Zeitschrift: IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

Band: 14 (1992)

Rubrik: Poster

POSTER

Use of Prestressed Steel Flexural Members for Bridge Construction

Eléments métalliques précontraints dans la construction de ponts

Vorspannung von Stahlbiegeträgern bei Brücken

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SUMMARY

In past several decades there is increase in use of new forms and shape for buildings, bridges, dams, power station in which technological competence and economic awareness play an important role. One of most important method for reducing the cost of steel bridges is use of prestressing in steel structure. Use of open web section of high tensile steel with prestressing gives a considerable saving in overall cost of bridges.

1. INTRODUCTION

1.0.1 Design example presented here is of flexural member of a deck type bridge for class A loading. An effective span of 30.0m and thickness of R.C.C. slab inclusive of wearing coat is 250 mm have been considered. Conventional structure is compared with open web section of mild steel and high tensile steel without and with prestressing.

2. ANALYSIS

2.0.1 As four plate girder are provided at 3 m c/c.
The intermediate plate girder of bridge is subjected maximum load. Therefore maximum bending moment and shear force due to deadload, liveload including impact are

a) Maximum Bending Moment = 5686.74 KNm
b) Maximum Shear force = 786.00 KN

3. DESIGN

3.0.1 Bridge girder is designed for maximum bending moment and shear force due to deadload, liveload, including impact by using different type of section such as

1. Using solid web section of M.S.
2. Using open web section of M.S.
3. Using open web section of H.T. steel
4. Using open web section of M.S. with prestressing
5. Using open web section of H.T. steel with prestressing.

3.0.2 Open web section used for construction of bridge girder is made up of standard rolled angles with cover plate. Theory of open web section is very simple, it is ideally suitable section where bending action is predominent. For prestressing of girder tendon is placed externally below the girder section on tension side. It increases the efficiency of structure.

4. COST CALCULATION AND COMPARISION

4.0.1 Based on the design prepared for bridge girder the cost of construction is calculated and compared. It is seen that open web section of H.T. steel with prestressing helps in reducing the cost of bridge girder.

5. METHOD OF CONSTRUCTION

5.0.1 Prestressing of steel structure can be carried out by two ways. (1) Pretensioning the Structure (2) Posttensioning the Structure.
In the first method girder is prestressed before the concreting of slab. Thus opposite stresses are developed in girder only.
In the second method girder is prestressed after complete construction of bridge but before its actual use.

ACKNOWLEDGEMENT

Author acknowledges with thanks, encouragement given by authorities of V.R.C.E., Nagpur, in completing this work.

More Precise Design Calculation of Bridge Deck Beams

Calculs plus précis d'entretoises de ponts

Genauere Berechnung von Brückenträgern

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Precise design calculations of bridge deck beams develope in three general directions, depending on the subject taken into account: there could be, firstly, spatial work of bridge deck, secondly, the influence of span elements on the work of bridge deck elements and thirdly, the peculiarities of the real work of joint elements and, certainly, conditions of load transmission.

Recently the most important direction in calculations is considered to be the third of abovementioned, because the majority of defects in bridge deck appear exactly in places where different elements joint. Only the least defects appear in other places and it is connected with the work of corresponded elements under local load.

But the questions of the local distribution of bridge deck stresses (third direction) could not be touched with out the other aspects of design calculation because all this more precise definitions bring in corresponding changes in distribution of the bridge deck efforts.

All the mentioned problems of design calculation in each direction could be solved by different methods and with different elabovation of details of the structure design scheme. And so, it is difficult to use the same design method for working out all the problems that meets all demands in equal measure.

All these questions could be solved with finite element method. But, in practic, it is not expedientiy and not disirable. Firstly, the quantity of equation grows considerably justified, secondly,the unification of finite element doesn"t allow to consider all peculiarity of the design scheme; and, thirdly, it is appears to be the complicated problem to determine the coditions of joint transmission of load.

General design scheme of the structure is irregular. So it is incorrect to use the finite element method. For this scheme the superelement method would be more appropriate. But in this case it is necessary to determine stiffness matrix of superelement.

For the solution of the general problem the next ways had been planed. For the problems of the first direction variation methods were used. Bridge deck is considered to be the beam-system. This problem was solved by L.V.Semenets" method. With definite assumptions the received function of surface is the function of two variables and is expressed by trigonometric series. Fitnees of the function is well enough. Thus the three members of series is quite enough for acceptable solution.

