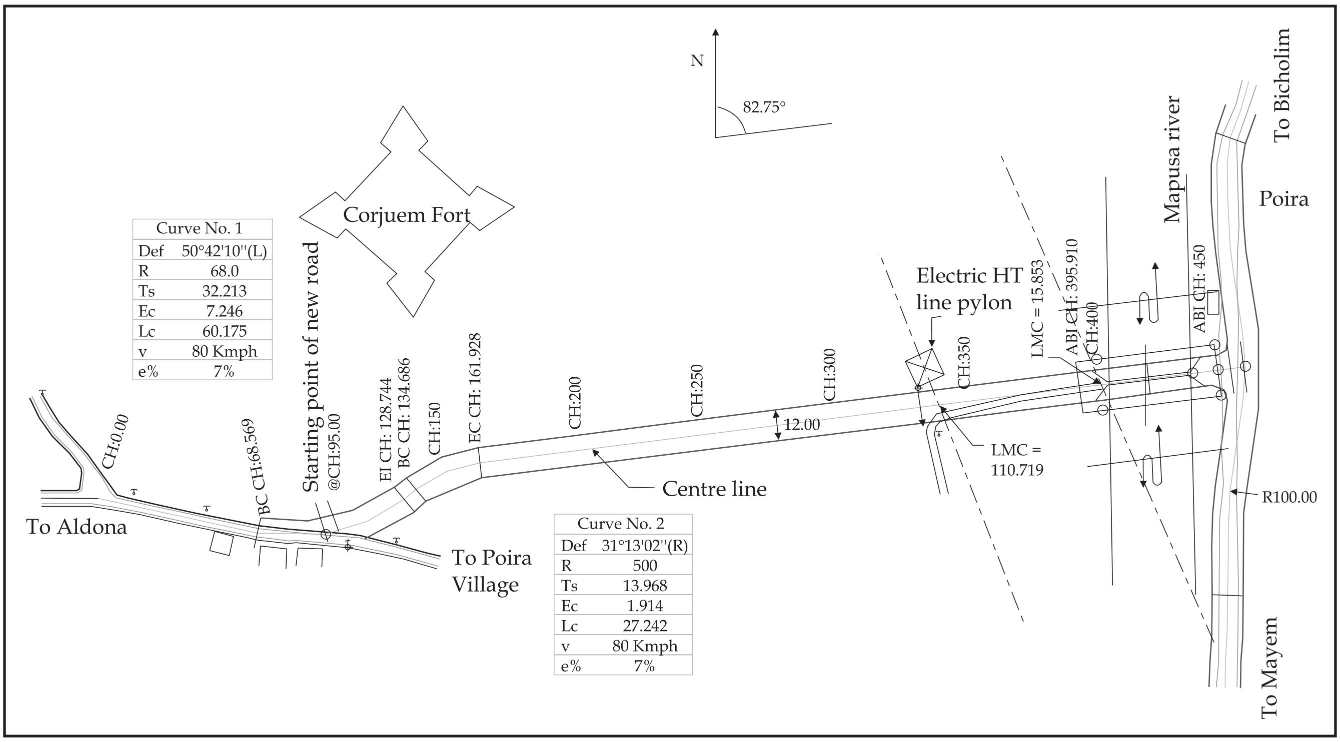


**Figure 1. Poira bridge site layout**

in-situ pile foundation with pile cap for piers.

8. Bearings: Neoprene bearings

9. Superstructure: Cantilever fabricated plate girders with RCC anchor span

10. Stitching of superstructure: By the prestressing of thirty-two 50 mm diameter Macalloy bolts.

11. Deck: 5 mm thick MS trough sheets with bituminous infill.

12 Hand rail: Pipe hand rail.

13. Rotation system: Manually operated: Designed for a vertical load of 700 t and bending moment of 250 t-m.

## Contract details

Cost of project: Rs. 4,23,50,000

Date of commencement: 15th March 2004

Completion date as per tender: 15th March 2005

Bridge was completed in December 2006, overcoming various difficulties and constraints, including land acquisition, non availability of material in time since it had to be imported.

## Design concepts

The bridge is horizontal swing bridge located over a navigation channel used by barges and small vessels. It consists of two swinging spans supported by rotation systems placed over pile caps on both the banks of the river. The obligatory spans are cantilever made of fabricated plate girders which are counter balanced by RCC anchor spans.

During normal working condition (open to traffic), these spans will rest on neoprene bearings mounted over pedestals of pile caps and abutment caps.

