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Laboratory Determination of Variations in the Relative Permittivity Values of Railway Ballast under Various Fouling Levels Using 2 GHz GPR Horn Antenna

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Railways are considered as a cost-effective, reliable and safe form of transport. Ensuring the timely maintenance of railway infrastructure of this transport mode is the prioritized task of the railway operators. Railway ballast is the key element of conventional track infrastructure, which plays an immense role in the overall track stability. However, there exists a critical drawback within the ballast structure called ballast fouling, i.e. contamination of ballast, which takes place when air voids in the ballast are filled with finer materials. It is of crucial importance to diagnose the fouled ballast, the level of fouling and the type of fouling material which may jeopardize the all-around safety of the track and its economic life. Ground Penetrating Radar (GPR), as a noninvasive geophysical diagnosis method, has proven its potential in the evaluation of railway infrastructure in a cost-efficient, time saving and continuous manner. To that effect, present study targets to improve the current railway investigation practices with GPR, where accurately measured relative permittivity values of railway ballast with GPR under different fouling levels in controlled laboratory conditions can bring beneficial information during the field railway surveys with GPR. In the present work, numerous experiments have been handled by using 2 types of railway ballast and 3 types of fouling agents in a testing container. A common ballast type used in the Czech Republic, namely granite ballast and a finer sized limestone ballast were used. Three types of fouling agents were inserted into both ballast materials; silty sand, fine gravel and a volumetric mixture of these two materials were placed and compacted within the ballast in the testing container in increasing volumes adjusted according to the air void volume of the ballast materials. Air-coupled 2 GHz horn antenna was operated and a metal plate i.e. perfect electric conductor at the bottom of the testing container was used during the experiments. The results show how the rise in the fouling level in case of all three fouling agents leads to an increase in the relative permittivity values of both types of ballast and a decrease in the electromagnetic wave velocity. Granite ballast was observed to have slightly smaller relative permittivity values than limestone ballast at the same fouling levels contaminated by all three fouling agents. For both ballast types, the relative permittivity values of silty sand fouled ballast were found to be higher than the ones fouled by fine gravel. Relative permittivity values for both types of ballast fouled by the mixed material fall into the values between silty sand fouled ballast and fine gravel fouled ballast. Strong linear trends exist between the relative permittivity values and fouling levels introduced with the three fouling agents for both ballast materials which enable to predict the relative permittivity of those types of ballast in real field surveys when fouled by similar materials, hence improve the evaluation and monitoring efficiency of railway site investigations.
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