This function of the surface may be used to determine the bridge deck stiffness matrix, as the matrix of a superelement. It is necessary to take as much members of series as is needed for the indepedent coefficients quantity to be equal to the quantity of superelament degrees levels of freedom.

The role of such approach is important, especially for wide bridge deck, because taking into account of flexures in traversal section allows to determine the real bending stiffness EI of bridge deck in vertcal plane.

Problems of second directon, where the influence of girder elements on load distribution are taken into account, are solved by means of expanding design schemes which was proposed by author of this paper. The very idea of expanding design schemes is to sequentially join the inloaded elements to the loaded part of construction. The influence of the part of construction that was not taken into account on each iteration is interpretated as resilient connections.

Influence of girder elements is substituted by equivalent resilient connections. The method for determination of resilient coefficients of connections was proposed both theoretically and practically. In practice all statistic characteristics are determine during the determination of resilient coefficients.

The method of estimation of the influence of statistic characteristics of resilient connections on the determined efforts valuex was proposed.

Each superelement which interprets the resilient characteristics may be present in the form of finite undeformable element with resilient connections. For such elements stiffness matrix can be determined.

Problems of the third direction could be solved by means of finite elemement or superelement method.

For the solution of a problem as a whole the superelement method with stiffness matrix which was determined beforehand is used.

The approach described allows to quite precisely solve the proposed global problem, which the design scheme peculiarities of each component problem"s part maximally preserved.

Second Thane Creek Road Bridge, Bombay, India

Deuxième pont-route sur la Thane Creek, Bombay, Inde

Zweite Thane Strassenbrücke in Bombay, Indien

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1. GENERAL FEATURES

This 1.835 km long 6 lane bridge across Thane Creek links Bombay and New Bombay. The bridge has two independent decks, each 12.37 m wide and supporting 3 lanes of traffic.

2. SUPERSTRUCTURE

The superstructure is in six continuous units, each continuous over maximum four spans, with a typical length of 321m for the unit. Each of the two decks consists of a single-cell prestressed concrete box girder of depth varying from 3.5m to 7 m. A continuous superstructure with spans of this order constructed by cantilever construction is probably the first of its kind in India. Each deck supports one carriageway for three traffic lanes, a 1.2 m wide footpath and a median verge and a maintenance walkway below the deck slab. The prestressing tendons are located only in the deck slab and soffit slab, keeping the webs free of any cables to facilitate concreting of the deep webs.The superstructure is built by the in-situ balanced cantilever construction method. For typical intermediate units cantilever arms are built up on either side of the three intermediate piers symmetrically and connected in between by key segments. At the two outer ends of this continuous unit, the deck will simply rest on expansion joint piers since hinges/articulations have been prohibited and additional internal counterweight consisting of cast in-situ PCC will be provided to ensure positive reaction at these supports for all loading conditions.

3. SUBSTRUCTURE AND FOUNDATIONS

The superstructure rests on four POT-PTFE sliding bearings with a centrally located lateral restraint. The RCC pier cap is located over a tapering RCC pier which rests on a RCC circular pedestal and a PCC plug cast inside a cavity excavated inside rock to minimum 1.5 m depth. Such open foundations are provided for all foundations except two at one end of the bridge for which caisson/well foundations have been provided.

Two alternative methods are used for the construction of the open foundations in the creek with water depths ranging upto 10 m. In the first method a short height (equal to depth of bed material) thin-shell concrete cofferdam is cast near the shore on a pontoon. The pontoon is towed to the required location and the cofferdam is lifted off the barge and lowered in position using a specially designed floating gantry. It is extended upwards with hollow segments of steel cofferdam during the lowering process. Thereafter the materials inside the cofferdam are excavated. A concrete seal is provided at the interface between the cutting edge of the cofferdam and rock, thus forming a barrier against water infiltration. Rock cutting, casting of PCC are generally done under dry condition and the upper RCC elements are always under dry condition. Once the RCC pier comes above high water level the steel cofferdam is dismantled and taken away for reuse. In the second method the sacrificial concrete cofferdam is sunk down to rock, like in conventional well sinking from a sand island formed inside a steel sheet-pile enclosure and the balance operations are similar to the other method.

