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Weigh-in-motion implementation in an old metallic railway bridge

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ABSTRACT

The structural assessment of old metallic bridges is a challenge for civil engineers. This is mainly due to difficulties in identifying material properties and vehicle characteristics. A great number of these bridges were built with materials that are no longer used in modern structures and are presently subjected to loads very different from the ones considered in the design. In this context, structural monitoring can be an important tool to characterize the structural behavior and to support the safety assessment. In this paper, the steps taken to implement a Bridge-Weigh-in-Motion algorithm for traffic characterization in a railway bridge are presented. For that purpose, a long term monitoring system based on strain gauges was installed in the Portuguese Trezói Bridge. The measurements from a period of approximately two years were used to obtain axle loads, axles spacing and velocities of the trains that crossed the bridge during this period, enabling the accurate characterization of the real traffic conditions. This was achieved applying a method for traffic characterization based on the research developed by Moses (1979) and also based on the recent research developed by Liljencrantz et al. (2007) and Quilligan (2003), which was enhanced by an optimization algorithm implemented to minimize the error of the simulated response when compared to the measured response of the structure, thus allowing the estimation axle loads, axle spacing and speed.

1. Introduction

In the context of structural design and safety evaluation, the uncertainty associated with the loads is one of the most relevant since, in general, the remaining variables of the problem can be estimated with a certain level of accuracy using, for example, laboratory tests for material characterization. Thus, methodologies that lead to the estimate of the loads applied to a structure are essential to increase the confidence on the evaluation of the structural behavior. In particular, old bridges endure loads higher than originally envisaged and the present real traffic conditions normally are not well known. The importance of these methodologies is even more relevant since the safety evaluations based on code traffic scenarios can overestimate the stresses in the structural elements. These unrealistic high stresses may lead to repairing strategies with unnecessary costs or even to unnecessary replacement of the structure.

Furthermore, in Europe there is a wide number of structures that have cultural significance and that cannot be submitted to retrofitting that would compromise their identity. In this context and for the case of railway bridges, a methodology that leads to an accurate estimation of axle loads, axle spacing and vehicles velocity can be extremely useful to assess the condition of the structure, avoiding extensive retrofitting or even the replacement of these old structures.

Weigh-in-motion (WIM) is the process of estimating the weight of a moving vehicle and the portion of that weight that is carried by each axle by measuring and analyzing the dynamic forces originated by the wheel using specific devices placed in the path of the vehicle. In recent years, WIM methodologies have been implemented to estimate axle loads with good results and several research projects have been developed in order to improve their accuracy. In particular, the Weigh-in-motion of Axles and Vehicles for Europe (WAVE) project [4] was an important European research project in the subject.

Bridge weigh-in-motion (B-WIM), an alternative to traditional WIM, is also an extremely relevant methodology to address the problem of estimating dynamic axle loads. It is the process of converting an instrumented bridge to a scale for weighing crossing vehicles. B-WIM has the potential to produce similar results to traditional WIM, while overcoming some problems associated with the use of sensors in the rails, since it is potentially less sensitive to train dynamics than WIM.

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Fig. 1. The Trezói Bridge.

Most B-WIM algorithms are based on the work done by Moses and his team [1] in the late 1970s. This author originally implemented this algorithm to composite road bridges and, nowadays, it continues to be the basis for research in this field and is one of the most widespread algorithms in commercial B-WIM systems.

One of the first B-WIM systems developed specifically for railway bridges was implemented by Karoumi et al. [5] in a Swedish single span bridge. These researchers used strain gauges placed inside the concrete bridge and aligned with the rails to estimate the axle loads. The algorithm implemented in this weighting system, and also in 2007 by Liljencrantz et al. [2], is based on the methodology proposed by Quilligan [3]. It was developed in Matlab and leads to the estimation of the number, the loads and the distance between axles. Furthermore, the velocity and acceleration of the train are also estimated.

Other methods for the estimation of axle loads are described in the literature. For example, in the European projects SUPERTRACK [6] and FADLESS [7], pressure cells placed bellow the track and strain gauges placed on the rails were used for that purpose with good results.

It is also important to notice that the relevance of traffic characterization in terms of axle loads, axle spacing and velocities is high in the context of traffic control by the railway administrations. It is also useful for forecasting traffic, estimating dynamic amplification factors, for research and fatigue assessment based on predicted loads [8]. Information on train weight data is also important for many functions of maintaining the infrastructure and transportation network as rail and ballast design and maintenance.

