# DESIGN OF CHENAB BRIDGE IN INDIA

Anusha Bhasam
Department of Geotechnical Engineering JNTUH Hyderabad India
bhasamanusha@gmail.com

Hathiram Jatothu
Department of Geotechnical Engineering JNTUH Hyderabad India
hathiramjatothu@gmail.com

Tejaswini Akabilvam
Department of Geotechnical Engineering JNTUH Hyderabad India
Teja23akabilvam@gmail.com

## ABSTRACT
The Chenab Bridge's conceptual design and structural design principles are described in this study. The major goal is to describe the unique bridge concept in difficult terrain and to provide an overview of the design solutions employed in one of the world's tallest steel arch railway bridges. The construction of a new railway line in India has been taken on by Indian Railways as a mega-project in the state of Jammu and Kashmir. The project includes a large numberof 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 deck height is 359m and bridge length is 1315m. Indian railways constructing the iconic arch bridge on river Chenab as a part of the USBRL project to connect Kashmir valley to the rest of nation. Arch bridge completely made of steel. Foundations and the approach viaduct piers are made of concrete. This paper describes the design and engineering of the bridge. The bridge has numerous design challenges such as erection of the steel arch by cable crane, the bridge’s huge dimensions, and the special design requirements- redundancy of the arch, the earthquake load and blast load effect. The challenges in the design and erection of the bridge is described in this paper.

**Keywords:** bridge, long-span, railway, arch

## INTRODUCTION
The Udhampur- Srinagar- Baramulla Rail link project is the most challenging project. It is highly essential to provide an alternative and a reliable transportation system to Jammu Kashmir to join Kashmir valley to Indian railways network. Indian Railways has started on the massive task of building a new railway line from Udhampur to Baramulla in the state of Jammu & Kashmir. The project has been designated as a national initiative. The alignment is the result of a significant number of tunnels and bridges that must be built in extremely harsh and mountainous terrain, with complex Himalayan geology. The project was launched in 2003. The 345km long railway line between Jammu and Baramulla regions will enhance mobility with in the state and across India. The railway line traverse along Jammu- Udhampur- Katra- Quazigund- Baramulla. Construction of Jammu to Udhampur section was completed and opened in April 2005. Work is progressing on the Udhampur to Baramulla section. In this section this railway line passes through the Chenab River at an elevation of 359m from the riverbed level near Bakkal and Kauri villages. Hence a bridge is under construction at the site whose piers are supported by two large rock slopes. The alignment spans the Chenab River's deep gorge, necessitating the construction of a long-span bridge. The bridge is part of the Ministry of Indian Railways' Jammu-Udhampur-Srinagar-Baramulla Rail Line (JUSBRL) project. A 14-meter-wide dual carriageway and a 1.2-meter-wide center verge will be included in the bridge. Chenab Bridge forms a massive steel arch.
Chenab bridge is located in Himalayas and comes with extremely complex fragile, and geological features like folds, faults, and thrusts. Many challenges are associated with the structural design of the bridge. Bridge has been designed Blast load in consultation with DRDO. First time on Indian railways, Phased Array Ultrasonic testing machine for inspection of welds used.
The project is anticipated to be completed by December 2021 and will have a 120-year lifespan. It will

contribute to the state's economic development and improve transit accessibility inside the state and throughout the country.

**Need for the Chenab rail bridge**

Locals have found it difficult and unsafe to travel in and around the rugged terrain of Jammu and Kashmir. As a result, a national railway project connecting Jammu Kashmir to the rest of India is being built.

## DESIGN DETAILS

### Description of bridge

The bridge is built in the shape of a gigantic steel arch. The Chenab Bridge is a steel railway arch bridge that spans 1315 meters (4314ft). The deck is 359 meters high (1178ft). The span of the arch is 485 meters (1532ft). There are 17 spans in total. The pier's maximum height is 133.7 meters.

Figure 1: The Chenab bridge when completed

### Geology

The Chenab Bridge is situated in the most difficult portion of the Jammu-Udhampur-Srinagar-Baramulla rail route, which is characterized by young Himalayan rock. Broken rock with dolomitic limestone and firestone lentils with a silicate concentration make up the topography. Rock formation exposed to between Jammu and Quazigund are crossed by three major thrusts besides a number of local thrusts, shear zones and faults. There are rocks of class 3 to 5 with a strength of 60 to 100 MPa and a volume weight of 2.7 t/m3. The RMR (rock mass rating) is a measure of the amount of rock in a certain area.

