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Conceptual design of the Chenab Bridge in India

P. Pulkkinen[a], S. Hopf[b] and A. Jutila[c]*

[a]*WSP Finland, Oulu, Finland*
[b]*Leonhardt, Andrä und Partner, Germany*
[c]*Extraplan Oy, Kaskenkaatajantie 22 A 6, 02100 ESPOO, Finland.*

Abstract

Indian Railways has undertaken the mega-project of construction of a new railway line in the State of Jammu and Kasmir. The project includes a large number of tunnels and bridges which are to be implemented in highly rugged and mountainous terrain. The alignment crosses a deep gorge of the Chenab River, which necessitates construction of a long-span railway bridge. The main feature of the Chenab Bridge is its 467 metres long steel arch main span located about 320 metres above the surface of the river. The paper describes mainly the conceptual design, but partly also the structural design of this bridge. In the design work both national Indian codes as well as several international codes had to be followed considering that the design standards match the construction standards.

Keywords: arch; bridge; long-span; railway; steel

1. Introduction

Indian Railways has undertaken the mega-project of construction of a new railway line in the State of Jammu and Kashmir, from Udhampur to Baramulla. The project has been declared as a national project. The alignment is a culmination of a large number of tunnels and bridges, which are to be implemented in highly rugged and mountainous terrain, with the difficult Himalayan geology. The alignment crosses a deep gorge of the Chenab River, which necessitates construction of a long-span bridge.

The Chenab Bridge was scheduled to be completed in December 2009. In September 2008 it was announced that the Chenab Bridge Project was interrupted despite the completion of substructure of the approach viaduct.

* Tel. +358-(0)400-438313
Email address: aarne.jutila@extraplan.fi

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As of mid-2009, it was decided that the original route is back on track and the bridge will be built as originally planned. However, it was concluded that the main span of the bridge will be modified to be 467 meters.

The current paper describes mainly the conceptual and structural design of the Chenab Bridge. In the design work the National Codes of India, Indian Railway Standards (IRS), Indian Road Congress (IRC) recommendations and Indian Standards (IS) have been supplemented with International standards like British Standards (BS), standards of the International Union of Railways (UIC) and some national codes.

Fig.1. Location of the Chenab Bridge in Reasi district of Jammu and Kashmir in India, about 600 km north of New Delhi. (Google Maps, 2012)

2. Description of the Chenab Bridge

The Chenab Bridge is a steel railway arch bridge with a total length of 1315 metres. It is formed by an approach bridge, which is 530 metres long, and an arch bridge, which is 785 metres long. A 467 metres long steel arch (one of the longest in the world) supports the steel deck. The deck, which is 13,5 meters wide and has two tracks running on it, is located about 320 metres above the surface of the river flowing in the valley. WSP Finland has the main responsibility for the planning of the bridge. The design of the steel arch is done by subconsultant Leonhardt, Andrä und Partner of Germany.

An illustration of the completed bridge and a design model are shown in Fig. 2 and Fig. 3, respectively. The construction of the approach bridge has now restarted and concrete piers already cast are shown in Fig 6.

Fig. 2. The Chenab Bridge when completed.

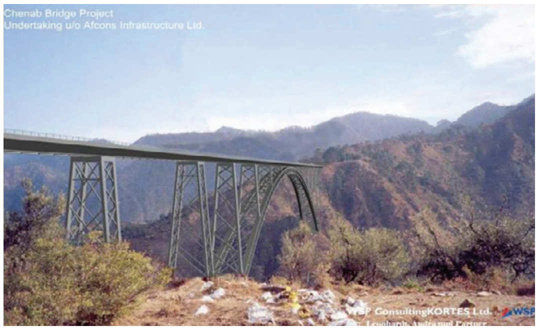

Fig. 3. View of the Chenab Bridge design model.

3. Design basis notes for the Chenab Bridge

The bridge Owner set strict rules and standards that had to be obeyed in the design. Indian Railway Standards (IRS Standards) had to be used wherever applicable. British Standards, UIC Standards and other international standards including Eurocodes could be used as a supplement.

The design speed of the railway was set to be 100 km/h and the design life had to be 120 years. Fatigue assessment shall be done as per BS: 5400 Part –10.

Wind loads will be derived using physical topographic models of the site and tests in a wind tunnel laboratory. Even full-scale models are required. The test results of the bridge are used to extract equivalent static wind loads, which are used in the final structural analysis. These equivalent static wind loads take into account wind-induced dynamic actions of the bridge, as well as size reduction effects related to the patchy distribution of wind pressure peaks. The service wind load corresponds to a maximum wind pressure of 1500 Pa. The wind load is governing the arch design.

In addition to all conventional railway bridge loads, this bridge has to sustain special blast loads specified by the Client, and to provide sufficient redundancy in case of local failure. The most important design criteria in the steel deck is fatigue.

