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Benedetto, Andrea, Bianchini Ciampoli, Luca, Tosti, Fabio ORCID: <https://orcid.org/0000-0003-0291-9937>, Pajewski, Lara, Alani, Amir, Loizos, Andreas, Umiliaco, Andrea, Brancadoro, Maria Giulia and Pirrone, Daniele (2016) A GPR-based simulation approach for the analysis of railway ballast. In: EGU General Assembly 2016, 17 April - 22 April 2016, Vienna, Austria.

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## **A GPR-based simulation approach for the analysis of railway ballast**

Andrea Benedetto (1), Luca Bianchini Ciampoli (1), Fabio Tosti (2), Lara Pajewski (1), Amir M. Alani (2), Andreas Loizos (3), Andrea Umiliaco (1), Maria Giulia Brancadoro (1), and Daniele Pirrone (1)

(1) Roma Tre University, Department of Engineering, Rome, Italy (andrea.benedetto@uniroma3.it; luca.bianchiniciampoli@uniroma3.it; lara.pajewski@uniroma3.it; a.umiliaco@gmail.com; mgiulia.brancadoro@gmail.com; daniele.pirrone20@gmail.com), (2) University of West London, School of Computing and Engineering, Saint Mary's Road, W5 5RF, London, UK (tosti.fabio@gmail.com; Amir.Alani@uwl.ac.uk), (3) National Technical University of Athens, Laboratory of Pavement Engineering 5 Iroon Polytechniou St., 15773 Zografou, Athens, Greece (aloizos@central.ntua.gr)

This study aims at proposing a model capable to assess the physical conditions of railway ballast, in terms of percentage of fouling within the material, by analyzing its electromagnetic response.

For the calibration of such a model, a laboratory set-up was implemented in order to reproduce a real-scale railway environment. In more details, a 1.47 m long  $\times$  1.47 m wide  $\times$  0.48 m high plexiglass formwork was laid over a metal sheet, to define a proper domain of investigation. The formwork was then filled up with railway ballast, progressively fouled with a fine-grained pollutant material, namely, an A4 soil type according to the ASSHTO soil classification. At each step of fouling percentage, electromagnetic surveys were carried out by employing several ground-penetrating radar (GPR) systems, in both ground-coupled and air-coupled configurations.

On the other hand, the validation of the model was performed through a simulation-based approach. In particular, the main physical and geometrical properties of each ballast-pollutant configuration were reproduced by means of a random sequence absorption (RSA) approach. For the representation of the shape of the solid matrix of the ballast, a relatively complex geometry was here adopted. Finally, the developed geometries were processed by the GprMax 2D numerical simulator, employing a finite-difference time domain (FDTD) model capable of generating a synthetic GPR response for the several configurations analysed in laboratory environment.

As result, the potential of the combined use of RSA and FDTD approaches is demonstrated, and a model for characterizing such a complex coarse-grained heterogeneous material is finally proposed.

### **Acknowledgement**

The Authors thank COST, for funding the Action TU1208 "Civil Engineering Applications of Ground Penetrating Radar."