# Train-bridge interaction influence on the safety of a short span railway bridge

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## Summary

The behaviour of short span railway bridges is known to be particularly difficult to predict due to the complex coupled train-track-bridge system, as well as for being particularly sensitive to resonant phenomena. The objective of this paper is to evaluate the safety of this type of structure inserted in high speed railway lines, bearing in mind the real variability of the parameters that influence the bridge dynamic response. This requires the definition of variables related to the structure, the train, the track and also the wheel-rail contact. Simulation techniques are used to evaluate the structural safety. The system behaviour is assessed by analysing the results obtained using two distinct methods: the moving loads method and the train-bridge interaction method. This allows assessing the influence of the train-bridge interaction effects on the dynamic response of the bridge, confirming its importance for the analysis of short span structures, particularly under resonant speeds.

**Keywords:** Train-bridge interaction; High-speed railway traffic; Short span bridge; Resonance effects; Safety assessment; Probabilistic approach.

## 1. Objectives/Description

The behaviour of short span railway bridges is known to be particularly difficult to predict due to the complex coupled train-track-bridge system, as well as for being particularly sensitive to resonant phenomena. The objective of this paper is to evaluate the safety of this type of structure inserted in high speed railway lines, bearing in mind the real variability of the parameters that influence the bridge dynamic response.

As a case study Canelas Bridge, a bridge with six simply supported spans of 12 m each, was selected. The bridge deck is a composite structure consisting of two half concrete slab decks with nine embedded rolled steel profiles HEB 500. This kind of structural system is called filler beam and is a very common structural solution for small span bridges in the European high-speed railway lines, especially in France and Germany. A general view of the bridge used as case study, as well as the typical cross section of the bridge deck is shown in Fig. 1.

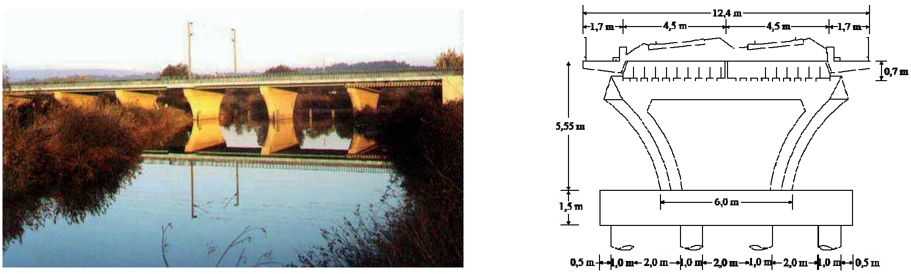


*Fig. 1: Canelas Bridge – General view and typical cross section*



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This sort of analysis requires the definition of variables related to the structure, the train, the track and also the wheel-rail contact. Having already studied the structural parameters in previous papers, this paper focuses its attention on the train and wheel-rail contact variables. A train model of the TGV Double train was developed. This train has a total length of 400 m and is constituted by 4 power cars, 4 power passenger cars and 12 passenger cars, with a total of 52 axles. The car bodies are modelled as concentrated masses with mass $M_c$, whereas the bogies are simulated by rigid bodies with mass $M_b$, and rotational inertia $I_b$. The primary and secondary suspensions are simulated by a spring-damper set with stiffness, $K_p$ and $K_s$, and damping coefficient, $c_p$ and $c_s$, respectively. The wheelset is simulated by a concentrated mass, $M_e$, whereas the wheel-rail contact stiffness is simulated by a spring with stiffness $K_h$.

## 2. Train-bridge interaction

The influence of train-bridge interaction effects on the dynamic response was analysed as they may induce significant changes to the obtained dynamic response since the case study used is a short span bridge, typically sensitive to resonance phenomena. A sensitivity analysis was carried out in order to identify the train parameters with higher influence on the dynamic response. This sensitivity analysis allowed concluding that the bridge response is practically unaffected by the changes of the train properties. The only exception occurs when the car bodies mass and the non-suspended mass, which consequently affect the loads per axle, are changed.

Another important aspect regarding the train bridge-interaction are the track irregularities since they can lead to the amplification of the dynamic effects, originate resonance phenomena on the trains or lead to the instability of the wheel-rail contact. Artificial track irregularities profiles were generated using the power spectral density functions proposed by several railroad administrations. The influence of the track irregularities on the dynamic response was assessed and it was observed that their presence can either increase or decrease the maximum bridge acceleration but there are almost no differences between standard and carefully maintained tracks. This makes the track irregularities negligible when analysing the dynamic response of the bridge.

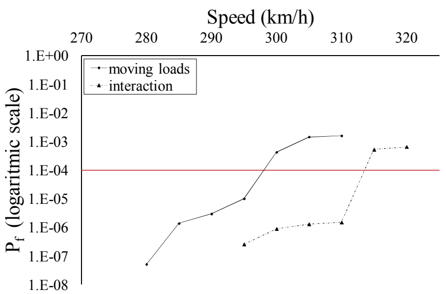


*Fig. 2: Evolution of $P_f$ with increasing train speeds*

In order to assess the influence of train-bridge interaction effects on the dynamic response of a short span high-speed railway bridge and to account for the structural variability, simulation techniques were applied. For the analysis, 5000 Monte Carlo simulations were carried out and the obtained results were the basis for the safety assessment of the bridge. The acceleration of the deck was the most restrictive aspect of the response and a limit of 7 m/s$^2$ was considered, which is the value laboratory tests confirmed to be the threshold for the beginning of ballast instability.

Furthermore, a comparison was made between the results obtained when the train-bridge interaction effects were taken into account and when the moving loads method is used. The obtained results are illustrated in Fig. 2.

## 3. Conclusions

Significant differences can be observed when comparing the obtained results for both methods. Train-bridge interaction leads to a reduction of the maximum accelerations, confirming what was observed in a deterministic analysis. As a result, the estimated train speed limit increases to 310 km/h, which represents a 5% gain (15 km/h). It can also be observed that if a more conservative approach was used, by lowering the probability of failure limit to values up to $10^{-5}$, the speed limit would be unchanged. The results also showed that despite reducing the maximum response the train-bridge interaction does not induce changes in the resonant speeds. Therefore, when studying bridges where the safety is jeopardized by resonant effects the train-bridge interaction should be taken into account as it allows a more realistic and also allows the bridge to operate under higher train speeds.