4.DURABILITY MEASURES

In view of the highly aggressive and polluted marine environment, a number of precautions have been taken for enhancing the durability. In general, a four-stage anticorrosive treatment to all reinforcing bars, additional surface protective treatment for all elements in the form of m.s.liner/epoxy-based paint/sacrificial concrete cover, minimum concrete thicknesses, minimum concrete grade and cement content, high degree of quality control on materials, proper drainage of the deck etc. have been adopted.

5. ACKNOWLEDGEMENTS

The owners of the bridge are Public Works Department of Government of Maharashtra who have engaged as proof consultants, M/s. Rendell, Palmer & Tritton of U.K. The contractors are M/s.U.P.State Bridge Corporation Ltd for whom M/s. STUP Consultants Ltd. are providing Design and Construction consultancy services.

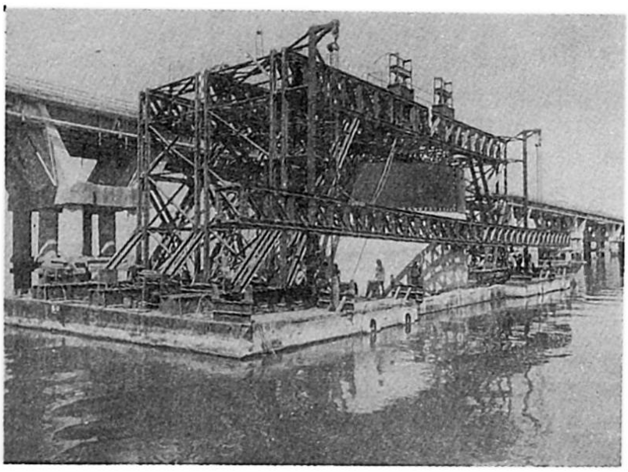

Fig. 1 Floating Gantry with Cofferdam Assembly

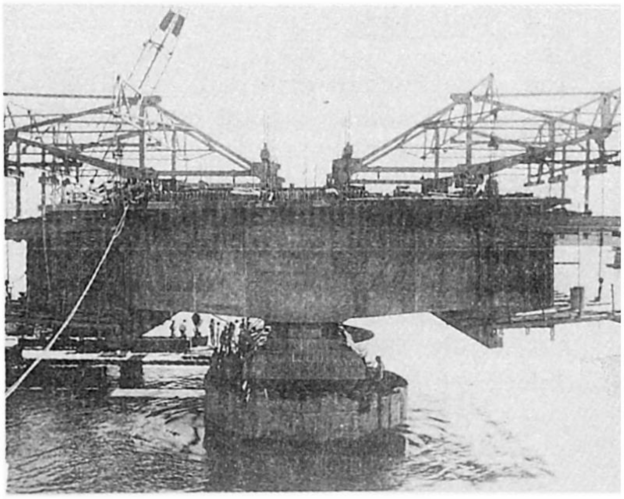

Fig. 2 Superstructure under construction

Two Railway Bridges across Vasai Creek, Bombay, India

Deux ponts-rails sur la Vasai Creek, Bombay, Inde

Zwei Eisenbahnbrücken über den Vasai Creek, Bombay, Indien

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1. GENERAL FEATURES

A large number of bridges have been constructed as part of the Indian railway network and till recently they have been in structural steel. Only during the last one decade or so prestressed concrete has been used in the construction of railway bridges. The two bridges across Vasai Creek are notable for the construction techniques adopted, the economy in material consumption and features enhancing durability. The two bridges are spread out over about 3 km length and have two independent decks, each catering to one broad gauge track. One bridge has 28 Nos. and the other 11 Nos., of simply-supported spans of 48.50 m length, totalling 78 girders.

2. CONSTRUCTION METHODOLOGY

2.1 Precasting

The prestressed concrete girders were fully precast and completed on the shore itself to ensure good quality control. Since land was not readily available for precasting yard at the site, it had to be reclaimed from the creek. In the limited space available the casting and stacking beds which were on piles had to be located with ingenuity for optimum serial and parallel sequencing of the various operations on the various girders in the casting yard. The structural designs were optimised to minimise the material consumption and the self weight of the girders to be handled. Since all the girders were precast at one location, the variations in the thickness of deck and soffit slabs and webs did not pose much problem for the design and repetitive usage of the shuttering.

