Dynamic Train-Bridge Interaction in Monorail Sao Paulo Metro Line 2

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Summary

Engineering understanding of interaction between the moving train, track and bridge is necessary to successfully design rail bridges. Besides non-linear static behaviour guided by UIC 774-3 leaflet a complex dynamics vibrations due to the train movement, centrifugal forces and imperfections occurs in the interaction structure which includes bridge, track and train. Checking of the passenger comfort criteria requires sophisticated dynamic numerical analysis including the modelling of train/track/bridge interaction.

In this paper the numerical simulation of dynamic interaction between the moving monorail train and the bridge frame for the new line known as Expresso Tiradentes, which will serve as an extension of the São Paulo Metro Line 2 in Brazil, is presented. Checking of passenger comfort criteria is executed for most critical straight and curved frame bridge on the line. Bombardier Transportation, train manufacture from Canada, is a designer of Monorail 300 system for this line.

As a first step the detailed 3d modelling of the train is done including the car bodies, bogies and guiding tires in typical 7 cars multi-body mechanical system. Damping and spring systems are taken into account in lateral, vertical and longitudinal directions. The passenger masses are taken into account in dynamics analysis. As different variants of the train exist, numerical simulation is repeated for several train configurations

In the second step the calibration of the train mechanical model is done; natural modes and frequencies of the train are compared and validated against references provided by Bombardier Transportation.

The bridge frames are modelled including superstructure and substructure in third step. Special care is given to the realistic modelling of the transverse behaviour as the train path is fully eccentric to the bridge centreline.

Finally, the full interaction between the train and bridge is modelled. The coupling between moving multi-body train and bridge is taken fully into account applying the novel procedure which is presented in this paper. Overview of numerical parameters and calibration procedure of the modelling of interaction are presented together with relevant results.

Keywords: numerical analysis; modelling; linear analysis; rail/track interaction; track/bridge interaction; time history; comfort criteria; Newmark.

1. Introduction

The São Paulo Metro is the main rapid-transit system in the city of São Paulo and the largest in Brazil. It was decided to extend Line 2 (Green Line) in São Paulo from west to east with a monorail system named Expresso Tiradentes like the one in Tokyo. The manufacturer of the Monorail 300 train is the company Bombardier Transportation

The Tiradentes Monorail is 24 kilometres long; from the whole line two most critical frames are chosen for numerical analysis. The results of interest in train – frame interaction are the accelerations in the train car, which serve as a basis for the passenger comfort check.

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2. Dynamic Train Model

In this step the reference 3D dynamic model of the typical 7 cars multi-body train is created, including the car bodies, bogies and guiding tires. Although the train is modelled straight in its initial position, in dynamic analysis it follows the track curvature including centrifugal forces and 3D effects.

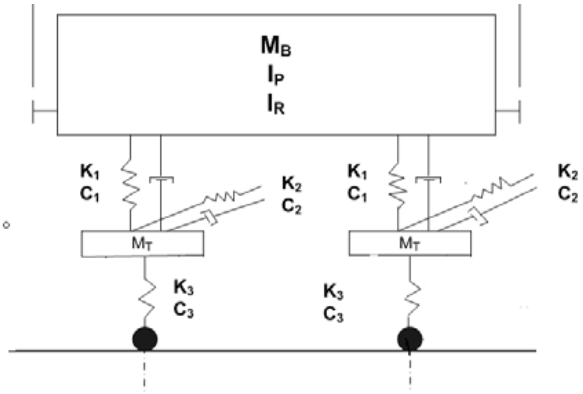


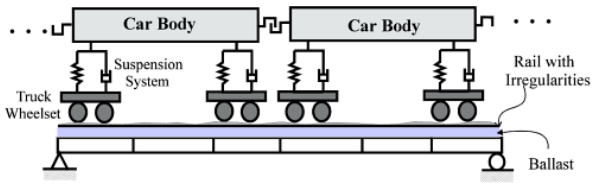
Figure 1: Vehicle Spring Diagram

3. Calibration of the Train Model

Natural modes and frequencies are calculated for train mechanical model consisting of seven cars. The calculated results have been validated against the references given by the manufacturer of the train (Bombardier Transportation).

4. Interaction between the Train and the Bridge

The interaction between the bridge and the vehicles moving over the bridge is a coupled, nonlinear dynamic problem. The most accurate modelling approach is the full train-track-bridge interaction with fully coupling of the train, track and bridge static and dynamic effects. The latest approach has been used in this work. Special computer software has been developed which carries numerical simulation of the train-bridge interaction. Within time history analysis, based on the Newmark method, the node contact layer of guideway is coupled in train and bridge model. Contact forces are transferred from the train model to the bridge; bridge movements at contact node layer are introduced as a base displacement in the train model.



Train-track-bridge interaction

Figure 2: Interaction model

Using developed computer software, train/frame interaction is investigated with two frame types – straight frame and curved frame. The goal was to investigate the comfort criteria - vertical and lateral accelerations - in the train passenger compartment.