World Academy of Science, Engineering and Technology
International Journal of Civil and Architectural Engineering
Vol:16, No:09, 2022

Approach for the Mathematical Calculation of the Damping Factor of Railway Bridges with Ballasted Track

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Abstract : The expansion of the high-speed rail network over the past decades has resulted in new challenges for engineers, including traffic-induced resonance vibrations of railway bridges. Excessive resonance-induced speed-dependent accelerations of railway bridges during high-speed traffic can lead to negative consequences such as fatigue symptoms, distortion of the track, destabilisation of the ballast bed, and potentially even derailment. A realistic prognosis of bridge vibrations during high-speed traffic must not only rely on the right choice of an adequate calculation model for both bridge and train but first and foremost on the use of dynamic model parameters which reflect reality appropriately. However, comparisons between measured and calculated bridge vibrations are often characterised by considerable discrepancies, whereas dynamic calculations overestimate the actual responses and therefore lead to uneconomical results. This gap between measurement and calculation constitutes a complex research issue and can be traced to several causes. One major cause is found in the dynamic properties of the ballasted track, more specifically in the persisting, substantial uncertainties regarding the consideration of the ballasted track (mechanical model and input parameters) in dynamic calculations. Furthermore, the discrepancy is particularly pronounced concerning the damping values of the bridge, as conservative values have to be used in the calculations due to normative specifications and lack of knowledge. By using a large-scale test facility, the analysis of the dynamic behaviour of ballasted track has been a major research topic at the Institute of Structural Engineering/Steel Construction at TU Wien in recent years. This highly specialised test facility is designed for isolated research of the ballasted track's dynamic stiffness and damping properties – independent of the bearing structure. Several mechanical models for the ballasted track consisting of one or more continuous spring-damper elements were developed based on the knowledge gained. These mechanical models can subsequently be integrated into bridge models for dynamic calculations. Furthermore, based on measurements at the test facility, model-dependent stiffness and damping parameters were determined for these mechanical models. As a result, realistic mechanical models of the railway bridge with different levels of detail and sufficiently precise characteristic values are available for bridge engineers. Besides that, this contribution also presents another practical application of such a bridge model: Based on the bridge model, determination equations for the damping factor (as Lehr's damping factor) can be derived. This approach constitutes a first-time method that makes the damping factor of a railway bridge calculable. A comparison of this mathematical approach with measured dynamic parameters of existing railway bridges illustrates, on the one hand, the apparent deviation between normatively prescribed and in-situ measured damping factors. On the other hand, it is also shown that a new approach, which makes it possible to calculate the damping factor, provides results that are close to reality and thus raises potentials for minimising the discrepancy between measurement and calculation.

Keywords : ballasted track, bridge dynamics, damping, model design, railway bridges
Conference Title : ICBRE 2022 : International Conference on Bridge and Railway Engineering
Conference Location : Lisbon, Portugal
Conference Dates : September 20-21, 2022