### Design of the bridge

The arranging of this endeavor has been accomplished through WSP team (Finland) and sketch of curve is cultivated by utilizing sub aide Leonhardt. Indian Rail line Norms (IRS Principles), IRC, IS have been utilized while planning the bridge.

BS:5400 is being utilized as the straightforward fundamental for the organization and improvement of the extension. The design speed of the rail line used to be set to be 100 km/h and the graph ways of life must be one hundred twenty years. Weariness assessment will be accomplished according to BS:5400 section 10. The most sophisticated TEKLA software used for structural detailing.

The profound Chenab Stream valley under the extension is inclined to high wind pressure taking a chance with the strength of the scaffold. Notwithstanding all traditional railroad connect loads this scaffold needs to support uncommon impact loads determined by Indian rail route.

Norway based power innovation research center led a few air stream tests to comprehend the impact of wind speed, static power coefficients and blast slamming. Wind burdens will be determined utilizing actual geographical models of the site and tests in an air stream research facility. The test aftereffects of the extension are utilized to extricate identical static breeze loads, which are utilized in the last underlying examination. Wind loads will be derived using typical topographic models of the site and tests in a wind tunnel laboratory.

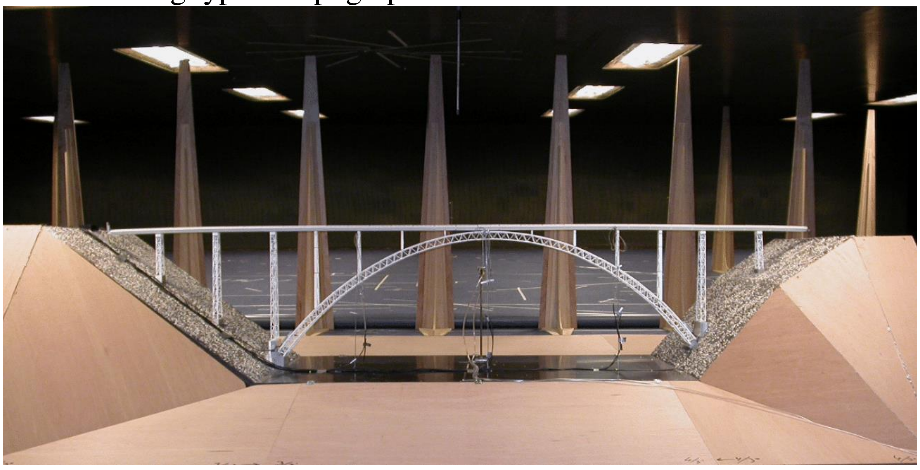

Figure 2: Full aeroelastic model of the bridge in a wind tunnel

The service wind load compares to a greatest breeze pressing factor of 1500 Pa. The breeze load is overseeing the curve plan. The extension is intended to oppose wind velocities of up to 260km/h. The seismic idea of the venture zone was additionally considered during its plan.

The limit state theory of configuration has been chosen to be followed according to BS codes. Arrangement of since quite a while ago long welded rail (LWR) over the extension and coming about power computation according to UIC774-3R rules. Distortion restricts according to comfort models of UIC 776-2R and UIC 776-3R rules.

The utilization of curve is only one way that designers can uphold the dead burden and live heap of the extension. The heaviness of dead burden and live burden consolidated has the impact of a descending power, the gravitational power. In a curve connect the descending powers are generally dispersed down to the projections, the two base backings of a curve that are safely secured in the ground. Since the extension is very still, the projections subsequently have an equivalent and inverse power to the descending powers.

The extension will incorporate 17 ranges, just as 469m primary curve length across the Chenab Waterway, and viaducts on one or the other side. The primary range of the scaffold will incorporate two 36m long methodology ranges. It will work as a two ribbed curve with steel brackets made of cement filled fixed steel boxes. The design will be upheld by two 130 m long, 100m high arches on one or the flip side through links. The arch and arch piers of the Chenab Scaffold will be produced using enormous steel supports. To give least wind obstruction, the harmony of supports and the diagonals are altered to become fixed steel boxes. Any remaining individuals including optional individuals were kept round, which extraordinarily improves on the association subtleties. The harmony individuals will be loaded up with concrete to help with controlling breeze prompted powers on the scaffold by improving damping proportion and solidness. The substantial fill likewise improves the general strength. In the curve part of the superstructure is upheld on steel wharfs with a tallness of up to 120m. Extension joints are given toward the end projections and at wharf S70 that different the principle curve range from the methodology connect. At this area there is additionally an adjustment of the deck stature. The mark of longitudinal fixity of the curve connect deck is at curve focus, where the powers are sent most proficiently and relocations at either end are negligible.

