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Critical Analysis of the Chenab Bridge, India

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Abstract

Chenab river is one of the big rivers in Northern India. Indian Railways has undertaken to make a bridge in the state of Jammu and Kashmir (J&K) over the Chenab river.This bridge is one of the perfect examples of steel and concrete arch bridge, which is in under construction at the height of 320m above the river. This construction has announced as National Project. According to the plan, after completion, the bridge can be declared as the World's highest rail bridge. Its steel arch main span is 467m long, which is the main key feature of the bridge. This bridge is aim to complete within December 2021. This paper provides an informative review and critical analysis along with conceptual design, the problem faced during the construction of the bridge.

Keywords:National Project, World's highest rail bridge, critical analysis, conceptual design

1. Introduction

India is facing an extensiveproblem while travelling in the hilly terrain of J&K.The knowledge about the atmosphere, nature of snowfall, frequency to space, and time is limited in the Himalayan region due to the intricacy of terrain and inaccessibility to several areas. The Government of India has pointed out an emergencyrequirement for better transportation facilities. Therefore, to link J&K with the remainder of India, a national railway project (JUSBRLProject) of 345 km lengthy line hasinitiated in 2003 on Jammu Akhnoor-Poonch road [10].This line is traversing Jammu– Udhampur—Srinagar–Baramulla. It also improves dynamism of Jammu and Baramulla region within the state and across India. [9]. Since then, the Chenab bridge is one of the iconic bridges in the World due to its height and structure. The bridge remains incomplete for more than three decades — the construction work initiated in between 1932-34 AD. Later, J&K Govt. handed over the project to the Border Roads Organisation. In September2008, the construction work stopped due to stability and safety. Therefore, to overcome these challenges, the entire JUSBRL project alignmenthas reviewed. The review and design work approved in 2009 and July 2012, respectively.Now, construction work continues with all the safety. [8]. This paper provides an informative and critical analysis of the Chenab Bridge along with conceptual and structural design, problems faced during the foundation and loads effect on this bridge.

2. Location of the Bridge

It seems to be a great challenge to implement a massive number of tunnels and bridge in too rough mountainous terrain, in Himalayan geology. The crossing of the profound gorge of Chenab river by Chenab bridge believe to be the most challenging part. It situates in the Reasi district in J&K which is mainly between Kauri and Bakkal. Photograph of the site location and location of the map of the bridge has shown in Fig.1 and Fig.2

3. History of Chenab Bridge

Chenab Bridge is a challenging project of Konkan Railway Corporation. The construction workinitiated during the regime of MaharajaHari Singh. At that time the length of the bridge was 208m. It was a steel truss bridge with three spans (1 x 138m+2x35m) steel Girder type bridge. Jammu became easily accessible from the regions of Akhnoor,Jouria, Palanwalla, Chamba and so on. The thin bridge was not convenient for all classvehicles. As the bridge was a single lane, so there were some restrictions on the class of loading vehicles. The critical needs required is the development of another double lane path connect with Class 70R loading according to current IRC Codes. The Government of India wanted to improve the road and bridge to enhance availability up to the International Border/Line of Control, after the 1965's ChambJouria battle and 1971's Indo-Pak

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Fig. 1 Site location of Chenab Bridge

