Bridge across Zuari River: a boon to Goa

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The recently completed Zuari Bridge in Goa will not only boost the socio-economic development of this picturesque land but will also give immense impetus to the growing tourist traffic. This 627-m long bridge, along with a 180-m long viaduct, is an aesthetically elegant structure, blending well with its surroundings. A unique fendering system, adopted for the first time in India, was provided for the safety of the bridge. The paper describes the salient features of the bridge, viaduct and approaches which were constructed at a total cost of Rs. 5.50 crores.

The name of Goa is derived from Gomantak, a mention of which is found in the Mahabharata, Harivansha and Skanda Purana. It is also a Parasuram Kshetra i.e. a place where the saint Parasuram resided. St. Xavier strived hard here to spread Christianity. It was under the colonial rule of the Portuguese for 451 years. It became a part of India in 1961. Since then the development of Goa has taken positive strides and there has been considerable all-round development. The picturesque beauty of Goa with its silvery-golden beaches, internationally famous churches, and panoramic spots with lush green flora have attracted tourists from inland and from all over the world. The tourist traffic doubled in the past five years, touching 500,000 from inland and 40,000 from abroad. The `Retreat' event organised in Goa at the time of Commonwealth Heads of Government Meeting (CHOGM) in 1983 had given further publicity to the tourist potential of this tiny and lovely part of India.

The socio-economic development of a country/state is not only determined by parameters like per capita income, gross national product and gross domestic product but also by the length of roads per square kilometre of its area. While the all-India average of the length of road per 100km^2 is hardly 47km, that of Goa is already 167km. All types of communication, such as air, sea, rail and road, are available to the tourist, though the population of Goa is just one million. The export of nearly half the iron ore from India occurs through the natural harbour at Mormugoa, fetching Rs. 87 crores of foreign exchange. All these required well-knit communication facilities.The merger of Goa with India enabled linking of various roads in Goa with the National Highways of India. National Highway No. 17, starting from Panvel near Bombay passes through Konkan, Goa, Karnataka and Kerala, extending upto the southern tip of India. Being a coastal area it is criss-crossed with too many streams and rivers flowing into the sea and being subject to tidal variations. For better and faster communication these rivers need to be bridged. As far as Goa is concerned, the Portuguese had done little to construct major bridges. This job was undertaken by Indian engineers. A bridge across river Mandovi was completed in 1971 and that across Zuari was completed in April 1983. A bridge across Colvale River is in progress. A new bridge across Banastarim River is coming up shortly, and those across Talpon and Galgibag in the short link will be taken up in the seventh Five-Year Plan.

Zuari Bridge

Zuari River, which flows into the Arabian Sea, divides Goa into north and south. Before the construction of the bridge, the passenger and the vehicular traffic used to cross the river through a ferry system. The Portuguese had planned to construct a bridge across Zuari River on lease to a firm, the cost of which was to be met by a toll. But, this did not materialise. While the Dabolim Airport, Mormugoa Port and the railhead and business centres at Margoa and Vasco are situated on the south side of the river, the state headquarter Panaji, Mapuca town and other important places are located on the north side of the river. The importance of a bridge across the river was, therefore, keenly felt. Especially during the arrival time of planes, long queues of motor cars for crossing the river by ferries were seen. The irony of the situation was that while the time required for travelling from Bombay to Goa by plane was less than an hour the waiting period for crossing the river by