The superstructure is a plate brace with a shut deck, where rails are associated. The shut deck keeps the water and gives generally dry climate beneath the deck. Wind noses of the deck are given in the primary curve divide. Launching of curved viaduct portion done for first time on Indian Railways using End Launching method. NABL (National Accreditation Board for Laboratories) accredited lab established at site for weld testing.

Steel was picked to develop the scaffold as it will be more prudent and ready to oppose temperatures of - 20o C and wind rates of above 200km/h. The Jammu and Kashmir area observer to visit fear monger assaults. To upgrade the wellbeing and security the extension will be made of 63 mm thick uncommon impact evidence steel. The substantial mainstays of the scaffold are intended to withstand blasts. It is normal that the construction will actually want to withstand quakes of greatness eight on Richter scale and up to 40 kg of dynamite impact. Bridge designed to bear earthquake forces of highest intensity zone-V in India.

A ring of elevated security will be given to protect the extension. A web-based checking and cautioning framework will be introduced on the scaffold to ensure the travelers and train in basic conditions. Pathways and cycle trails will be given adjoining it. The scaffold will be painted with extraordinary consumption safe paint which goes on for a very long time.

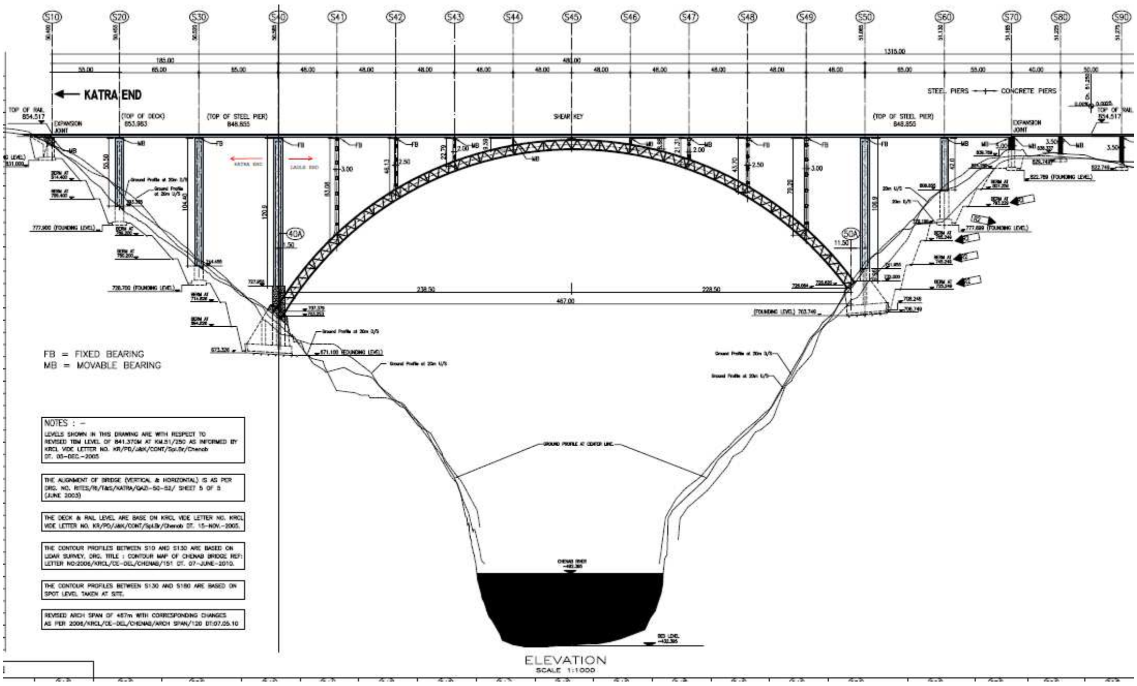


Figure 3: Side elevation of the bridge

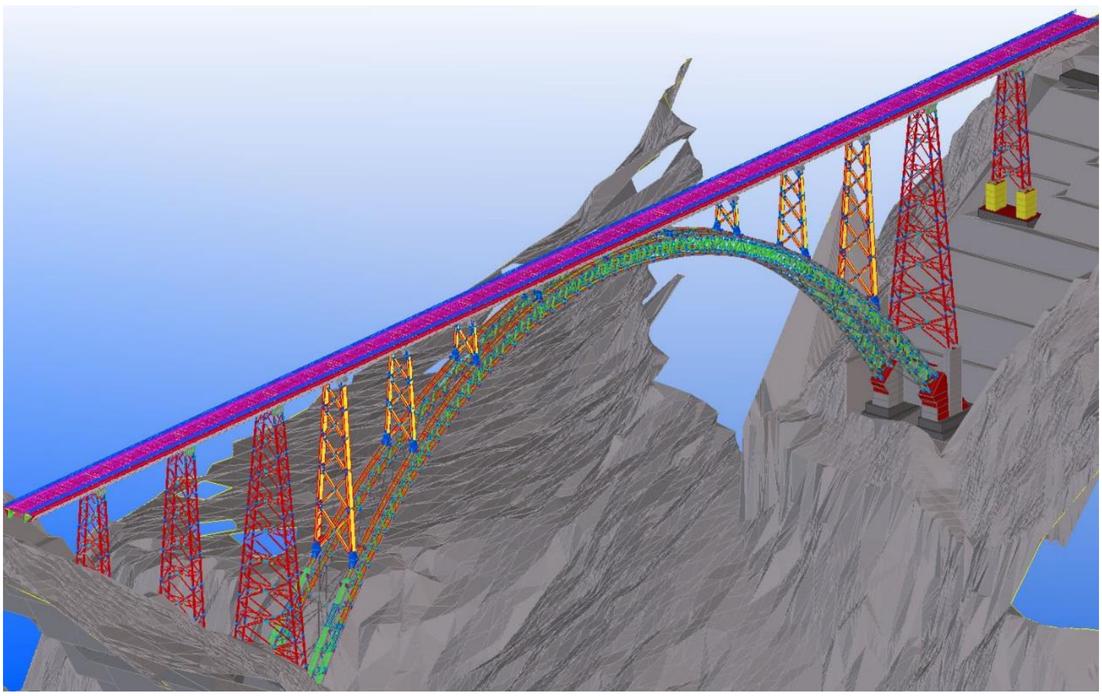

Figure 4: Steel arch details

## BRIDGE CONSTRUCTION

The scaffold's development guideline involves a huge extension curve with access viaducts at each side. The enormous curve planned as a 2-overlay ribbed curve including steel supports with platform supports delivered on the spot. 5 scaffold columns for the entrance viaducts are made of steel and 13 of cement.

The steel constructions of the scaffold will be fabricated in workshops worked in the mountains. Four workshops have been underlying the mountains. Workshops and paint shops worked close to them are situated on the two sides of the valley. All steel materials, with the exception of the little moved profiles, are conveyed to mountains as steel sheets. All power created at site and water provided from additional away in mountains. The extension will comprise of 25000 tons of steel structures, the principle bit of which will be utilized