2.2 Launching

At .the site, the creek had a tidal range of maximum 4.5 m and this was taken advantage of to evolve a simple but effective and economical solution for launching the girders. After completing all the finishing operations including addition of partial track ballast, the girder was brought to a launching jetty located at the end of the casting yard. A launching pontoon with a spreader truss was specially designed to handle the girders which had a finished weight of 750 t. The height of the truss was carefully correlated with the tidal levels and the levels at final location and the launching jetty was also accordingly planned. At low tide the pontoon is brought below the girder and as the tide rises, up the pontoon also rises and lifts the girder off the jetty. The pontoon is towed to site and positioned in final location at high tide. As the tide falls the pontoon lowers down and the girder on top gets seated at its location. Then the pontoon is withdrawn.

3. DURABILITY MEASURES

A number of measures for enhancing the durability were adopted such as giving a four-stage anticorrosive treatment to all reinforcement, surface protective painting for the girder, adequate cross drainage of the deck and waterproofing of the deck top, limiting the water-cement ratio for the concrete and grout used for sealing the ducts and protection against stray currents.

4. CONCLUSION

With proper prior planning, all the girders of the two bridges were successfully launched and located within the required accuracy. A load test has also been successfully conducted to check the performance of the girders. The owners of the project are Western Railway who had engaged as proof consultants, I.I.T., Bombay. M/s. Indian Railway Construction Co.Ltd. were the main contractors with M/s. Bhagheeratha Engineering Ltd as their associate contractors. M/s. STUP Consultants Ltd provided design and construction consultancy to the contractors.