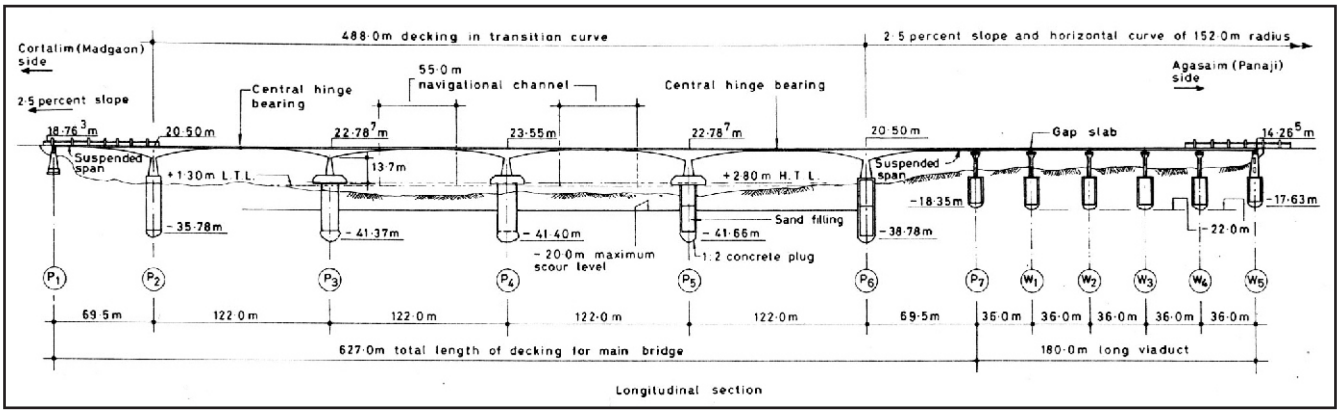

Figure 1. A longitudinal section of the Zuari Bridge

ferries was more than an hour. This obviously was an irksome affair. More than 10,000 people and 25,000 vehicles of all types used to cross the river by the ferries daily. As the river is subjected to tidal variations, the ferry crossing was uncomfortable at high tides, especially during the rainy season.The sanction for the construction of the bridge was accorded by the Ministry of Shipping and Transport in 1970 for Rs 1.50 crores, and the work commenced in 1972. The main bridge along with viaduct and approaches, which were completed and opened to traffic in April 1983 for a total cost of Rs. 5.50 crores, posed many challenges during construction.

General arrangement

The Zuari Bridge is a two-lane bridge with 7.5-m carriageway width and 1.5m wide footpaths on either side. The total length of the bridge is 627m, Figure 1. It has 4 spans of 122m each and shore spans of 69.5m at either end. For Goa, this is the first long span bridge, the earlier Mandovi Bridge being of 50-m spans. At one end of the Zuari Bridge, a 180-m long viaduct with 5 spans of 36m each has been provided due to poor soil conditions and nallas running along and across the approaches. The geometrics needed the viaduct to be located on a curve of 152-m radius. A vertical clearance of 13.7m above the high tide level (HTL) with a channel width of 55m is provided in the two central spans. In view of the poor soil conditions and with a view to reduce the height of embankment the entire bridge is located on a summit curve sloping from the centre towards the approaches in a slope of 1 in 40. The double curvature of the bridge alignment has added aesthetic beauty to it. The length of approaches on both sides is 2.5km. The approaches are on high embankment and on poor marine soil. The bridge and the viaduct are designed to National Highway loading standards.

Foundation

The river at its deepest bed level contains 8m to 10m of standing water with a tidal variation of 1.5m. Well foundations going as much as 42m below water level were adopted. Three well foundations are almost in the midstream. Because of the poor soil conditions all wells had to be sunk by the floating steel caisson method, though in any other situation the problem could have been tackled by the sand island method. In fact, sand islands, originally attempted on two wells, had failed entailing loss of time and money. The first part of the caisson was fabricated on a launching pad and towed into the river to the exact location and secured properly in position with the help of guide piles, anchors, etc. The caisson was then stabilised by filling concrete and then by adding further steining heights until the caisson was evenly grounded. Addition of steining and sinking was continued progressively till the requisite founding depth was reached. The strata met with during sinking were conglomerate, varying from top slushy soil to quartzitic veins and ores, which created enormous problems during the sinking operation. One well tilted badly to a slope of 1 in 15, the correction of which posed a terrific problem, resulting in enormous delay. In one foundation, conglomerate rock was met with only in part of the area of the well which posed a challenge in the design, methodology of sinking, and needed anchoring measures for safety against various odds. In all 20,000 diving hours were consumed in the sinking of the wells. This indicates the enormous efforts and consequent delay involved in completing the foundations. The viaduct foundations were also of the well type. Colecreting was adopted for bottom plugging of wells.

Measures against barge impact

The river is used extensively by barges carrying iron ore to Mormugoa for export, which accounts for 50 percent of the ore exported by India. Hence, the three central wells had to be designed for the impact of barges of 1000-t capacity moving at a speed of 6 knots/hour. Model studies were conducted at the Central Water and Power Research Station (CWPRS), Khadkavasala, near Pune, and a maximum force of 500t at HTL was taken for design purposes. Two adjacent wells beyond the navigational channel were also designed for an impact of 250t to account for stray hits. An in-built fendering system similar to the system adopted at Tsiangye Bridge, was adopted for the first time in India for the central three piers. The system consisted of steel-nosed reinforced concrete fins supported by diaphragms projecting from cellular cofferdam-type protective fenders. In the event of impact by barge the fender would yield and move for a nominal distance and the impact force is absorbed in friction, causing no harm to the structure. In view of sturdy fenders the captain of the barge will be likely to cruise through the navigational span more carefully as the damage to the barge due to a hit will be more serious. The system of fendering has been functioning well.

