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Non-linear Dynamic Behaviour of the Multi-arch Gallery Masonry Bridge of Kalka Shimla Mountain Railway

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Abstract

The Indian railway network is amongst the oldest railway networks in the world. Some of the bridges in the Indian railway that were constructed under British rule are still operational. Although these bridges have crossed their service life span, their present-day serviceability is questionable, especially those located in high seismic zones. The performance of such heritage bridges in the occurrence of any seismic activity is poor due to inadequate seismic resistance. Consequently, the seismic vulnerability assessment of these heritage bridges is necessary to understand the most vulnerable structural elements and performance of the bridges for different seismic loading. This research study presents the seismic vulnerability assessment of Bridge No. 493 of Kalka Shimla Mountain Railway (A UNESCO recognized World Heritage). For this purpose, an experimental campaign adopting Ambient Vibration Testing (AVT) and Operational Modal Analysis (OMA) was performed on the bridge to estimate the dynamic characteristics (mode shape, frequency). Further, a three-dimensional numerical model of the bridge was developed in ABAQUS finite element software. The initial numerical model was updated by modifying the material properties to match the behaviour results from AVT and OMA. Then, the nonlinear dynamic behaviour of the bridge was simulated with the updated model using the synthetic time history in agreement with different hazard scenarios (Zone IV seismicity with return period of 95 years, 475 years, 2475 years). Lastly, the results of the performance of the bridge for different seismic hazard scenarios are discussed. The numerical simulation showed that the bridge is heavily damaged by the seismic loading having a return period of 2475 years and the primary failure mechanism is the shear failure of the bridge's piers.

Keywords: Ambient vibration testing, Operational modal analysis, Seismic analysis, Heritage, Bridge