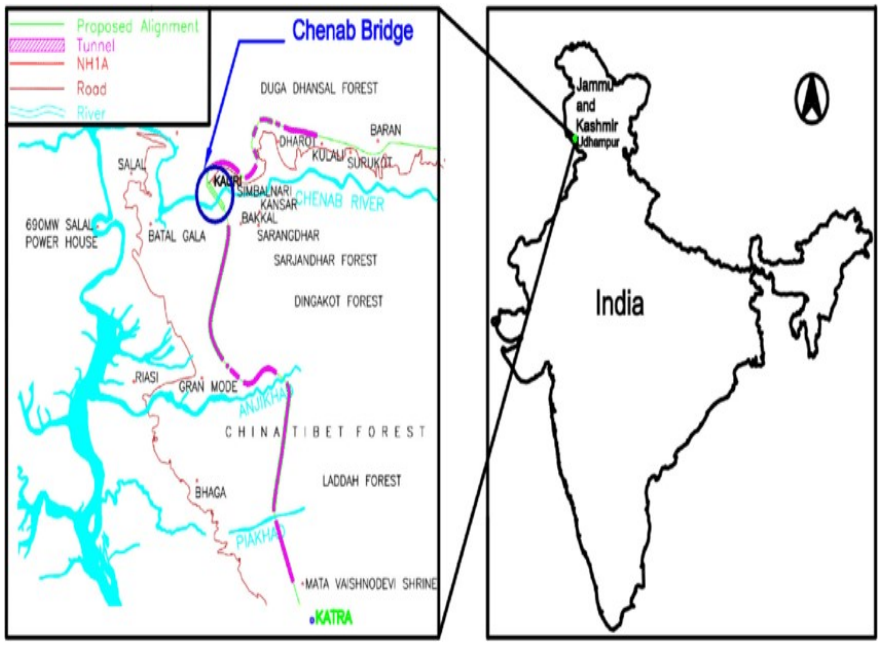

Fig. 2 The location map of the bridge site

war. Considering its vital significance, J&K State Govt. handed over the Jammu Akhnoor road and the Akhnoor steel bridge to the Border Roads Organization (BRO). In September 1971, the Border Road Organisation took over the Akhnoor road and the existing steel bridge. After that, they carried out all the details of ground survey to transform the single lane road to double lane road and construction of a permanent bridge over the river Chenab. Further, a suitable site was selected to make a permanent RCC bridge, and subsoil investigating test on the ground has performed. The competent authority planned to construct 231m length with five spans steel bridge. But due to various constraints on the foundation construction, a new 280m extended continuous cantilever bridge scheme proposed. Finally, after several changes, a steel deck of 467m with 17 no of spans is decided. Step to step work progress report described in the construction of the Chenab bridge Segment [8].

4. Chenab Bridge Description

The Chenab Bridge is a 1,315m long rail bridge which is in under-construction. It has built at the height of359m. Fig. 3, is showing a schematic diagram of the bridge, which helps to understand the bridge parts.

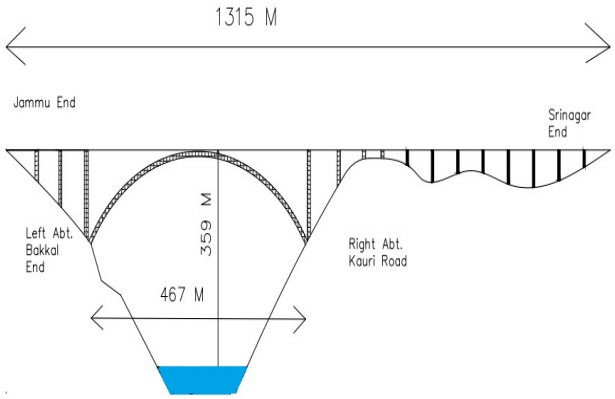

Fig.3 Schematic Diagram of Chenab Bridge

4.1 Aesthetics

All the bridge components have been planned by collaborating and correlatingone another aesthetically. Later, it has assured that superstructure box and substructure is in the same width of 5m.It is in c/s to maintain the sleekness and slenderness of the bridge.[8]

The designer has considered the aesthetic merit of the bridge and made a strong attempt to fetch a natural cadence to the spot. [3]

4.2 Sub Structure

a) Foundation

The execution of the work initiated in 1978 and couldn't be finished even after engaging of 2 contractors till 1994. A new proposal has given after detailed investigation of the behaviour of the river and records. Further, the competent authority has examined the proposal and designed a 280m long cantilever bridge and having a single main span of 160m. In this plan, the pier has kept well inside the bank, well away from the waterline. Due to high water current and conglomerate strata, the earlier contractors have failed in the construction of the foundation. Hence, theopen foundation of the bridge has proposed. To avoid foundations edge from the waterline, a 160m single main span with two end spans of 60m each has chosen.

b) Piers

Piers are consisting of the hollow rectangular section on a raft foundation. The piers are with 6.6 m x 5.0 m outer dimensions.

c) Bearings

The track of the approach bridge is curvature, which makes the job challenging. The design of the bearing has adopted in a way that the segment is become easy[4].

4.3 Super Structure

A plate girder is in the form of the main superstructure portion with a close deck. The closed-deck provides a dry environment keeping the rainwater out. Girder helps to connect the rail.Deck wind nosesare designed in the main arch portion [4].

a) Pylons

The height of the pylons isapprox. 127m and 105m at the end of Kauri and Bakkal respectively. The amount of steel used in this bridge is nearly 25000 tonnes. This steel structure has used to make the arch section of the bridge. A cable crane has been built with 34 ton lifting capacity to construct the steel structure. Both sides of the valley are associated with the pylon towers. The same helps the cable cranes to move in between the pylon towers. [6]

b) Arch Foundation

The arch portion of this iconic bridge has entirely made of steel. The height of the main arch foundation at Bakkal end is about 47m and Kauri end is about 34m. To give the least wind obstruction, at first it has been expected to apply pipe segments for every individuals' members of the through truss. The diagonal members and the chords of the trusses have adjusted later to get sealed steel boxes, mainly for encourage production on site.On the other hand, the alternate members havekept as circular. The concrete filling has done to improve the stiffness and damping ratio.Again, the same has performed to the members of the chord to control the wind forces. The superstructure in the main arch portion is getting support with the help of steel piers, [2].

