Safety-related Issues for High-Speed Railway Bridges

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ABSTRACT: Railway bridges have specific requirements related to safety, which often are critical aspects of design. In this paper the main phenomena are reviewed, namely vertical dynamic effects for impact effect of moving loads and resonance in high-speed, service limit states which affect the safety of running traffic, and lateral dynamic effects.

1 VERTICAL DYNAMIC EFFECTS

Railway bridges per se have some special requirements with respect to ordinary road bridges: larger traffic loads, dynamic phenomena which may increase substantially their effects, and more stringent requirements to guarantee safety of the guided traffic.

The dynamic increment from single moving loads on smooth tracks has a maximum value of $\varphi' = 77\%$, at speeds which are achieved for current trains and bridges. Current codes [1], [4] introduce an *impact coefficient* $(1 + \varphi')$ with a maximum value of 2.32 (132% increment). Some additional dynamic effects must be considered in real cases from irregularities of tracks and wheels.

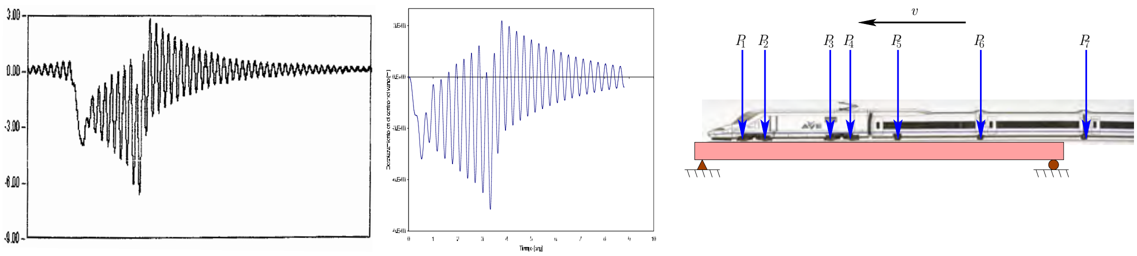

Figure 1. Dynamic response of railway viaduct (Tajo river) showing resonance (AVE S100 at 219 km/h)

The new high-speed trains introduce a new and potentially much greater dynamic action, due to resonance from regularly spaced axle loads at speeds whose effective frequency coincides with the fundamental frequencies of bridges. As an example, figure 1 shows measured and computed results for a real bridge, with an impact coefficient of around 2.0. This is not a problem for the ULS of the bridge, as it is sufficiently covered by the safety margins in project. However, the vibrations induced in the catenary posts were excessive and they had to be relocated in different positions. Other cases may show much greater resonant effects, which must be avoided in the design of bridges. Adequate evaluation of this risk requires a dynamic analysis.

2 SERVICEABILITY CRITERIA FOR RAILWAY BRIDGES

In structural engineering service limit states (SLS) are not generally associated to catastrophic consequences. The case of railway bridges is different, as safety concerns for traffic actually define many of the SLS for railway viaducts [2]; these limits are actually ULS for the traffic [5].

Regarding vertical dynamic effects, due to existing safety margins in current codes for actions, ULS is usually not the prime concern in the design. More often, the critical issue is the limit of vertical accelerations of the bridge deck (for ballast track $a_{\max} = 3.5\ \mathrm{m/s^2}$, in order to ensure track stability and safety of traffic). Additional limits are placed on maximum relative displacements and rotations of decks and track, in longitudinal, transverse and vertical directions.

Special consideration must be made for interaction between track and structure. At deck joints allowing longitudinal movement the effects from braking and thermal actions are concentrated on the rail, whose stresses must remain within allowable limits. For long continuous decks, as is often the case in new HSR line layouts, a careful design must be performed for fixed points and eventually rail expansion devices.

3 LATERAL DYNAMIC EFFECTS

An important safety issue for railway bridges, not so well studied, is the lateral dynamic effects, which may lead not only to excessive vibrations and discomfort but also to risk of derailment, especially if combined with lateral actions such as high wind forces or earthquakes. For this reason limitations for lateral deformation of bridge decks and minimum natural frequencies have been introduced in the codes [2].

Some modern high-speed railway viaducts may be very flexible for lateral actions. These are tall, slender viaducts, with long continuous decks, significantly different from the cases studied by ERRI D181, with much longer deformation mode wavelengths. Some recent research work for this case is reported in [3] (figure 2).

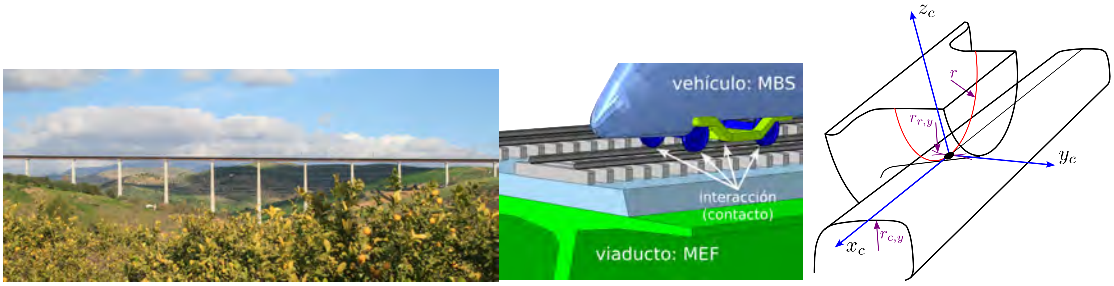

Figure 4. Viaduct in Córdoba-Málaga HS line and model for analysis of lateral dynamics.

4 REFERENCES

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