Experimental Validation of a Numerical Model for the Dynamic Analysis of a Bowstring Arch Railway Bridge

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This paper focuses on the development and experimental validation of a numerical model for the dynamic analysis of the São Lourenço railway bridge, located at the Northern line of the Portuguese railways, for the passage of railway traffic.

The bridge is a bowstring arch consisting of two half-decks with 42 m span, each one carrying a single track. Each deck consists of a 40 cm thick prestressed concrete slab suspended by two lateral arches. The suspension is performed by means of metallic hangers and diagonals in the proximity of the support blocks of the arches. The deck seats in the abutments by means of pot bearing supports. The distance between the supports is 38.4 m, and the extremities of the deck slab work as cantilevers with 1.8 m span. In Fig. 1 are presented two general views of São Lourenço bridge.

Fig. 1: General views of São Lourenço bridge

The numerical model involves the modelling of the bridge, the train and their dynamic interaction.

The finite element model of the São Lourenço bridge is shown in Fig. 2 a) and consists in a planar model with beam elements.

The finite element model of one of the vehicles of the Alfa Pendular train is shown in Fig. 2 b). In this model, the rigid bodies, referring to the box and the bogies, were modelled as beams of high bending stiffness and uniformly distributed mass along its length, the suspensions were modelled as spring and dash-pot assemblies, the wheel-rail connections were modelled as springs, and the masses corresponding to the axles and wheels were concentrated on the nodes. Additionally the seats and passengers were modelled with masses concentrated on the nodes, connected to the vehicle box and seats by means of spring and dash-pot assemblies.

The preliminary experimental campaign consisted of an ambient vibration test and a dynamic test for the passage of railway traffic.

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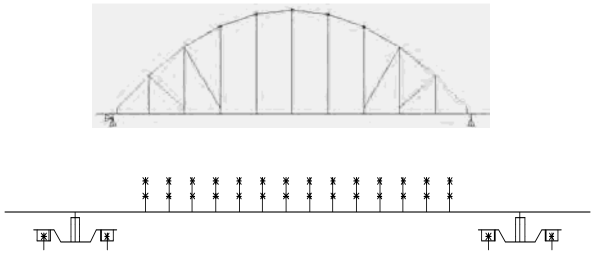

a)

b)

Fig. 2: FE models: a) Bridge; b) Vehicle

The comparison of the numerical and experimental natural frequencies revealed limitations in the initially developed numerical model.

The study of the influence of several parameters in the dynamic properties of the structure enabled to identify the inclusion of the track as the most relevant factor due to the deck-track composite effect. The inclusion of the track, in conjunction with changes in the mass of the deck, the modulus of elasticity of the concrete and the vertical stiffness of the supports, enabled to effectively minimize the differences between the numerical and experimental frequencies.

The updated numerical model was used to predict the dynamic response of the bridge under traffic loads. The modelling comprised not only the bridge, but also the train and the interaction between these two systems by means of contact algorithms available in the ANSYS software. The comparison of the vertical accelerations on the deck for the passage of Alfa Pendular train, recorded on the dynamic test for the passage of railway traffic, with the records obtained from the numerical simulation, shown in Fig. 3, provided a good match between numerical and experimental results.

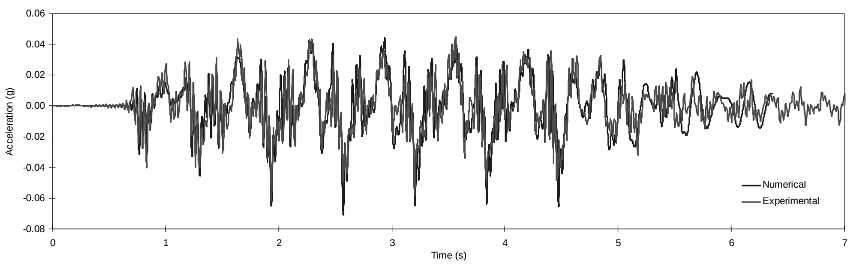

Fig. 3: Comparison between the numerical and experimental results in terms of the vertical acceleration of the deck obtained for the passage of the Alfa Pendular train at 147 km/h