During opening the span is lifted by 50 mm using 4 hydraulic jacks provided in each rotation system and then rotated horizontally through 90° by using manual winches located on both the banks. The span is thus kept in open position for navigational traffic. While closing the bridge same operations are followed with swing in reverse direction. The design has been carried out, as per stipulations as per Indian Standards.

## General arrangement and configuration of spans

Figure 2 shows the general bridge and span arrangement. The bridge has two abutments and two intermediate supports. The abutments have open foundations while the intermediate supports are resting on cast-in-situ bored friction piles. The superstructure rests on neoprene bearings provided over the pedestals on abutment cap and pile cap. RCC piers have not been provided to the bridge and the rotation systems are mounted directly on the pile caps of the intermediate supports. Total bridge length of 54.09 m is divided into end spans/anchor spans of 8.545 m length and the obligatory span consisting of two cantilever arms, each measuring 18.50 m from centre of rotation system.

Figure 3 shows the RCC counterweight span. This span is provided to counterbalance the moments of the cantilever span during the operation of opening and closing. This particular span is simply supported while the superstructure is in closed position.

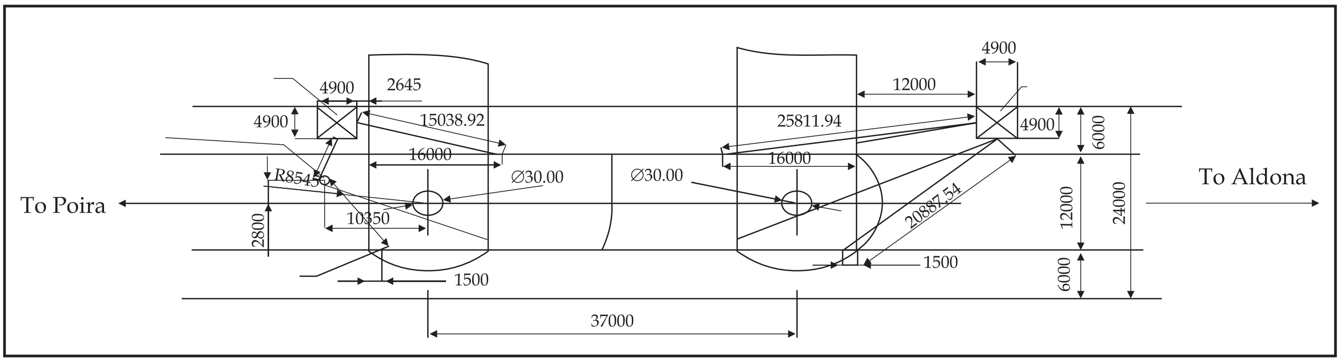


**Figure 2. Bridge and span arrangement**

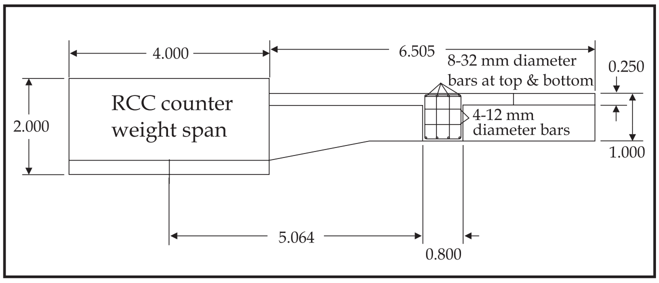


**Figure 3. RCC counterweight span (elevation)**

## Construction

### Sub-soil investigations

Sub soil investigation was carried out by a soil expert. Trial bores were taken at every pier location and at Poira side abutment along the centre line. Detailed soil investigation reports were prepared and the core boxes have been preserved for any future reference.

### Foundations

Pile foundations have been provided for piers. The type of pile used is bored cast-in-situ friction piles. Diameter of piles used in this project is 1000 mm with 8 mm thick MS liner. The liners are coated with one coat of zinc rich primer and two coats of coal tar epoxy for increasing corrosion resistance. It has been ensured that all piles are cast as per approved standard practice and stringent quality control has been maintained. Initial load test by conventional loading method and routine load test by dynamic method with pile integrity tests were conducted successfully.