In this context, this paper proposes a new method for traffic characterization taking into account the previous work developed by Moses [1], Liljencrantz et al. [2] and Quilligan [3]. The description of the implementation of both WIM and B-WIM to estimate axle loads, geometric and cinematic properties of the trains crossing an old railway bridge is presented. Within the framework of

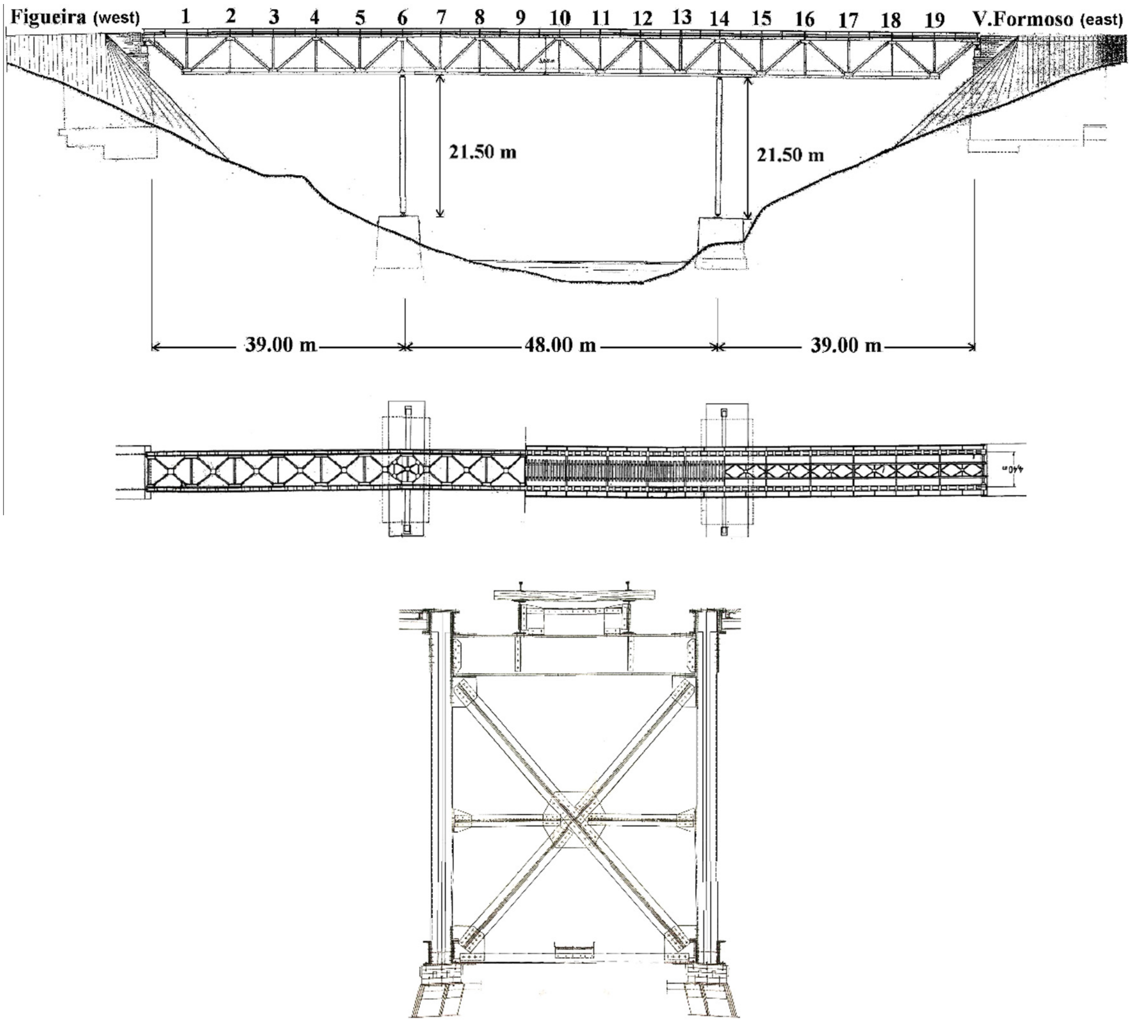

Fig. 2. Elevation, plan view and cross section of the Trezói Bridge.