4. Design of the bridge

The concept of steel arch was clearly the preference of the Client (Fig. 4). In the tender phase several numbers of alternatives of the steel arch and also a concept of a cable-stayed bridge were studied. In the railway line another steel arch bridge, the Anjikhad Bridge, will be built. It follows a similar concept at a smaller scale.

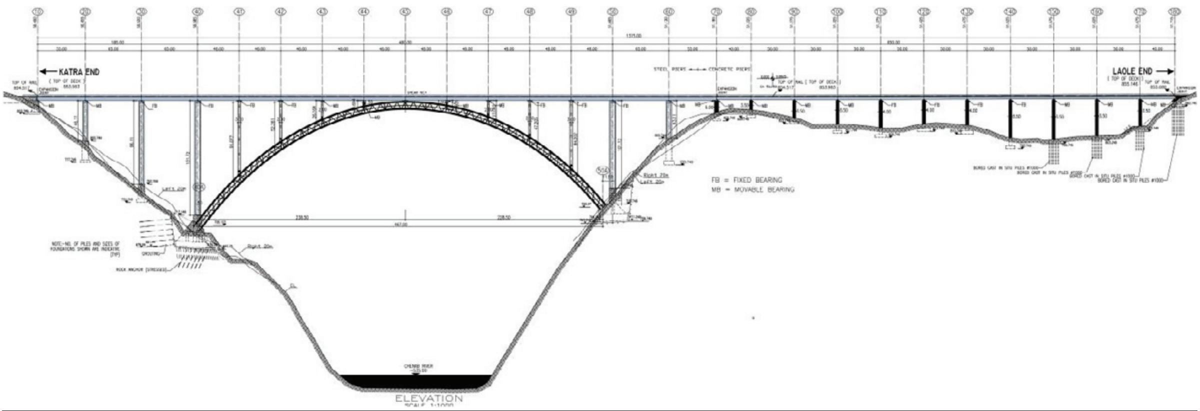

Fig. 4. Side elevation of the Chenab Bridge.

The arch and arch piers of the Chenab Bridge will be made from large steel trusses. In order to provide minimum wind resistance, it was initially intended to use pipe sections for all members of the arch. In order to facilitate production on site, the chords of the trusses and the diagonals were later modified to become sealed steel boxes (Fig. 5). All other members including the secondary members were kept circular, which greatly simplifies the connection details. The chord members will be filled with concrete in order to assist in controlling wind-induced forces on the bridge by improving the damping ratio and stiffness. The concrete fill also enhances the overall robustness.

In the arch portion, the superstructure is supported on steel piers with a height of up to 120 metres. Expansion joints are provided at the end abutments and at Pier S70 that separates the main arch span from the approach bridge. At this location there is also a change in the deck height. The point of longitudinal fixity of the arch bridge deck is at the arch centre, where the forces are transmitted most efficiently and the displacements at either end are minimal.

The superstructure is a plate girder with a closed deck, where rails are connected. The closed deck keeps the rainwater out and provides mostly dry environment below the deck. Wind noses of the deck are provided in main arch portion.

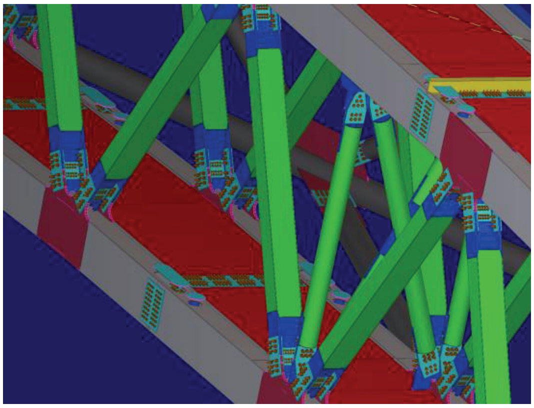

Fig. 5. Details of the steel arch.

Fig. 6. Present state of the construction work of the Chenab Bridge.

5. Construction method

The steel structures of the bridge will be manufactured in workshops built in the mountains. The workshops have been moved to the building site, because there is no proper road network in the challenging terrain. The longest building parts that can be delivered to the site are 12 meters in length. Therefore, four workshops have been built in the mountains. Workshops and paint shops built next to them are located on both sides of the valley.

All steel materials, except for the smallest rolled profiles, are delivered to the mountains as steel boards. The insufficient infrastructure of the area causes additional problems. There is no electricity and the water of the river is not suitable for manufacturing concrete. All electricity must be produced at the site and the water is delivered from further away in the mountains.

The job is also challenging, because the track has curvature in the approach bridge. In this section, the construction stage bearings have been designed in such a way that it is possible to launch the steel deck in the curvature portion as well.

The bridge will consist of about 25000 tonnes of steel structures, the main portion of which will be used for the arch bridge section. First, a cable crane will be built over the valley for constructing the steel structures. The cable crane will move between pylon towers built on both sides of the valley. The crane can deliver a maximum amount of 40 tonnes of steel parts. For example, the over 100 meters long steel columns with bolted couplings will be constructed using this technique.