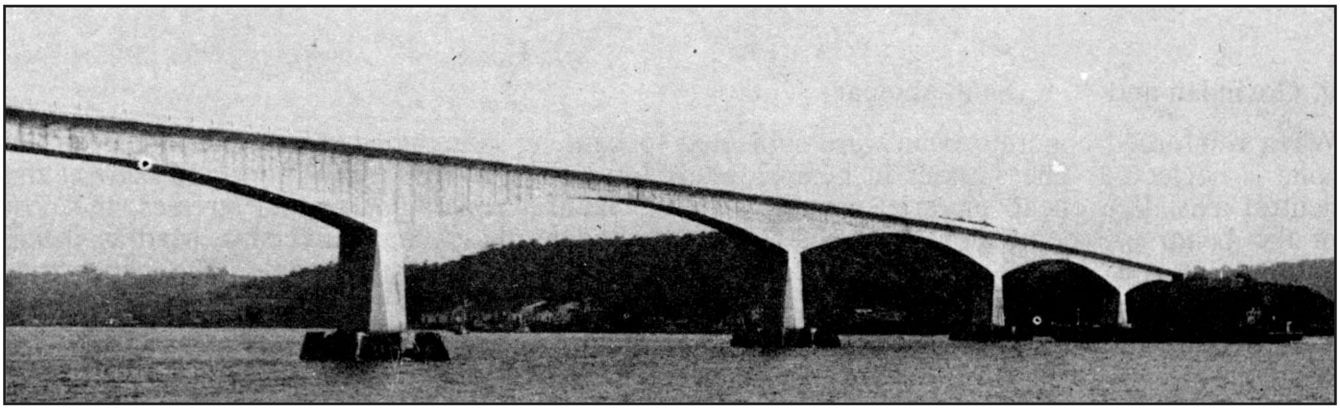

Figure 2. partial view of the completed bridge

Substructure

Hollow reinforced concrete piers, having an octagonal shape at the base but converging into a rectangular shape at the pier head with diaphragms in between, were provided. The pier rested on the haunches provided in the well. The load was transmitted directly to the steining of the wells, instead of through the well cap. For the viaduct reinforced concrete hollow circular piers, resting directly on the well cap were provided.

Superstructure

In view of the continuous barge movements, large depth of standing water and poor soil conditions, superstructure construction on centering was not feasible. A cast in-situ prestressed concrete box girder having a variable depth was, therefore, constructed by the free cantilever segmental method. A pair of travelling cranes progressed simultaneously from each end adding a 3-m segment at each length of travel. Requisite pre-cambering was also provided in the deck, duly accounting for shrinkage and creep losses and progressively increasing deflection, etc. The cantilever tips were cast in-situ and linked with a central hinge of the rocker-plunger type of cast steel. The superstructure of the viaduct was a simply supported prestressed concrete box girder, with gap slab over the pier. The horizontal curvature of the superstructure was achieved by having the web of the girder straight, but projecting the deck slab unequally on either side, as required. Finger-type expansion joints with 20-mm plates for the main bridge and 40-mm plates for the viaduct were provided. In both cases the plates were anchored into the deck.Reinforced concrete in-situ footpaths, 1.5-m wide, and reinforced concrete wearing coat were provided. Precast H-type reinforced concrete railings fixed over bottom rails and in-situ columns were also provided. Hand rails were given cement paint and the kerb was painted black and white with yellow dividers for lane marking to enhance to elegance of the structure. The bridge was illuminated, using sodium vapour bulb system at 40-m intervals on one side. The spacing and height of pole was decided to give a uniform light intensity of 100 lumen/Watt.

Materials and cost

The 807-m long bridge with viaduct consumed nearly 9000t of cement, 1700t of reinforcing steel, 260t of high tensile steel and 600t of structural steel. The concrete used in the construction varied from M-150 to M-450 in various elements. Cost of the bridge was Rs. 4.0 crores and that of the viaduct was Rs. 0.50 crores, totalling to Rs. 4.5 crores. Cost of the bridge per metre is Rs. 66,000 and that of viaduct Rs. 30,000 approximately. Figure 2 shows a partial view of the completed bridge.

Approaches

The construction of the bridge involved construction of high embankment on poor soil with maximum height varying from llm to 17m. On one side, an embankment with balancing berms was provided while on the other side a novel mud replacement method of flushing out the marine soil by fast dumping was adopted on a massive scale for the first time in India. Cost of the 2.5-m long approach road was Rs. 1.00 crore. The embankments are functioning well for more than two years.

Agency

The design and construction of the bridge and viaduct were done by Gammon India Limited. The construction was supervised by the Public Works Department of Goa. Being a bridge on the National Highway, the designs were approved by the Ministry of Shipping and Transport. The bridge was financed by the Government of Lndia.

Conclusion

The Zuari Bridge is located in a panoramic scenic spot. The architecturally elegant shape of the bridge structure not only blends well with the surroundings but also enhances the aesthetic value of the spot. The completion of this bridge is a boon to Goa, ensuring quicker and safer communications.

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