For abutment, open type foundation has been provided. As surrounding strata is of marine sandy / clayey soil, RCC cofferdam was required to be provided on both the banks. Excavation was done manually by deploying cranes for lifting excavated material. Arrangement for dewatering like submersible water pumps and mud pumps were made to remove water from foundation pit and keep it dry. Pneumatic breakers were deployed for breaking hard rock. After reaching founding level of 94.00 m and shear key level, it was cleaned off of any loose soil and dressed to perfect horizontal plane.

The pile caps (where pile foundations are provided) are resting on the piles and the top of the pile cap is kept at required level as per GAD (General Alignment Drawing). After excavating the earth and exposing the pile top, piles were stripped off of concrete leaving 150 mm above PCC. Pile cap reinforcement was then tied and pile caps were concreted. The dowels of the pedestals were provided from the pile caps which were then cast with a groove for laying elastomeric bearings.

For open foundations in abutments shear key on the approach side of abutment was first cast. Then levelling course for raft was laid. After laying of reinforcement for raft, the raft was cast with dowels for solid abutment and return structure.

### Substructure

The abutment with return structure was cast in lifts of 1200 mm with 100 mm diameter weep holes provided at 1000 mm c/c. After reaching required level as per approved drawing, abutment cap was cast with MS pipe of 150 mm diameter for abutment anchors and dowels for pedestals which were cast later. The external faces of the pile caps and abutments which are exposed to earth were coated with coal tar epoxy.

**Figure 4. Completed bridge from Poira side**

**Figure 5. Completed bridge from upstream side**

## Superstructure

Superstructure consists of RCC anchor span stitched with fabricated plate girders using Macalloy bolts. First staging was erected as per approved staging scheme using beams and channels. After laying of girder soffit as per approved drawing, reinforcement was laid. Provision for hand railing, wire rope pulleys and MS trough sheet in the form of MS insert plates was made. 16 bright metal sheathing pipes of 4000 mm length was used. A pocket in cantilever portion of deck was left for accommodating prestressing jack. Arrangement in the form of MS pipe of 150 mm diameter for abutment clamp was provided. Thereafter, anchor span was cast using M35 grade concrete and cured.

Plate girders were fabricated at site using tested MS plates of various thickness and sizes as per approved drawings. Quality of welding was maintained by periodic checking of welded joints by DPT (Dye Penetrant Test), radiography and ultrasonic testing of critical joints. After welding and checking of joints, fabricated girders were sand blasted and painted using one coat of epoxy primer and two coats of epoxy paint having total thickness not less than 150 microns. To support one end of fabricated plate girders, 4 temporary piles were driven in river bed along the alignment and suitably braced. Temporary piles in form of MS liner, were driven to refusal in river bed and then filled with empty cement bags containing aggregates.

After casting of anchor spans on both banks, prefabricated and radiographically tested main plate girders and cross girders were erected using 70-t hydraulic crane on temporary piles driven in the river bed on one side and welded to end plates provided in RCC anchor spans on other side. After erection and welding of all girders in position, 5 mm thick MS trough sheets were laid along the span over cross girders and 11 drainage spouts were installed by cutting through MS trough sheets and welding at desired levels.

Approach slabs are provided on back side of abutment over bracket cast in dirt wall. For approach slab, filling in earth was done in layers on the back side of abutment and watered to be compacted. Over this, 900 mm thick laterite stone soling was done with murum infillings and compacted. Over this soling, levelling course was laid. After tying of reinforcement, the approach slabs were cast and cured.

### Stitching of anchor span and plate girders

Sixteen 50 mm diameter Macalloy bolts at each end were used for stitching RCC anchor spans with fabricated plate girders. Macalloy bolts were stressed to the required pressure using specially manufactured jacks and later pressure grouted with neat cement grout.

### Bearings

The bearings were specially designed and supplied by pre-qualified, specialist manufacturers. These bearings are placed over pedestals provided in pile cap and abutment cap.

### Rotation system

The rotation system has been indigenously designed and manufactured using special steel and processes. They are installed between anchor spans and pile cap to true horizontal plane. They are bolted at top and bottom by using high tensile strength foundation bolts. It supports the cantilever movable spans. The operation for opening of spans involves raising the movable spans and rotating them by means of rotation of the rotation system.

## Salient features of rotation system

1. Vertical load: 700 t
2. Unbalance moment: 250 t-m
3. Horizontal thrust at bearing level
4. Operation system: 20 t
   i) Jacking up with power jack: Diesel engine powered
   ii) Rotation of arms: Manually operated winch
5. Hydraulic jack : 4 nos., each of 400 t capacity on both sides
6. Power pack (diesel operated): 2 nos.
7. Winch with pulley and wire rope systems : On both sides
8. Hydraulic piping : On both sides
9. Side clamps on abutments (2 nos. On both sides) : 4 nos.
10. Central pinned joint : 2 nos.
11. Main bearing unit installed on the pipe cap : 2 nos.

