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

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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.

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