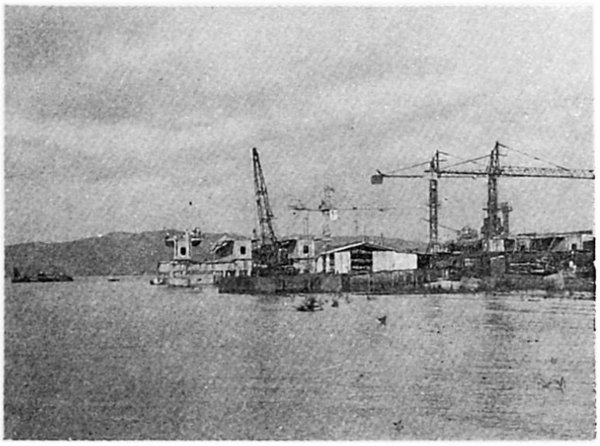

Fig.1 Casting Yard

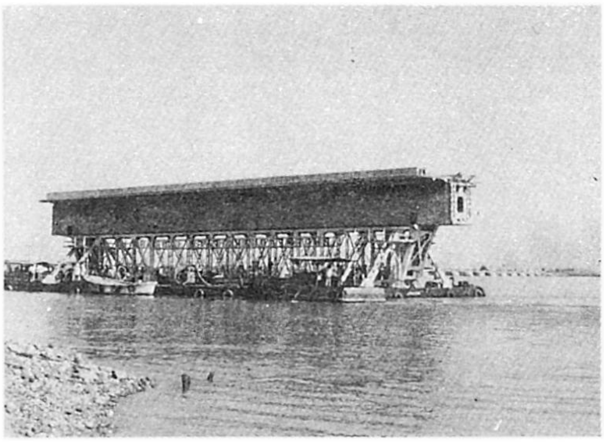

Fig.2 Girder being transported on a pontoon

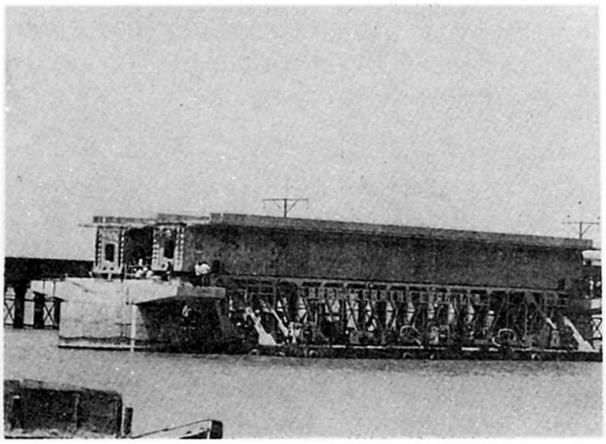

Fig.3 Girder in position

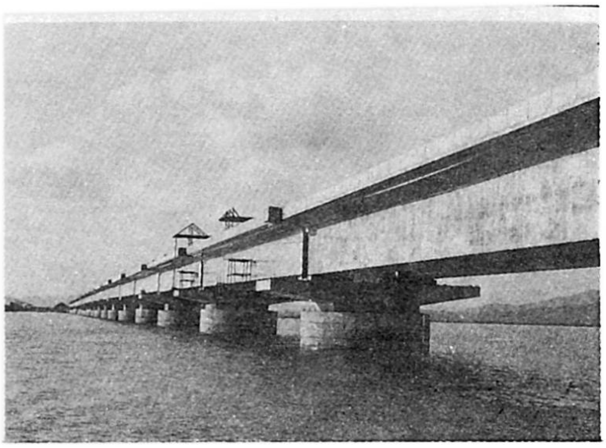

Fig. 4 Completed Bridge

Railway Bridges Constructed by Precast Segmental Construction Method

Ponts-rails construits à l'aide de voussoirs préfabriqués

Eisenbahnbrücken aus vorgefertigten Elementen

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1. GENERAL FEATURES

Railway bridges in India have so far been predominantly constructed using structural steel and only over the last decade or so prestressed concrete has come to be used as a construction material for superstructure of railway bridges. For three railway bridges located over marine backwaters near Cochin spread over about 5 Km length, prestressed concrete box girders constructed by precast segmental construction were adopted. The three bridges had 29, 5 and 4 simply supported spans respectively of 30.5 m length. Lack of adequate space and other site constraints restricted any major casting work at or near the site. Hence conventional cast in-situ working or precasting at site or elsewhere and launching the girders were ruled out. A system of precast segmental construction was adopted for these railway bridges for the first time in India.

2. PRECASTING

The girders were precast in seven segments by the match-cast long line system at a centralised precasting yard located about five kilometers from the site. Shear keys were provided on the matching faces. A travelling portal gantry was provided in the yard to handle the segments from casting bed to stacking beds and then on to a launching jetty supported on pipe piles. From there the segments were taken to the different sites on a pontoon towed by a tug. The maximum weight of a segment was about 35 t. Concrete brackets were provided to facilitate lifting of the girder in future to replace the neoprene bearings. Provisions for adding cables in future, if required, have been made.

3. ASSEMBLING

A travelling assembly truss system consisting of two independent rectangular trusses of about one and one-third span length was adopted for assembling the segments. Underslung cross trusses spanning between the main trusses supported the segments. An overhead crab travelling over the top of the main trusses picked up the segments from the pontoon below and placed them on the cross trusses. All segments were thus placed on the assembly truss with gaps in between. After applying an epoxy formulation on the match-cast faces, the segments were pressed together using temporary prestressing to cure the epoxy under pressure. Temporary prestressing was applied using HTS strands on top of deck slab and on soffit slab of the box girder. Thereafter permanent cables were threaded through, stressed and grouted. After assembling one span the trusses were shifted to the next span, with the front end resting over a trestle mounted pontoon and the rear end resting on a trolley moving over the previously erected span. After completing one bridge the assembly trusses were partially dismantled and taken to the next bridge. Thereafter finishing operations were carried out on the girders.

4. CONCLUSION

The precast segmental construction system proved to be the optimum solution for this site. A maximum speed of one span per week could be achieved with this methodology. The owners of the project are Southern Railways and the contractors, M/s. Bhagheeratha Engineering Ltd. M/s. STUP Consultants Limited provided design and construction consultancy services to the contractor.