5. Design of Chenab bridge

As per a case study [4], combining approach type (530m) and an arch type bridge (785m), this Chenab bridge has formed. The steel deck has supported by a 467m long steel arch with 17 spans: most extended steel decks in the World. The leading responsible authority for the planning isWSP Finland. A sub-consultant Leonhardt, Andräund is assigned for the design of the steel arch.Two 36m-long approach spans have also designed with the main span of the bridge. It has constructed like a two ribbedarch. Again, steel boxes sealed with concrete-filled for the use in steel truss.The construction and design are possible with the basic guideline from BS: 5400. StandardNational Indian codes such as IRC, IRS, IS and some International codes like BS, UIC etc has been followed to match the design and construction. As per design the lifespan of the bridge is 120 years. The Railway design speed of has set initially as 100 km/h.Structural analysishas done by conventional analysis program used in steel bridges. The design consultant has used a unique program for wind analysis. Another Special feature in this bridge is that all steel structure has modelled by 3D software TEKLA [3 and 4].Table 1 is showing the list of companies which are involved in the all project responsibility.

6. Construction of Chenab bridge

One of the most isolated and complicated terrains has chosen for the bridge construction site. Without resisting the flow of the river for construction is one of the biggest challenges [2].Fig. 4 is showing the year-wise progress of the project and Fig. 5 and 6 are the snaps of the site view during construction.

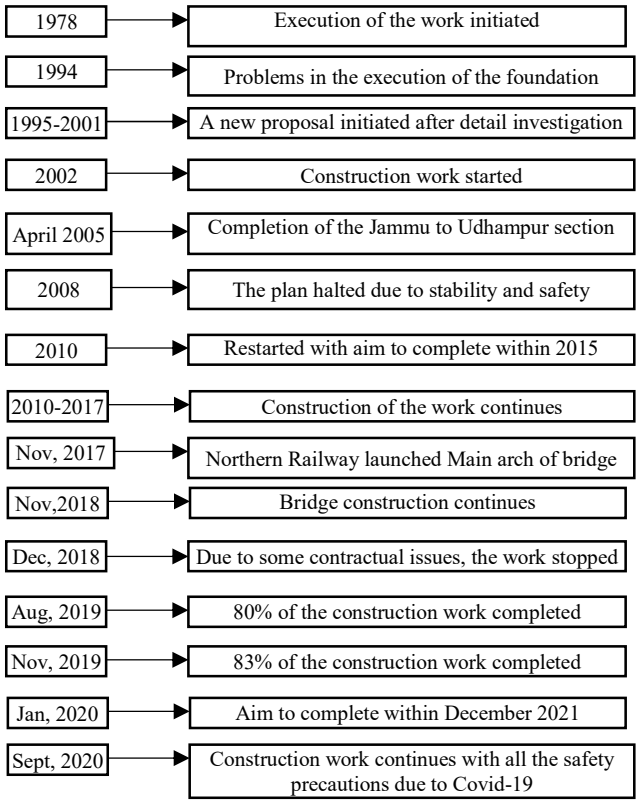

Fig. 4 Year Wise construction Progress of Chenab Bridge

Table 1 Companies handling responsibility at construction time

Company Name	Work Handel
Amberg Engineering	Review of the alignment
South Korean Company Ultra Construction, Afcons Infrastructureand VSL India in 2004	A joint venturehas awarded for the design and construction
WSPFinland and Leonhardt Andra Germany	Project Consultant
Konkan Railway	Executing the project
Jochum Andreas SeilTransporte	Pylon cable installation
VCE Consult ZT-GmbH	Pylon Design
AkzoNobel	Painting services
AECOM	Monitoring services and technical guidance

Fig. 5 Construction of Arch

Fig. 6 Site view during construction

Workshops that have built in the mountains manufactures the bridge's steel structure. The inaccessibility in the complex terrain causes to move the workshop to the building site. Four workshops have been built in the mountain because the 12 meters, the longest building part is delivered to the site. Next to them, workshops and paint shops have made on either side of the valley. All steel materials have provided as steel board to the mountains except the smallest rolled profiles. Additional problems arise for the cause of insufficient infrastructure. There is a lack of electricity, and the river water is unsuitable for concretemanufacturing. Therefore, water is brought from far away mountains and all electricity has to produce at the spot [4].

7. Loading

7.1 Super Imposed and Dead Loads

The self-weight of the arch, through truss and vertical suspenders, is considered for the dead load of the bridge.

