Dynamic Serviceability and Traffic Safety Assessment and Upgrading of Historic Railway Bridges

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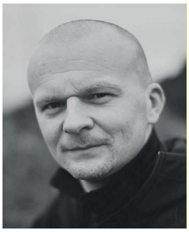

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Summary

The paper discusses the application of modern computational dynamic analysis to the assessment of the dynamic performance of historic railway bridges. The phenomena, such us dynamic amplification, serviceability-critical bridge and train accelerations, as well as bridge-train interaction and resonance are outlined and discussed. The background to the current serviceability requirements, based on the UIC and Eurocode recommendations is provided and these requirements are discussed. This is followed by applications demonstrating the use of the advanced dynamic analysis in the assessment of railway bridges. Examples include historic bridges that were analysed to assess safe operational speeds, based on the serviceability criteria. Means of improving the dynamic performance of these bridges are examined and discussed.

Keywords: Bridge Dynamics, Bridge-Train Interaction, Dynamic Amplification Factor, Dynamic Assessment.

1. Introduction

The dynamics of bridges subjected to moving loads has been attracting much attention in recent years. This can be attributed mainly to worldwide developments of high-speed railway lines, a common drive to upgrade existing railway infrastructure for higher speeds and loads, as well as to ageing of the infrastructure that requires proper planning of maintenance efforts and budgets. All of these activities require specialist knowledge, as well as accurate and efficient methods to calculate and assess the dynamic performance of structures carrying moving loads. The design codes are often found to be very conservative when used for the assessment of existing structures and historic bridges in particular. This can be attributed to the fact that the design codes are developed in a very general manner to encompass a wide range of structures, load cases and other conditions. However, the use of the codes can be optimised with a better knowledge of local conditions, e.g. type of rolling stock using the bridge, type and condition of the railway track on the bridge, etc., without compromising the safety levels of the structure. This paper discusses the background to investigations carried out in recent years by the author on the basis of the UIC industry codes, [1], and the Eurocodes, [2], [3]. The paper also presents some of the case studies on existing railway bridges and their major findings.

2. Modelling of Bridge-Train Dynamics

A number of different approaches to modelling and analysis of bridges subjected to moving loads exist. These vary from simple analytical models with closed form solutions to elaborative finite element models with many of degrees of freedom. In order to provide a tailored solution and to overcome some of the limitations and shortcomings of the commercial finite element packages, the author previously developed and extensively verified a customised finite element-based bridge-train interaction model DBTI (Dynamic Bridge-Train Interaction), as summarised in [4]. The DBTI model was employed to carry out all the analyses presented in the paper.

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3. Case Studies on Dynamic Analysis and Assessment of Bridges

The dynamic analysis and assessment of two existing historic bridges, Fig. 1 and Fig. 2, was carried out as part of their serviceability and traffic safety assessment. Both bridges were originally constructed with the waybeam track, where longitudinal timber sleepers continuously supported the rails and were fixed directly to the open deck of the bridge. This type of track suffers from rapid deterioration of the track quality requiring more stringent inspection and maintenance regimes, which have significant cost implications. A programme was put in place in the early 2000's to investigate all the waybeam bridges within the Irish Rail network. This was to be carried out by the traffic safety assessment and, where required, by the provision of modern decks on those bridges with either ballasted or embedded tracks. Various serviceability and traffic safety checks were carried out on the basis of the results of the dynamic analysis in accordance with the Eurocodes [2] and [3], and selected results are presented and discussed in the paper. The results were used to inform the decision making process and the design of remedial works.

Fig. 1: The River Slaney Bridge

Fig. 2: The River Nore Viaduct

4. Conclusions

It is a conclusion of this paper, that the current Eurocodes provide a framework for the use of the advanced dynamic analysis by facilitating the bridge and train-specific dynamic analysis, and allowing for the refinements to the dynamic response to be achieved. This is of particular importance in the case of existing railway bridges, where the structural and serviceability assessment can be optimised with the use of bridge and train-specific dynamic analysis. This may allow for extending the service life of certain bridges and provide a more cost efficient and sustainable solution.

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