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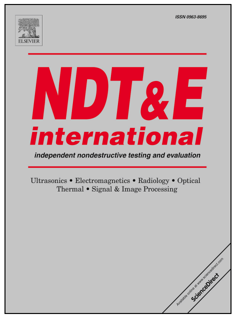

Investigating ultrasonic wave dispersion and attenuation in fresh cementitious materials: A combined numerical, analytical, and experimental approach

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Investigating ultrasonic wave dispersion and attenuation in fresh cementitious materials: a combined numerical, analytical, and experimental approach

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Abstract

The heterogeneity of cement-based materials and the severe wave-microstructure interactions at the fresh state render the thorough investigation of ultrasonic wave propagation imperative, especially when the latter is used for material characterization and quality control. In this study, parallel to the advanced ultrasonic wave dispersion and attenuation experiments, numerical simulations are also performed offering faster, reliable and accurate solutions at low cost, as well as flexibility on the design and measured properties. Cement pastes and mortars are investigated and the observed dispersive and attenuative trends are further explained with scattering theories reinforcing the characterization potential. The results pinpoint air bubbles and sand grains as causes of the dispersion and attenuation frequency dependent trends. The distinct frequency regimes where these phenomena are observed allow for the more accurate characterization of the microstructure. For the first time, the strong qualitative and quantitative agreement between experiments, scattering theories, and numerical simulations provides holistic insights into wave propagation in fresh cementitious materials and firmly connects the dispersion and attenuation of waves to their origin.

1. Introduction

The quality control, material characterization, assessment and monitoring of the performance of fresh cement-based media [1-6] has been successfully based for decades on elastic wave propagation. The reason for the aforementioned success is the direct connection of elastic waves to elastic properties, the numerous empirical correlations with strength and quality as well as the relatively easy application with commercial devices. The microstructure of heterogeneous media (for instance air bubbles and sand grains in cement pastes and mortars), however, can significantly affect a propagating wave and impact the results. Despite the seemingly disadvantageous effect of the wave-microstructure interaction in terms of amplitude loss, the frequency analysis of wave features (velocity and attenuation) can prove beneficial for monitoring purposes. It reveals interesting information on the microstructure, it highlights the influence of each separate component on the overall performance [7-8] and leads to a more reliable characterization of cementitious materials [9-10]. Moreover, the investigation of dispersion and attenuation provides detailed insights into the internal condition of the structure [11-12] and should be considered in fresh cementitious materials despite the inherent difficulties arising from the strong energy losses at high frequencies.