for the curve connect area. Initial a link crane will be worked over the valley for building the steel structures. The link crane will move between arch pinnacles based on the two sides of the valley. The crane can convey a greatest measure of 40 tons of steel parts. Derrick crane introduced, which is equipped for lifting around 100 tons. For the first time continuous welded plate girder used on railway bridge.

**Foundation**

To set up the establishments for the extension in the troublesome territory, safe uncovering at the two sides of the valley is being ready for a terrific scope, penetrating for establishment. The tallest wharf is 137.7m tall, a particularly tall design is required gigantic establishment of 150m*36.5m.

**Slope stabilization**

The side slant of the valley differs from $43^{o}$ to $77^{o}$. The incline adjustment measures are finished by Indian Organization of Science. After uncovering of rock bolt of design length of 4m, 8.5m and 11.5m are introduced. Permeable lines are introduced to forestall the hydrostatic pressing factor. Guniting with steel support is given to reinforce and balance out the slant.

**Deck and arch construction**

At the point when long steel sections are prepared, the steel deck will be pushed on top of the segments. After this a derrick crane will be set on top of the deck. The derrick will extend the curve fragment from deck level to the erection of front of the curve. Deck erection will continue all the while with the erection of curve. Both curve and the deck cantilever unreservedly by up to 48m. At the point when the following curve dock area is reached, brief links will be introduced to help the curve, and the new curve wharf will be built on the free end. The superstructure would then be able to be upheld by curve dock, until the last curve wharf is reached. The absolute last curve range of the curve and the components of the key fragment will again be conveyed by the link crane; conclusion of the superstructure is finished through derrick erection.
The deck of the extension is halfway straight skyline and part of the way in bends. It is situated on a progress bend with evolving span. Development is hence being done in stages following the progressive change in the arrangement. The deck of the extension will be welded in workshop about 8m long segments, on the grounds that the welding point in the last construction are predominantly situated under the scaffold.

