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Transition zones to railway bridges: Track measurements and numerical modelling

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ABSTRACT

Railway tracks degrade faster at transition zones to railway bridges. In modern lines, backfills with bound and unbound granular geomaterials have been used to minimize this problem. To provide insight into the behaviour of the train–track system and to fill the gap between numerical and experimental studies, the authors carried out extensive field measurements. These were then used to validate a FEM model that considers the relevant track components, earthworks and bridge; accounts for the train–track interaction using contact elements; and is very accurate in reproducing the measurements. Results showed that the backfill design fulfils its purpose in that it provides a stiffness transition from the embankment to the bridge. The dynamic component of the train–track interaction remained low. The performance of the model makes it a very useful tool to further study the railway track at critical locations, such as transition zones.

1. Introduction

The railway tracks frequently show higher degradation rates at bridge approaches – the transition zones. This leads to expensive maintenance operations for infrastructure managers and causes disturbances in train operations [1–4]. Although the sources of the problem are yet to be fully understood, it has been attributed to two main factors [1,5–7]: (1) abrupt variations of the track's vertical stiffness due to different support conditions (softer on earthworks; stiffer on bridges); (2) differential settlements between the bridge and the backfill of the abutment, causing uneven longitudinal rail profiles. These two factors can severely amplify the dynamic train–track interaction if the transition zone is not properly designed or/and the track is poorly maintained. In such scenario, the train wheels and the track degrade at a faster rate, levels of passenger comfort decrease and risk of derailment may arise. To address these problems, railway infrastructure managers have developed numerous design specifications for the construction of transition zones [8]. Most of the recent designs have in common a 20 m-long wedge-shaped backfill with well compacted layers made of bound and unbound granular material [5].

Despite the past efforts, the behaviour of the train–track system at transition zones is not completely clear [9–11]. Previous studies have addressed it using numerical models with different levels of complexity, but only a few performed adequate calibration and validation using track measurements, as summarized in [12].

This study aims at developing a numerical model of a transition zone to a railway bridge, using the 2D FEM numerical procedure proposed in [13]. The key aspect of this study is that it contributes to fill in the gap between numerical models and experimental studies, in that it uses extensive field measurements for the calibration and validation of the model. In the framework of a research project on the transition zones of the Portuguese railway network, this work shall establish the grounds to study in greater depth the transitions zones to bridges and study their long term behaviour.

2. The case study

2.1. Description of the transition zone

The present case study is the transition zone at the southern approach of the new railway bridge over *Sado* river (Fig. 1), located in the Portuguese South Main Line (coordinates: 38°23.778′N, 8°35.670′W), in the 29 km-long *Alcácer* bypass. The line was opened in late 2010, allowing mixed traffic, with maximum axle loads of 250 kN and maximum speeds of 220 km/h for the Portuguese tilting passenger trains – the *Alfa Pendular*. It comprises a

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single track with Iberian gauge (1.668 m) using continuously welded UIC60E1 rails, 2.6 m long monoblock concrete sleepers (spaced 0.6 m), Vossloh W14 fastening system with elastomer rail pads Zw700/148/165 (static stiffness of 50–70 kN/mm, measured under a load between 18 and 68 kN, as provided by the manufacturer).

The southern part of the bridge deck is a composite structure with a concrete slab supported by a steel plate girder with multiple spans of 37.5 m. The last span rests on a counterfort abutment in reinforced concrete, founded on ten 21 m-deep piles, with a large opening at the front. The natural foundation of the transition zone consists mostly of monogranular fine-grained sands that provide good foundation conditions to the track. The transition zone includes a backfill, about 9 m high, that was constructed using materials with better performance (higher stiffness and lower plastic deformation) than the embankment soils. The backfill comprises two zones, forming a wedge-shape with the geometry depicted in Fig. 2. The first zone is located behind the abutment and comprises layers of cement bound mixture (CBM), with binder content (BC) of 5%. The average degree of compaction *in situ* was *Dc* = 100%, regarding the Optimum Modified Proctor reference value (OPM). The other zone is located between the CBM and the embankment with soils. It comprises unbound granular material (UGM): a well graded crushed limestone aggregate with min./max. particle sizes of 0/31.5 mm, placed with average *Dc* = 99% OPM. Fig. 2 also depicts aspects of the track instrumentation that will be addressed in Section 3.