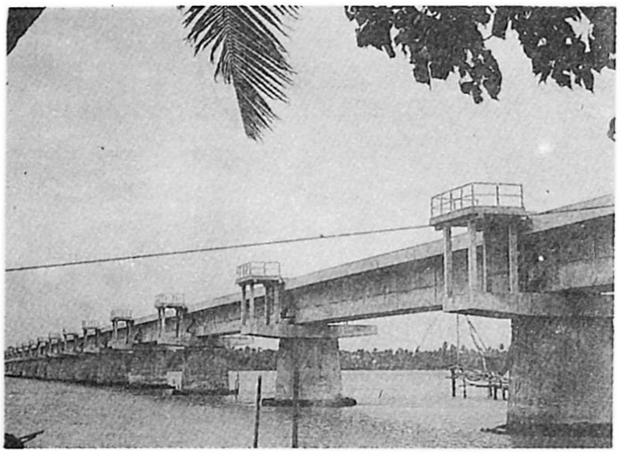

Fig. 1 Bridge at Aroor-Kumbalam

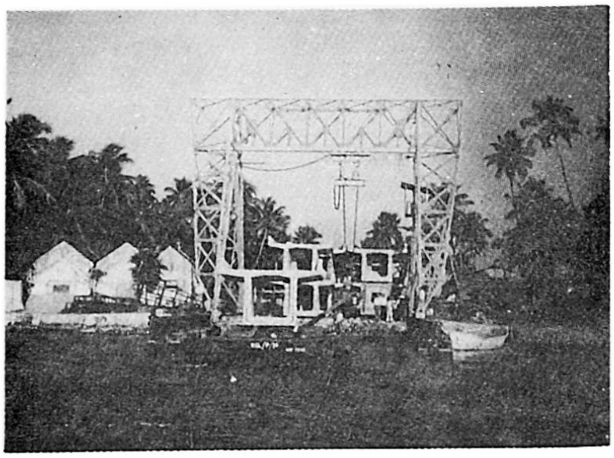

Fig. 2 Casting Yard

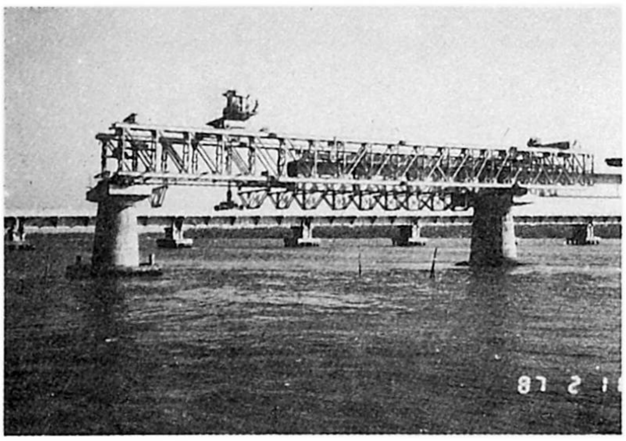

Fig. 3 Assembly of Segment

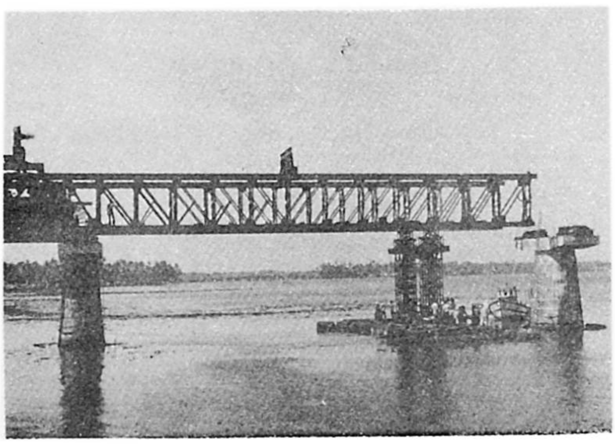

Fig. 4 Movement of Assembly Truss

Bridging Pamban Strait near Rameshwaram Island in India

Pont sur le détroit de Pamban, Inde

Die Brücken über die Pamban Meerenge, Indien

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1. INTRODUCTION

This bridge linking the Tamilnadu Main land and the Island of Rameshwaram is the longest bridge across Open Sea in India. The scope of work consisted of completing major portion of the bridge which was partly executed by a local contractor and left on account of technical and other problems. The completion of this bridge was a formidable challenge on acccount of the Open Sea as also the area being prone to frequent cyclonic storms, one of which had resulted in disruption of the initial work.