When the long steel columns are ready, the steel deck will be pushed on top of the columns. After this, a derrick crane, which is capable of lifting about 100 tonnes, will be placed on top of the deck. The derrick will crane the arch segments from deck level to the erection front of the arch as shown in Fig. 7. Deck erection will proceed simultaneously with the erection of the arch. Both the arch and the deck cantilever freely by up to 48 metres. When the next arch pier location is reached, temporary cables will be installed to support the arch, and the new arch pier will be constructed on the free end. The superstructure can then be supported by the arch pier and so forth until the last arch pier is reached. The very last span of the arch and the elements of the key segment will again be delivered by the cable crane; closure of the superstructure is done by means of derrick erection (Fig. 8).

The deck of the bridge will be welded in the workshop upside down in about 8 meters long sections, because the welding points in the final structure are mainly located under the bridge. When the job is completed, the sections are turned around and delivered to the next stage of the process.

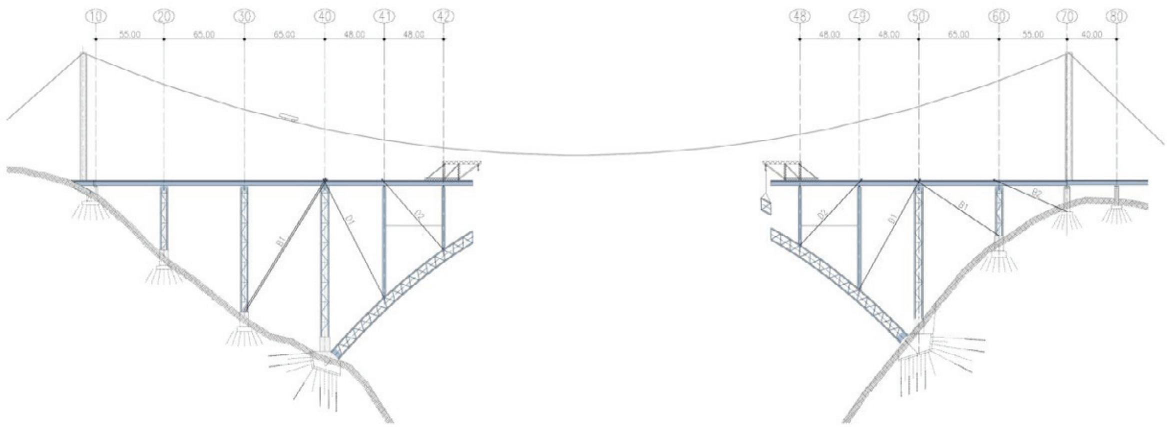

Fig. 7. Typical arch erection by derrick crane.

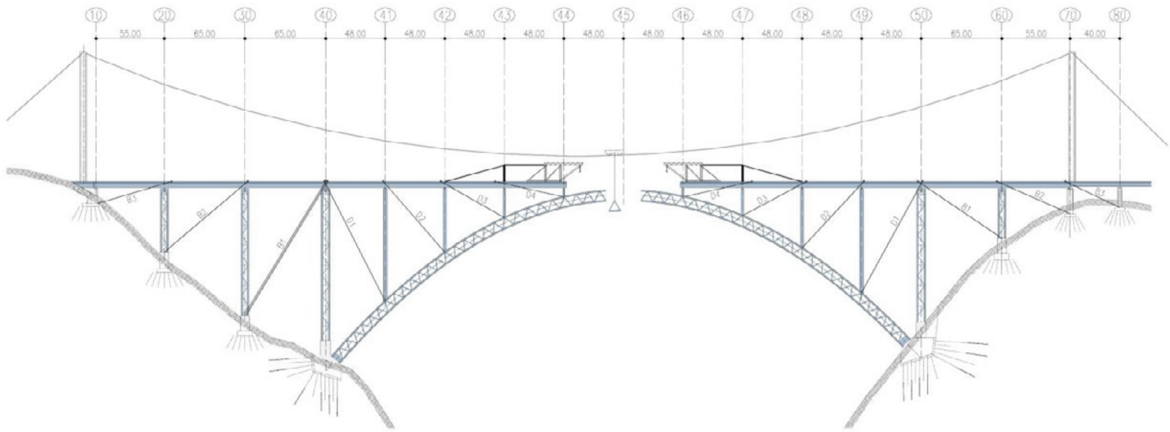

Fig. 8. Erection of last span and key segment by cable crane.

6. Conclusions

The design of the main arch requires consideration of a number of additional parameters, such as fatigue, global stability, second order effects, composite action, etc. It also requires that such a bridge is designed to achieve a consistent level of reliability for all load cases, and that the design standards match the construction standards. That has been considered in the current design work as well.

The Chenab Bridge will be the biggest / the longest-span / the highest railway arch bridge ever built in the world. Its design offered great challenges to the design team, but the challenges will be even more demanding before the gap between the main arch halves is filled.