Manufacturing of rotation system involves following processes:

1. Pattern making: Making of wooden patterns by providing adequate allowances for casting of main components of the system such as pile plate, jack plate, etc.
2. Moulding: Preparation of sand moulds by forming impressions of the patterns for castings.

3. Casting: Pouring of molten metal into the moulds and allowing it to cool and solidify in the form of desired castings.

4. Heat treatment: Annealing of poured castings for softening and removal of stresses from the cast components for deriving desired properties

5. Testing: Testing of castings and other materials were done at various stages of manufacturing and assembly in raw as well as finished conditions by ultrasonic tests and dye penetration tests for surfaces as well as internal crack detection. Mechanical property test, physical inspection for surface defects and size measurement were carried out. This testing was done after heat treatment to find out blow holes, internal cracks, etc.

6. Machining: Machining of castings and other components were done as per detailed drawings using processes such as turning, milling, drilling, tapping, threading, grinding, bending, straightening, etc. The machining was carried out precisely within the tolerances and specifications mentioned in the design, so as to suit its matching part in assembly.

   The most critical parts that needs utmost care are the rollers and race plates as these are required to be produced precisely within a very close dimensional tolerance and are subjected to the ultimate load during application, for which the system is designed.

7. Assembly: Fitting of all the components was done according to their sequence and they were fastened together with nuts, bolts and screws in their respective position.

   The most critical aspect of the assembling process is to ensure adequate clearances for moving parts so as to achieve free and friction less motion of rotating elements.

8. Mock-up trial of the rotation system was carried out successfully at Pune. The system was tested by reaction method using hydraulic jack pressure and rotated manually with winch.

### Winch cabin

Two winch cabins were constructed on both banks of the river for housing diesel operated hydraulic power pack and winch. Foundation for winch cabin was made with six 400 mm diameter cast in situ bored lined piles with pile cap and RCC raft. ISMC 100 channels were used as inserts for welding the winch to the foundation. Superstructure was of plastered laterite masonry with GI sheet roofing laid over ISMC 100 and 32 NB GI pipes.

### Approach and BT work

Approach consists of earthwork infilling on Poira side and earth work with part infilling and part in cutting on Corjuem side. Excavator (Caterpillar 320D) was used for cutting on Corjuem side. The excavated earth was tested for suitability and then used for filling in approaches (GSB - Granular sub-base).

Earth work was done by filling earth in layers. Each layer was levelled and then dry rolled, after which water was sprinkled and then levelled using static roller. Sand replacement method was used for determining density of compacted layer. After reaching required level, broken basalt was laid in two layers (WBM - Water bound macadam). Each layer was laid to required level and then soil of required plasticity was spread as infilling which was watered and broomed, after which it was levelled with a roller.

After finishing earth work, bituminous work was done. BT layers consist of 75 mm thick BM, 50 mm thick DBM and 25 mm thick BC. Before laying BM, WBM surface was cleaned manually and also with compressed air to remove any loose and deleterious material. Tack coat was subsequently applied and then BM was laid to the required level and profile using sensor paver. Similarly, DBM and BC were laid and finished. After BT work, thermoplastic paint was applied for lane marking as per IS specifications. Cat eyes were also installed at the centre and edge line as per specifications.