2. SALIENT FEATURES

This bridge consists of 53 non-navigational simply supported spans on Mandapam side and 12 non-navigational spans on Pamban side each of 27.13 M with 9 additional via-duct spans of 27.58 M on a curvature across a Railway track underneath. The bridge also provides one navigation span of 115.21 M and 2 adjacent anchor spans of 68 M with 2 non-navigational spans of 40.69 M one each on either side of the navigation span.

3. DESIGN ASPECTS

The bridge provides for a 7.5 M roadway for vehicular traffic with 1.57 M footway on either side. The simply supported spans consists of 4 Nos. of precast PSC girders while the navigation and anchor spans consist of a single cell box girder of 5.5 M width with projecting deck slab covering the full width of roadway and footway and kerb amounting to 11.10 M.

The bridge is designed for the critical of the following live loads :

i) Crowd load of 500 Kg. per sq.m. over the entire width of carriageway and footpaths.

ii) Two lanes of Class A with crowd load on footpaths.

iii) One lane of Class 70R with crowd load on footpaths.

The box superstructure is also designed for temperature differential as per BS:5400 - Part 4. Untensioned mild steel reinforcement is provided in the box decking to cater for 15 percent loss in prestress in addition to the losses worked out as per codal stipulations.

Tetron spherical bearings (S3) manufactured by M/s.Freyssinet International, France are provided below suspended spans. The bearings were chosen since they can accommodate rotation upto 3 degrees and are made of aluminium alloy hence corrosion-resistant.

Since the bridge is located in an aggressive marine environment, special care had to be taken in specification, design and detailing of various components of the bridge.

4. CONSTRUCTION ASPECTS

The PSC girders for simply supported spans were precast and launched into position and the decking was cross-prestressed after casting the gap slabs. The original scheme envisaged precasting of the PSC girders with flanges just short of touching each other which were transversely prestressed after filling in the gap with dry mortar. Since this resulted in threading difficulties for the transverse cables on account of the differential hogging, the scheme was altered to introduce an insitu gap between the flanges to provide a smooth transition for the transverse cables.

The box superstructure was constructed by the cantilever method. Extreme precaution and precamber control was necessary to ensure matching of part of decking cast over rigid support of staging at the anchor pier and the decking cast on the main navigation pier with cantilever construction gantries.

Mild steel reinforcement is given anti-corrosive treatment developed by CECRI, Karaikudi.

The bridge has been instrumented for the temperature and stress monitoring in the navigation spans.

Bridging the River Alaknanda for Badrinath Shrine in Himalayas

Pont sur la rivière Alaknanda dans l'Himalaya

Die Brücke über den Alaknanda in Himalaya

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1. INTRODUCTION

This bridge located in a picturesque Himalayan ranges across the river Alaknanda leads to the Holy Shrine of Badrinath, consecrated by the great philosopher and preacher 'Adi Shankaracharya'. Bridging across a deep gorge of over 37 M was a challenging task, as the fast flowing river underneath has all the risks which demanded a long span bridge with hardly any space available for balancing the cantilever construction. The bridge provides for a 7.5 M wide roadway for vehicular traffic with 1.5 M cantilever footway on either side.

2. SALIENT FEATURES

The total length of the bridge as finally constructed is 125.1 M between the faces of the dirt walls of the abutments. The bridge is located in a highly seismic region, it was, therefore, necessary to reduce the seismic forces transmitted to the base of over 33 m tall piers. This was achieved by providing a 3 span continuous bridge with a span configuration of 25.7 M x 68.8 M x 29.7 M.

To keep in with the aesthetics of the locale it was proposed to provide a uniform depth box of 4 M for the entire length of the bridge, though not an ideal proposition for a bridge located in seismic zone. With a view to reduce the forces on the piers, the hollow circular piers of 5 M were provided with roller bearings on top. This enabled not only to reduce the longitudinal forces but also forces due to high water current. However, in order to provide stability and avoid tension at the base, it was necessary to fill up the lower portion of the hollow piers with mass concrete. The balancing effect of the cantilever construction as also the transient loads was countered by housing the shore spans inside the end abutments. This provided the necessary dead weight to counter the uplifting forces. The bearings used at the fixed end are of spherical type. The spherical bearings were adopted so that they would reduce the rotational restraints. The bridge is prestressed longitudinally by Freyssinet cables consisting of 12 Nos. of 1/2" dia. strand with braking force of 2250 kN.

