Third Godavari Bridge : Salient design features

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The article presents a brief overview of the salient design features of the third Godavari Bridge.

The superstructure of the third Godavari Bridge at Rajahmundry was originally conceived with K-type trusses in steel. However, with the increasing use of prestressed concrete technology on Indian Railways for larger spans, it was decided to go in for prestressed concrete deck instead of a conventional steel truss design. After the prequalification process, two designs of superstructure, namely a bow string arch girder and a prestressed concrete truss with precast bottom deck units glued together were found feasible. After technical and financial evaluation of the offers, it was decided to go in for bow string arch solution for the bridge.

The bridge consists 28 spans of 92.552m (centre to centre of piers). The distance between centres of bearings is 94m. Each span has been designed to carry MBG loading-1987 specified in Indian Railway's Bridge Rules. The structure is designed to withstand a wind pressure of 240 kg/cm^2 (corresponding to a wind velocity of 200 km/hr) when there is no live load on the deck. When the deck carries the live load, the wind pressure is restricted to 150 kg/cm^2 (corresponding to a wind velocity of 158 km/ hr). The wind loads are computed as per clause 2.11 of IRS Bridge Rules.

Superstructure

Each span comprises a prestressed concrete deck of box section hung from twin arches by means of 12 pairs of hangers. The parabolic arches rise 20m above the neutral axis level of the box girder. The arch has uniform thickness of 800mm all through the span whereas its depth varies parabolically from 1,700mm from its junction with the tie-girder to 1,150mm at the crown. The arches are of reinforced concrete having concrete grade of M45. They are braced in the lateral direction by means of precast RC struts. There are seven such struts, the smallest of them being at the crown with three on each side. The precast RC struts have uniform thickness, while the width varies from their junction with the arch to half way between the twin arches. The uniform thickness of the struts is 500mm. Originally, the design consultants of the contractors proposed steel diagonal bracings between the twin arches. But the proof consultants of the Railways suggested avoiding steel bracings from the maintenance point of view, especially with a view to avoid possible corrosion problems. Their suggestion of using a frame system of vierendeel-girder type has been adopted in the final design.

Arch

The arch is constructed using segmental type construction. Each half-arch consists of seven segments of varying length supported from a central temporary tower located on the pier by means of steel cables. The segments are cast-in-situ over a movable arch form carrier. During the design stage, it is found that the decisive combination of the moment and the axial force occurs when the first segment is cast and the wind blows parallel to the direction of arch. Suitable reinforcement is provided to cater for these forces. Internal forces have been computed for each stage of casting the arch segment and reinforcement provided accordingly. For each stage, wind forces have been considered, both parallel to the span as well as across the span. The wind forces parallel to the traffic direction are found to govern the design in deciding the reinforcement at top and bottom portion of the arch. Wind blowing perpendicular to traffic governs the provision of reinforcement along the vertical walls of the arch. The tie-girder is constructed by supporting the formwork on tie-girder scaffolding which inturn is hung from the arches. The tie-girder is cast in stages and the length of each segment is chosen so as not to exceed the permissible stress in the arch at any stage. As per the construction scheme, the arch segments have to be cast symmetrically on either side of the tower. It has been stipulated in the design that at any time during concreting, the imbalance in concreting should not exceed $2m^3$ on any side. In addition to this the design also permits an unsymmetry of full live load as also difference in concrete density by 5 percent on either side.

Tie-girder

The tie-girder consists of a box section, longitudinally prestressed by means of 16 cables. The overall deck width is 6,300mm with the clear distance between the ballast retainers at 4,500 mm as per the Railway's specifications. The depth of the box girder is uniform all through the length of the span. However, it varies from 2,365mm at the centre line of track to 2,292mm and 2,279mm respectively at either end in transverse direction so as to provide a 2.5 percent gradient for the purpose of cross drainage. The top slab thickness varies from 296mm at the centre line of track to 252mm and 289mm at either end. Although the top slab thickness is uniform along the length, it gets thickened to 550mm near the ends, called the starting stub portion. Also, the top slab is locally thickened at the location of every stiffener. Bottom slab has a thickness of 240mm throughout the length except in starting stubs where its depth increases gradually to 500mm at the end diaphragms. The webs have a thickness of 300mm. Their thickness also increases in the starting stub portion.