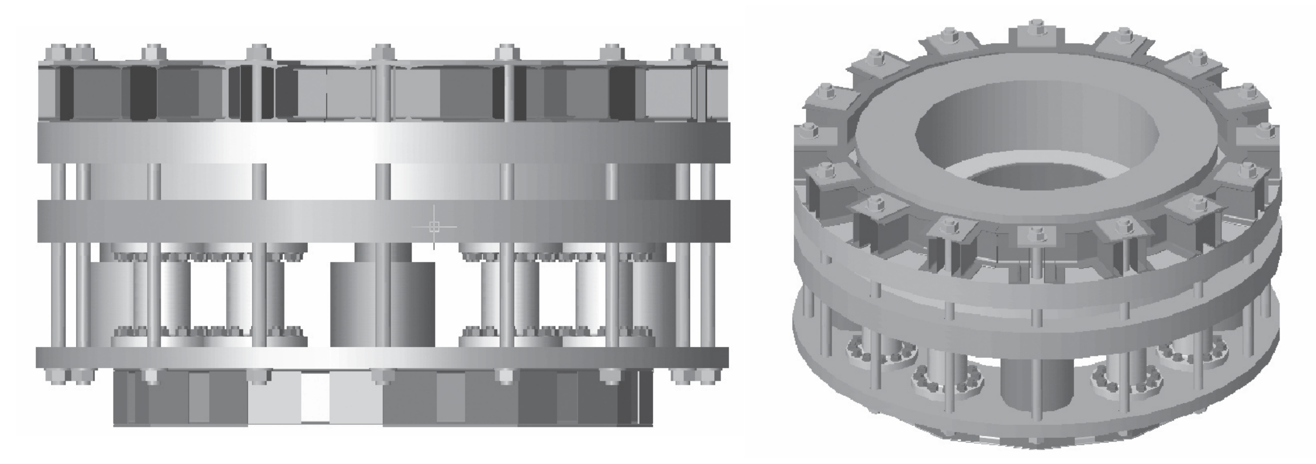

**Figure 6. Views of the rotation system**

### External painting

All piers, abutments and RCC structure up to 1000 mm above HFL are painted with one coat of primer and two coats of coal tar epoxy paint. For RCC superstructure (anchor span), one coat of a special paint and two coats of the relevant paint type have been used. For steel super structure, one coat of red oxide primer and two coats of epoxy paint of approved shade have been used. Oil paint was used for the kerbs.

### Side drains and footpath

RCC side drains of size 750 x 750 mm have been constructed along the inner edge of the footpath. Footpath is made up of interlocking paver blocks laid over compacted and levelled layer of river sand.

### Road illumination

Illumination of the approach road is arranged in staggered manner with street lights located on both the sides of the approach road in zigzag formation. This arrangement provides uniform lighting and better visibility on both sides of the road.

The poles considered for this purpose are of 'swaged type tubular poles' with overall height of 9000 mm. It was painted with red oxide primer and two coats of silver paint. Armoured cable was laid in trench along the inner edge of the footpath with sand cushioning and bricks on top.

## Challenges faced in the design and manufacture of the rotation system

1. Proper composition of steel for cast steel components
2. High capacity foundry for parts, with some weighing 10 t
3. Precision machining of heavy components weighing 10 t and 3 m diameter
4. Requirement of special grinding equipment which was not readily available
5. Choice and availability of proper material for main rollers and race plates
6. Heat treatment for rollers and race plates
7. Accurate grinding of rollers to have same diameters so as to avoid unequal loading on rollers
8. Erection and commissioning of system due to space restraint
9. Testing of rotation system under full load condition of 700-t at factory.

## Special features of rotation system

1. Main plates are of cast steel. This material composition was selected to for strength and resistance to corrosion
2. Roller bearings were selected for resisting thrust on the system,
3. Effect of variation of speed and twisting effect are eliminated by using split type design
4. Design was tailor made to suit the conditions at site for such type of horizontal swing type bridge.

## Load test

### Prior to load test

Take levels of girder tips with auto level at every hour for one full day prior to load test for profile correction due to temperature variation.

### Load test proper

1. Take initial levels at four above points – girder tips
2. Start loading sand bags at the rate of 500 kgs/$m^2$ over footpath on downstream side.
3. Take levels for instantaneous deflection after loading of footpath is completed
4. Net deflection due to load = Deflection observed-deflection due to temperature for that time of the day.
5. Maintain load for 1 hour Take levels again and note sustained deflections, if any.
6. Again calculate net deflection as above.
7. Repeat observations and calculations as above by loading, loaded vehicle no. I, II, III, IV, V and VI as per drawing.

## Operation of bridge opening and closing

### Operations before opening of bridge arms

1. Barricading of approaches: Close the road on either side with the help of barricading chain provided and put 'Stop' sign board.
2. Removal of pipe railing: Unbolt pipe railing on winch cabin side of both arms using spanner.
3. Remove central link and pins (2 nos.):

   Enter below the bridge deck using platform.

   Unbolt the bolts (4 nos) provided in the pins on the inner side.

   Remove roller bearings and collar bushes.

   Remove bolts provided in the pins on the outer side.

   Withdraw pins by holding link plates.

   Remove link plates
4. Remove abutment clamps (4 nos.)

   Unlock top bolt using specially prepared spanner.

   Unscrew Allen bolts provided on the sides of upper block.

