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Modelling of ballast gluing: Application to track lateral resistance

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Abstract

Ballast gluing to improve lateral resistance of tracks is analysed through the use of a numerical discrete element method including a cohesive contact model of CZM type. The results of the simulations are consistent with laboratory tests. Different configurations of ballast gluing are then tested in order to optimise the process in terms of gluing area, gluing depth or cohesion value.

Keywords: ballast, gluing, DEM, CZM.

1 Introduction

Ballast gluing is a recent solution used to address various problems related to ballasted track geometry, its resilience or stabilisation. It has been tested in several countries [1,2] to counter flying ballast, ballast layer deformation at transition zones or ballast flow during renewal of a track next to another. At SNCF it is used to treat some of these problems. Here the extension of this solution to improve the lateral resistance of ballasted tracks is analysed.

Maintaining the lateral resistance [3] of ballasted railway track above a critical level is essential to avoid rail buckling during high temperature rise with long welded rails for example. Adequate lateral resistance is obtained by correctly embedding the sleepers into the ballast layer and by adding ballast on the shoulders of the track. Sometimes this basic configuration does not prove sufficient and additional solution to increase lateral resistance like anchors between the sleepers to increase the shearing resistance of the ballast layer or gabions to increase its confining.

Ballast gluing is another option which can increase lateral resistance at a lower cost than the solutions mentioned above. It simply consists in pouring a glue above the ballasted bed introducing a cohesion at some of the contacts between the ballast grains.

The present work presents the modelling of ballast gluing using the discrete element method (DEM) [4] to improve the lateral resistance of ballasted tracks. Different gluing configurations are tested. Some experimental tests were performed to assess the quality of results of the model. DEM gives access to data at the scale of the ballast grains enhancing the understanding of the mechanisms leading to an increase of the lateral resistance.

2 Methods

The lateral resistance of a ballasted track is the reaction force measured while pulling sleepers along their main axis. In the present work, this test has been simulated using the DEM code LMGC90 developed by the university of Montpellier and based on the Non-smooth Contact Dynamics (NSCD) [5:8]. A cohesive model of CZM type is used to reproduce the effects of the ballast glue [9]. It relates the contact force rn between two glued ballast grains and their relative displacement Δg (fig.1). It includes an elastic part and a progressive rupture part beyond a given threshold. Its parameters can be calibrated via tests involving two glued ballast grains.

Experimental lateral tests have been realised in a laboratory by reproducing a ballasted track section. The first layer of ballast is laid on a rubber mat, two sleepers joined by two rails are set on the surface and additional ballast is poured between the sleepers and three lateral confining walls and a slope on one side. The ballast is then stabilised by applying a given number of vibration cycles through the sleepers. A lateral force is incrementally applied, and the two-sleeper system displacement measured. Typically, the force rapidly increases with displacement before reaching an asymptotic level which is taken as the lateral resistance.

Different gluing configurations have been analysed: gluing area (crib, shoulder), gluing depth, cohesion value.

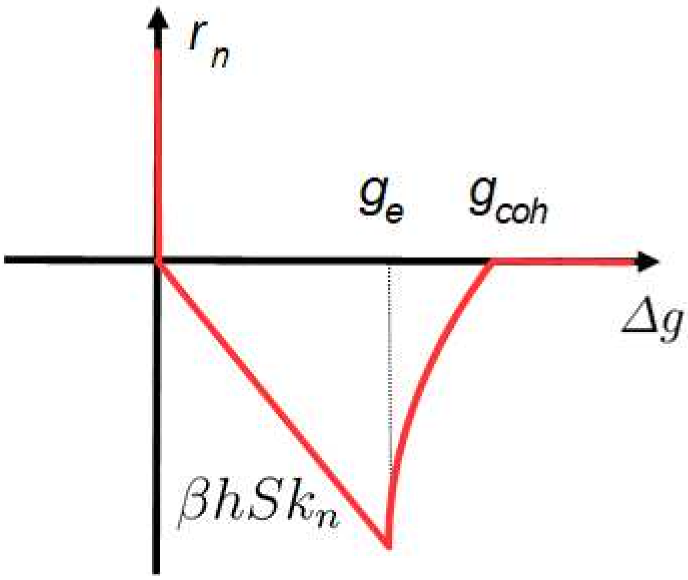

Figure 1 : Cohesive contact law

3 Results

The force-displacement curves obtained from the lateral resistance test simulations are consistent with the experimental ones indicating that the DEM numerical approach used is relevant and constitutes an adequate tool to improve the process of ballast gluing.

The simulations give a hindsight of how ballast gluing improves the lateral resistance of the track. The contact forces between the ballast grains accessible through the simulations (fig. 2), showed that gluing improves the shearing resistance contributing to the existing lateral resistance. The ballast grains involved are the ones located at the head of the shoulder below the sleeper bottom level. In addition, when the ballast at the surface is glued, a strong contact forces network appears between the head of the sleeper and the bottom of the slope of the track, adding a reinforcing arch pushing on the subgrade of the track.

The additional configurations analysed through this approach showed that it is possible to improve the gluing configuration by minimising the volume of glue to achieve a given lateral resistance.

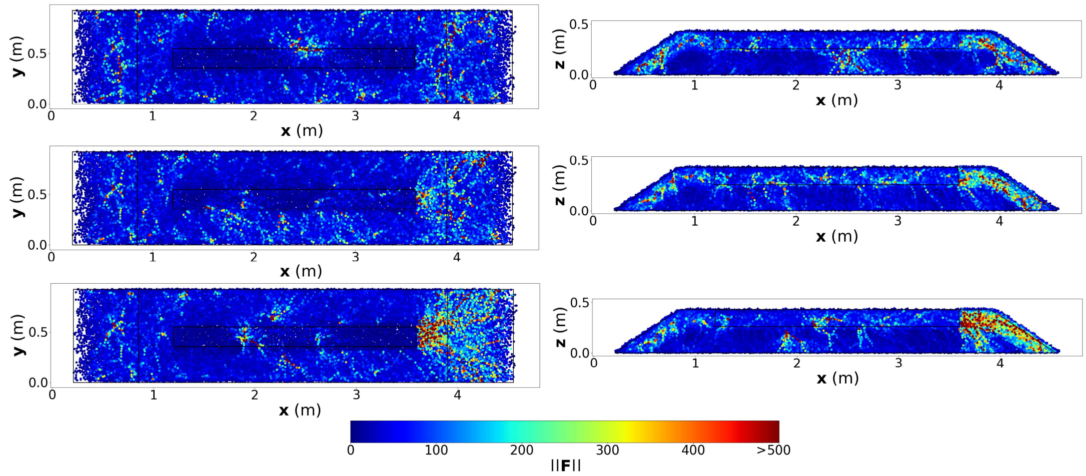

Figure 2: Contact forces between grains (N)

4 Conclusions and Contributions

This study shows that ballast gluing can be analysed through a DEM approach. This DEM code with a cohesive model proves to be an adequate tool to determine optimal ballast gluing configuration for industrial application. Besides improvement of lateral resistance, DEM modelling of ballast gluing can be used to address different problems like ballast layer deformation in transition zones, stabilisation during works or simply reduce ballasted track geometry deterioration.

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