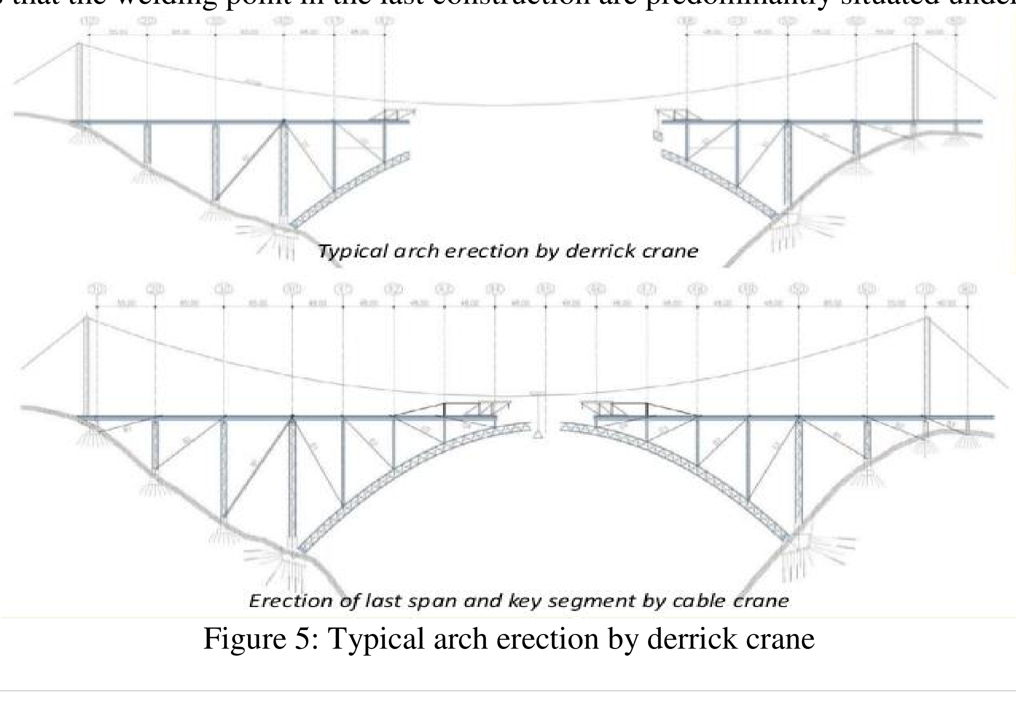


Figure 5: Typical arch erection by derrick crane

Figure 6: Connecting the both levels of arch

**Challenges in construction**

The extension is being built in quite possibly the most confounded and detached landscapes. Perhaps the greatest test included was development of the scaffold without discouraging the progression of the stream. No legitimate street network in testing territory. Approach streets, five kilometers long, were built to arrive at the establishments of the extension. The framework of the space causing extra issues. Transportation of the development hardware is a significant test. The development area is delicate for the psychological militant assault.

Stabilization of foundation and erection of the bridge were major challenges. For stabilizing the arch foundation, it is needed to control the deflection by anchoring the arch by numbers of forestay and backstay cables at nodal points. When wind speed exceeds 50 kmph the erection work has to be stopped. The work at height is carried out after fixing wire net underside so as to arrest fall of any object or material.

## CONCLUSIONS

The plan of the primary curve requires thought of some of extra boundaries, like weariness, worldwide steadiness, second request impacts, composite activity, and so on It likewise necessitates that such an extension intended to accomplish a predictable degree of unwavering quality for all heap cases, and that the plan norms match the development principles. The Chenab Extension will be the greatest, longest range and most elevated railroad curve connect at any point worked on the planet.

Development of the scaffold is relied upon to require 27000MT of steel, 4000MT of built-up steel, 66000m3 of concrete and 8 million cubic meter of unearthing. The development of the scaffold was ended in 2008 because of arrangement and security issues. It is continued in 2010 expected fruition in 2015, which was in this manner pushed to 2019. The development of the scaffold will be finished by December 2021.

## REFERENCES

1) GSI (1989) Geological Survey India, Special publication no 26.
2) Tiwari G, Latha GM (2016) Design of rock slope reinforcement: Himalayan case study
3) US Army (1999) Risk based analysis in geotechnical engineering for support planning studies engineering, and design
4) www.wsp.com/en-GL/projects/chenab-bridge
5) www.railway-technology.com/projects/chenab-bridge-jammu-kashmir
6) theconstructor.org/case-study/chenab-bridge-construction/63057
7) https://en.wikipedia.org/wiki/Chenab_Bridge

8) https://www.wsp.com/en-GL/insights/chenab-bridge-connecting-the-arch-up-in-the-clouds
9) https://www.pib.gov.in/PressReleasePage.aspx?PRID=1709652
10) https://konkanrailway.com/press/details/984
11) Tekla.com/resources/case studies/bridge information modelling chasing new highs in India.