Although the section of the girder is generally uniform all through its length, it becomes sturdy towards the end in a small length called the starting stub. This becomes necessary for the transfer of huge forces between the arch and the tie-girder and to the bearings. The reactions from the arch, prestressing forces in longitudinal direction, bearings reaction etc., are heavily concentrated in this zone and hence this portion needs to be extra strong with dense reinforcement. The length of starting stub is 5,329mm from either end of the span. At the location where the starting stubs are seated on the bearings below, solid diaphragm of 1,376-mm thickness are provided which are suitably designed for forces caused by the thrust of arch which is transferred subsequently to the bearings below. In order to counter the splitting forces caused by the arch thrust, which is eccentric with reference to the line of action of prestressing force in each web, the starting stub is prestressed transversely by providing 3 cables in the top deck slab. Each cable consists 31 nos. of 7mm diameter HTS wires with a force of 1,500 kN per cable. Thickness of the end diaphragms was originally proposed by the contractor as 900mm but has been increased on the advice of Railways' proof consultants as they felt that diaphragm should be thicker and extend further behind the bearing to allow proper introduction of the compression force from the arch to the bearings and give sufficient anchorage length for the tie forces in this zone.

In addition to end diaphragms, intermediate diaphragms are also provided at each of the 12 hanger locations. The internal diaphragms are 300-mm wide and 500-mm thick. The external diaphragms (that is, on the outside of the box) are 600-mm thick. The width varies from 345mm at the top to 450mm at the bottom. The intermediate diaphragms are prestressed transversely to contain the splitting force due to the hanger force. These cables, each comprising 7 nos. of 7mm HTS wires, stressed to a force of 580 kN per cable run through the thickened portion of the bottom slab at these diaphragms locations.

Top slab has been designed as a two-way slab supported on two sides by webs and the other two sides by the internal diaphragms. The internal diaphragms provide full restraint while the webs provide partial restraint against rotation.

The internal dimensions of box are proportioned so as to facilitate easy inspection inside the girder. The end diaphragms, though solid otherwise, have an opening of 1,200-mm width and 1,000-mm height so that a person can easily enter inside the box for inspection. The deck carries a footpath of 1,350-mm width on one side; on the other side a duct is provided for carrying services and is covered by a slab of width 850mm. The footpath elements as well as the elements to provide duct for services comprise precast elements which are supported on the ballast wall and also the top slab. Some of the footpath slabs have been widened by 800mm to use as a trolley refuges. Also, provision has been made in some of the footpath elements to carry OHE masts.

Prestressing

The tie-girder is prestressed by means of 16 nos. cables, each comprising 61 nos. of 7mm HTS wires. They are stressed to a maximum stress of 1,570 kN/mm^2, which is 0.8 times the ultimate tensile strength. Four of these cables are launched at the time of completing the arch so as to take the arch thrust when the tie-girder is not cast. Subsequently, when the tie-girder scaffolding is erected for the construction of tie-girder, four cables are installed and stressed in stages as the tie-girder construction progresses since arch thrust increases with progressive construction of tie-girder. After the tie-girder is fully concreted, 8 more cables are introduced and the girder is post tensioned to a force of 2,950 kN each. After a lapse of one month, the cables are restressed to 2,950 kN each to reduce the prestressing losses. It is estimated that the loss due to creep, shrinkage and relaxation of steel are around 15 percent after the restressing. Otherwise the losses could be more. The system of prestressing adopted is the BBRV system using button heads for both temporary as well as permanent prestressing.

Bearings

Each span is supported on four pot bearings of capacity 10,500 kN each, Figure 1. Each bearing is of a different type designated as PN, PNe and PNa respectively. PN is fixed type of bearing and does not permit movement in either lateral or longitudinal direction. It is designed for a rotation of 60 minutes. PNa type bearing permits movement both in longitudinal and lateral directions. The bearings PNa and PNe types are fabricated with 60 mm eccentricity to cater for the long term effects of creep, shrinkage etc. After these long-term effects have taken place the eccentricity becomes zero; thus coinciding the cen-trelines of top plate and bottom plate.