7.2 Earthquake Loads

The site of the constructed bridge falls under zone IV, severe intensity zone. As a precautionary, to resist the earthquake, it has designed forces of zone V. Zone II is the lowest intensity and zone V is the highest intensity earthquake zone. Chenab bridge can easily resist 8.0 magnitude earthquake. For earthquake loading calculation, two types of loading have to calculate. These two types are maximum considered earthquake (MCE) and the design basis earthquake (DBE). For Chenab bridge maximum ground acceleration may be taken as 0.31 g respect to MCE, and the corresponding value of DBE has needed to take as 0.16 g.

7.3 Wind Loads

Wind loads of the bridge have obtained from wind tunnel laboratory test and physical topographic model of that bridge. Up to 260km/h wind speed cab be resisted by the bridge [2]. These experimental results used to determine the equivalent static loads.These loads take into consideration for the analysis of dynamic actions due to wind. These results have used as structural analysis part. Further, testing the effect of flutter, buffeting, vortex-induced vibration and rain and wind-induced vibrations on the bridge is essential. Again, tunnelling is difficult as the site of the bridge is an earthquake-prone area. Therefore, this bridge will be the witness of wind effect. Wind Tunnel design has conducted in the Force Technology Laboratory in Denmark, which has shown in the Fig.7.Maximum wind pressureis 1500 Pa, corresponded with service wind load [4].

7.4 Blast Effect

It has observed that J&K region had been attacked by several terrorists again and again. To ensure its safety and security, it has entirely made of unique blast-proof steel. The

Fig. 7 Wind Tunnel Test of Chenab Bridge

thickness of the steel is 63 mm. To ensure the safety, the ridge has designed as a way that the pillar of the bridge can resist explosions. According to the design, the bridge can withstand up to 40 kg of TNT Blasts. If this type of blast occurs, then also the train can be operated at 30km/h speed[2].

7.5 Snowfall Effect

The ranges of Western Himalayas cover most areas of J&K, hills of western U.P. and Himachal Pradesh. These extents have high heights and run from north-west to south-east and apply the impressive effect on the climate and atmosphere of north India. Snowfall happens over the western Himalayas primarily from November to April in relationship with toward the east moving low-pressure system, known as western digital influences.[1].

8. The catastrophe over Jammu and Kashmir

The under-bridge portion of the river valley is liable for causing high wind pressure. It causes risking for bridge stability due to this wind pressure. An analysis [5] has been done on the catastrophic rainstorm over J&K between 4-6 Sept. in the year of 2014.

In the 1st week of Sept, devastating floods occurred in various region of the North-Western state of Jammu & Kashmir due to heavy rainfall continuously for five days. According to the information gained from the media, the J&K govt. declared that the disaster is worst in the century. This disaster causes massive loss of lives as well as roads, hospital, educational institutions, agricultural land and transport sectors also damages.

Therefore, to ensure safety, additional safeguard will be provided. To check wind velocity, some sensors require to install. If the wind speed exceeds 90 km/h, then the signal will be automatically turned into Red. This can prevent the train from further movement. Corrosion-resistant special paint will be using the precaution measurement. Footpaths and cycle trails also need to develop.

9. Stability analysis for bridge rock slopes

The design of the bridge in the context of structural view is associated with many challenges. The additional significant aspect of bridge construction to support the bridge is building stable rock slopes in a robust terrain. Several stabilization techniques, i.e. grouting,slope flattening, rock bolts, drainagehas designed to minimize the probability of collapses for the slope. The slope stabilization using active prestressed rock anchors and passive rock bolts have used against wedge failure. (7 and 9). Fig. 8 showing stability precaution for the Chenab site.

10. Key Observation

The key observation from the above critical review analysis is the following:

a) For main arch design, it needs attention to the various number of additional criteria. These criteria are fatigue, global stability, composite action etc.

Fig. 8 Stability of rock slope

b) Besides, needed that a bridge has designed in such a way that can attain a consistent level of reliability.
c) It has applied for all load cases, needs the design and construction standards should match. It has used in present design work also.
d) The bridge can declare as World's highest rail bridge after it's completion.Design team facing a significant challenge, but the main arch halves have filled, which is more demanding.
e) All geological problems have terminated successfully.
f) The bridge will usher in a new epoch in J&K due to building of access road, due to improved infrastructure, increased employment opportunities for the youth.

11. Conclusion

The location of this bridge is in the rail course of JUSBRL project. Here the run of the mill geography comprises of youthful Himalaya shake. The knowledge gained in the project will enable the construction of similar bridges in India.

Finally, is the chance to see the top spectacular view on the planet as the location is superlative. After completion of all, a great opportunity for the travelers for visiting the highest mountains in the World and one of the deepest river gorges. By this way, increasing tourist, it can also enhance India's revenue.

Disclosures

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