Design of tall railway bridges in North-East India

Sumantra Sengupta
Principal Consultant
STUP Consultant Pvt. Ltd.
sumantra.sengupta@stupmail.com

Mr. Sumantra Sengupta graduated from Jadavpur University in the year 1990 and post graduated in Structural engineering from the same institute in 1992. Since then he is working in STUP Consultants. His field of expertise is special structures.

Summary

The paper deliberates on the design of tall bridges of pier height varying from 50m to 140m in hilly river gorges in North-East of India which falls under highest seismic zone area of India. Due to the varying height and considerably high piers in seismic prone area, multi modal analysis is performed using peak ground acceleration (PGA) and acceleration response spectrum obtained from site specific seismic vulnerability study with the available data. Due to the pier locations on the steep slope of the hill, rigorous slope stability analysis has been performed. Wind analysis has been performed followed by wind tunnel analysis. Fatigue analysis has been performed for the steel superstructure as per the latest research findings.

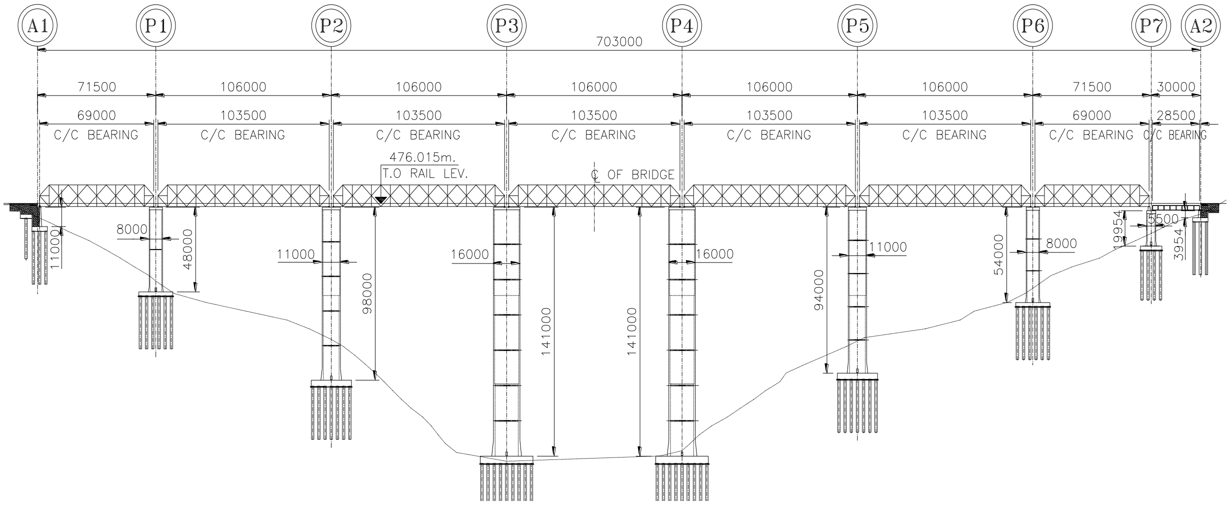
Key words: Tall bridges, slope stability, site specific seismic study, multi modal analysis, wind tunnel analysis, erection scheme, fatigue analysis

1. Introduction

Indian Railways intends to connect the capitals of the three North-East states, Manipur, Mizoram and Nagaland with Assam by railway link. The work of Manipur and Mizoram has been started and the design of 5 bridges in Manipur and 6 bridge sin Mizoram are in hand. The length of railway line in Manipur is about 125km and that of in Mizoram is about 60km. The alignments of the railway lines pass through steep rolling hills of Patkai region, eastern trail of Himalaya, and as a result large number of tunnels and bridges need to be designed. While the high mountains are penetrated by tunnel, the deep gorges between the mountain ridges are connected by tall bridges. The tallest of such bridges spans over a gorge at about 140m above its bed level with an overall length about 700m at rail level. With extensive study and discussion on possible alternative span arrangement of the bridges, considering the parameters like the length of span, type of span, location of the piers and constructability it was finally decided that main superstructures will be steel open web through type girders of 103.5m span (c./c bearing). The piers are RCC hollow type with the tallest piers of 140m height. Other piers on the slope of the hills vary from 50m to 90m height. The foundations are being designed with 1.5m diameter piles that penetrate into rock layers with maximum length of 30m. The critical issues of analysis and design involve preparation of site specific spectrum for seismic design of the bridge, rigorous slope stability analysis of the hill slopes on which the tall piers are standing, wind tunnel analysis to ascertain the actual behaviour of the structure in wind, fatigue analysis of superstructure with the latest provision of fatigue. Apart from IRS (Indian Railway Standard), other codes like IS (Indian Standard), IRC (Indian Road Congress), AREMA (American Railway Engineering and Maintenance-of-way Association), UIC (International Union of Railway) and Euro code

https://doi.org/10.2749/222137813815776160

provisions have been taken into account. The paper presents the steps followed for making these bridges as sustainable structures in a highly seismic zone at optimum cost.



Elevation of the tallest bridge

2. Critical Design Issues

Geotechnical appraisal: In general the top 3 to 10m is stiff clayey silty sand with mix of gravels below which highly weathered shale/ sandstone layer is there.

Slope stability analysis: Equivalent static slope stability analysis is performed using STED supported by deflection analysis of underneath soil using Plaxis.

Site specific seismic vulnerability study: Past 250 years' seismic record has been used for generating site specific PGA and acceleration spectrum which has been used for seismic analysis. While the PGA almost matches with that given in the code, the spectrum gives almost double values.

Seismic and Wind analysis: Multi modal analysis has been performed considering the superstructure, substructure and pile foundation as a whole. Wind analysis is performed on the same structure followed by wind tunnel test.

Serviceability consideration of the structures: Horizontal deflection limit of the piers has been considered as H/500. The superstructure vertical and horizontal deflections are also controlled.

Erection Scheme of the Superstructure: Cantilever erection method has been adopted and in design the effect of the same has been taken in to account.

3. Conclusion

Due to the criticality of the terrain, tall and varying height of the piers, large length of the bridges, position of the piers on the hill slopes and the presence of severe most earth quake zone the design of the above bridges are critical in many respect. The construction methodology of the bridges, transportation of the materials particularly in view of the winding approaches, the limitation of the size of the fabricated steel chord of the superstructure and erection of the superstructure affect the design aspect. During the design all the above issues has been taken in to consideration with due importance to each issue and an effort has been made to achieve safe and sound structures with optimum cost which will serve the railway connections to these remote areas of the North-East part of India.