The bearings are designed to carry a horizontal force of 853 kN. The four bearings are placed in the following manner. The

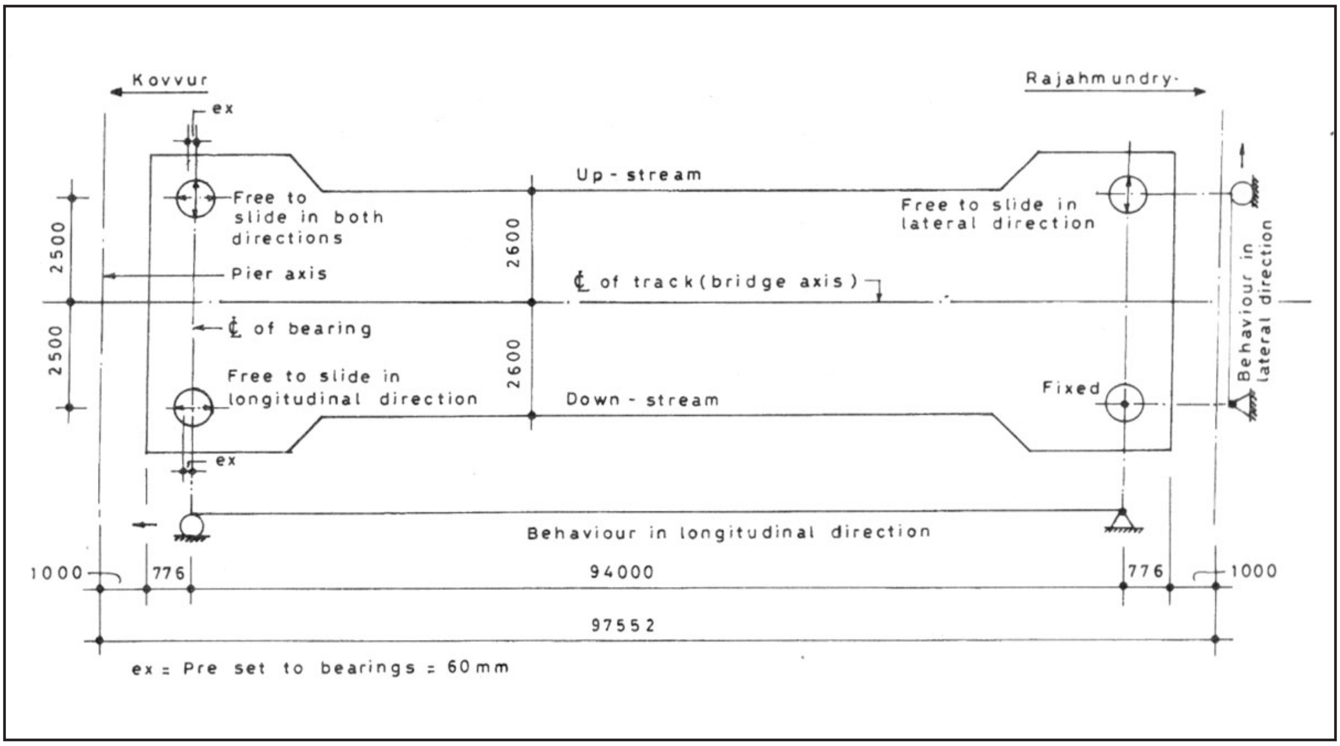

Figure 1. Layout of bearings for the third Godavari Bridge

bearing which is located on Kovvur side pier on upstream side is free to slide both longitudinally and laterally (PNa type) while the down-stream side bearing is free to slide only longitudinally (PNe type). Thus, both bearings on this pier permit longitudinal movement of girder. The bearing which is located on Rajahmundry side pier on upstream side can slide laterally (PNe type) while the one on the downstream side cannot slide in any direction (PN type). Both bearings on this pier are fixed in longitudinal direction. However, considering the lateral expansion of girder it is seen that while both the bearings on up-stream side can slide in lateral direction, both down-stream side bearings are fixed in lateral direction, Figure 1.

Hangers

Each hanger comprises 49 wires of 7mm diameter HTS wires. The hangers are designated as DINA hangers since the anchor heads are filled with a patented compound called DINA compound to enhance the fatigue resistance of the button heads. The wires are tested for fatigue resistance for 2 million cycles for a load range of 0.45 UTS N/mm^2. The girder has been designed such that no off-loading occurs for any DINA hangers when live load comes. In other words, the influence line of all hangers indicate on-loading of the hangers for all live load positions.

Conclusion

The superstructure of the third Godavari Bridge has been designed to produce an esthetically-pleasing and structurally efficient bridge. The structure is expected to be durable and maintenance-free. It permits conventional ballasted deck for the railway track in the bridge portion, which is advantageous in many respects.

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