(a) (b)

Fig. 1. Side view of the transition zone before construction (a) and general view of the track (b).

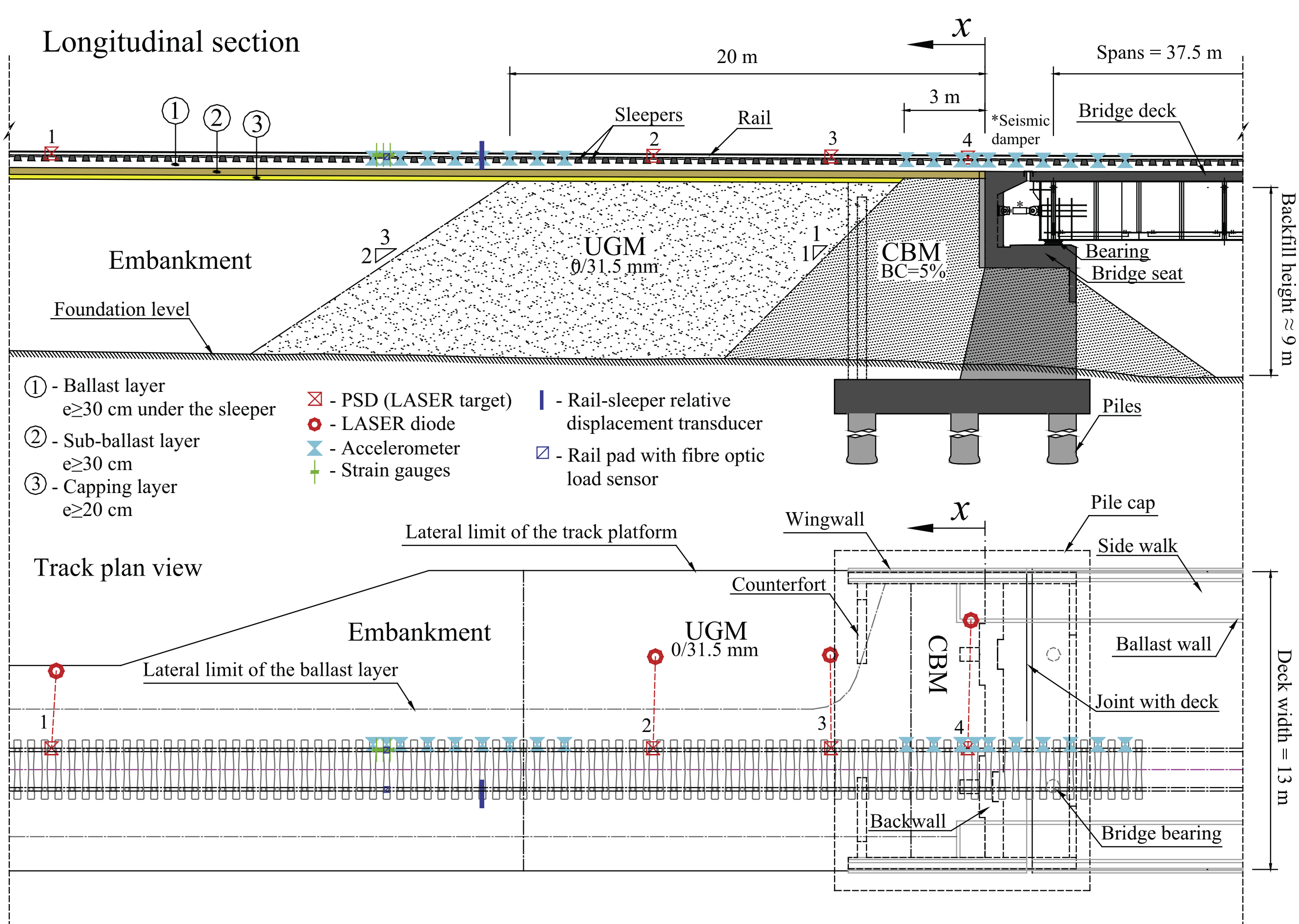

Fig. 2. Schematic longitudinal profile and plan view of the transition zone.