3. DESIGN

The deck is designed for IRC Class A / Class 40R - two lanes or Class 70R single lane of traffic whichever produces severest effects in addition to footpath loading as per IRC. The deck is designed as a Class I structure with no tensile stresses permitted, as the present codal provision do not permit partial prestressing.

4. CONSTRUCTION

The unsymmetrical span configuration demanded caution while taking up the construction activity for the deck in the central span. It was, therefore, felt advisable to cast the shore spans on staging first, before taking up the cantilever construction using cantilever construction gantries. The cantilever construction involved successive casting of 3 M segments progressively from each end and then joining by central continuity unit of 2.8 M. The local sand available being of finer variety, to improve and attain a mix of M-40 grade, it was necessary to mix the crusher dust together with admixtures. The footpath and other miscellaneous activities were taken up soon after establishing the continuity.

Though the bridge was awarded in 1983 due to difficult terrain conditions and approach to bridge site getting blocked due to heavy landslides, the completion of the bridge got unduly delayed.

Successful completion of the project has helped the pilgrimes to bridge the gap to Badrinath Shrine by one additional step.

Bridge across Mond Creek near Ratnagiri, Maharashtra, India

Pont sur le Mond Creek, Inde

Die Brücke über den Mond Creek, Indien

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1. INTRODUCTION

This prestressed concrete long span bridge could be called the first of its kind to adopt Limit State Philosophy with partially prestressed decking.

The long span continuous bridge proposal finally adopted is a modification to the original contract which consisted of 4 Nos. of 45.56 M of intermediate spans and 2 Nos. of 42.75 M end spans. There were 6 Nos. of well foundations with depth varying of 10 M to 30 M. As soon after starting the foundations, the subsoil exploration revealed that the wells required substantial sinking, to reach the sound rock. It was also realised that there were difficulties in precasting the PSC beams on the banks. This led to a long span continuous deck with a lighter weight to ensure the foundations, already undertaken, would meet with the design requirements. Therefore, a partially prestressed concrete decking was a necessity. As the prevailing IRC codes did not permit such lattitude, the authorities agreed for a Class 2 structure as defined in BS:5400.

2. SALIENT FEATURES

267.70 M long bridge consists of two intermediate spans of 92.20 M each and two end spans of 42.65 M each. The continuous decking between abutments provides for a 7.5 M clear roadway. The decking is supported on C.S. rocker-cum-roller bearings at the abutments and the penultimate piers. The decking is monolithic with a central pier, about which it is symmetrical.

All the piers are of plate type and supported on the well foundations with 7.8 M diameter for the penultimate and 8.5 M for the central pier.

The superstructure consists of single cellular box of overall width of 4.5 M over the webs and 8.10 M at the deck level. The box depth varies from 4.925 M at the piers to 2.065 M at the ends.

At the abutments, the end 3.0 M of box decking is widened to three cell box of 7.83 M overall width and is filled up with plum concrete to counter any uplift at the abutments. Further, the dirt wall of the abutment has been provided with a bearing beam at the top to hold down the articulated half joint of the webs. This was done as a measure of abundant precaution.

3. DESIGN

The bridge is designed for IRC 2 lanes of Class A or Single lane of Class 70R/AA loadings.

The superstructure is designed following the guidelines of BS:5400 Part 1,2 & 4 - 1978 as a Class 2 type structure. The IRC roadway loadings were considered equivalent to as BS Normal traffic loadings, for consideration of safety factors only, in the design.

4. CONSTRUCTION

All the well foundations were constructed by the sand island method except the central well, which was floated and sunk at location by the floating caisson method.

The superstructure was constructed insitu by using conventional cantilever construction gantries. The temporary supports were constructed on the either side of the piers directly over well steining. Sand jacks were fixed over each of the temporary columns. The segments were cast in 3.0 M on the either side of piers in such a manner that only one pair of temporary columns come into operation all the time. The rollers of rocker-cum-roller bearings over penultimate supports, P1 & P5, were frozen during the cantilever construction.

The continuity units of 5.1 M over the abutments were first cast on staging and the temporary supports were released. The central continuity units of 2.5 M were cast by extending cantilever construction gantries from one of the mating cantilever arms. The rollers were defreezed before the stressing of continuity cables.

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