   Remove thrust bearings and spacers from the block.

Slide out the link and disengage it from top shaft.

Gently lower the link.

5. Connect wire ropes (2 nos.)

   Remove Allen bolt from the sleeve provided in the Poira side approach slab.

   Insert stud.

   Place pulley in the stud.

   Install other pulleys in respective locations as per layout sketch.

   Engage the wire ropes to the hooks provided in the footpath of each bridge arm.

### Opening of the bridge arms

1. Take off the rotation table covers.
2. Check hydraulic oil in diesel operated power packs. Also check diesel level in oil tanks of the engines.
3. Take initial scale readings at the pedestals of pier cap and abutment.
4. Close the valve on supply line to manifold and jacks.
5. Check that hydraulic pressure is developed.
6. Ensure that lock nuts of all the jacks are raised in top position.
7. Open the valve gradually and slowly start increasing the hydraulic pressure by pushing the pressure lever. The pressure gauge shows pressure directly in tonnes.
8. Increase the jack pressure to 240 tonnes.
9. Open valves on the manifold and observe lifting of girder.
10 Lift girder uniformly by 50 mm above initial scale reading at pedestal locations (Lift of ram should not exceed 100 mm under any condition).
11. Lower ram lock nuts (only on Poira side).
12. Insert spacers (only on Corjuem side).
13 Slowly lower the jacks so that the jack plate / lock nuts rest on spacers.
14. Stop the engine and the power pack.
15. Make sure that there is no obstruction of any kind for rotation of the bridge arms.
16. Operate the winch in the direction marked as 'Open' and open the bridge arm on Poira side first.
17. After opening the Poira side arm by 7.5 m from its original position, start opening the Corjuem side bridge arm till both the arms are rotated through 90°.

### Closing of the bridge arms

1. Close the bridge sector on Corjuem side first and then on the Poira side.
2. Operate the winch in the direction marked 'close'. Close both the arms till they touch the side stoppers.
3. Close the valve on supply line to manifold and jacks .
4. Check till hydraulic pressure is developed.
5. Open the valve gradually and slowly start increasing the hydraulic pressure by pushing the pressure lever. The pressure gauge shows pressure in tones.
6. Increase the jack pressure to 240 tonnes.
7. Open valves on manifold and observe lifting of girder.
8. Lift girder by 10 mm.
9. Move ram lock nuts to top (only on Poira side).
10. Remove spacers (only on Corjuem side).
11. Slowly lower the jacks so that girder completely rests over neoprene bearings and see that the jacks rams are fully lowered.
12. Stop the engine and the power pack.

### Post closure actions

1. Fix the clamps on the abutments and see that all the clamps (4 nos.) are tightened.
2. Assemble the pin joints (2 nos.) at the centre of the bridge.
3. Remove studs, pulleys and wire ropes.
4. Remove road barricading chain
5. Fix pipe railing back in place.

The bridge is ready for road traffic.

## Problems and difficulties faced during construction

While carrying out boring for pile P-4 (Poira side), wire rope of chisel snapped and chisel fell. It got stuck at 30000 mm from top and could not be recovered. On account of this, additional pile had to be bored and pile cap had to be redesigned. The original pile bore was rejected and hence was filled with sand and plugged at top.

Additional land had to be acquired on Poira side for accommodating abutment and smoothening of road curve. On Corjuem side approach, additional land was acquired and bench cut was provided for stabilising side slope.

Road level of Corjuem side approach had to be lowered so as to have clear head room of 7200 mm as per Central Electric Commission’s requirement.

**Figure 7. Opening of one arm of the bridge**

**Figure 8. One arm of the bridge fully opened**

As there was increase in observed HFL, a protection wall around the rotation system had to be constructed for protection of rotation system from flooding during high floods.

## Operation and maintenance manual

An 'Operation and Maintenance manual' has been prepared considering all aspects of site conditions and covering various units of the bridge including the special rotation system

## Conclusion

Poira bridge is one of the marvels of civil engineering and it should be visited and studied by all Indian technocrats. The design and manufacture of the rotation system was done entirely in India, and mostly all the materials used in the structure are of Indian origin.

**Figure 9. The other arm of the bridge being opened**

**Figure 10. The other arm of the bridge fully opened**

Even though such type of construction was being carried out for the first time in the country, the cooperation of all the agencies involved along with the the strong backing of the client coupled with our past experience has made this endeavour a sucess without much constraints.


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