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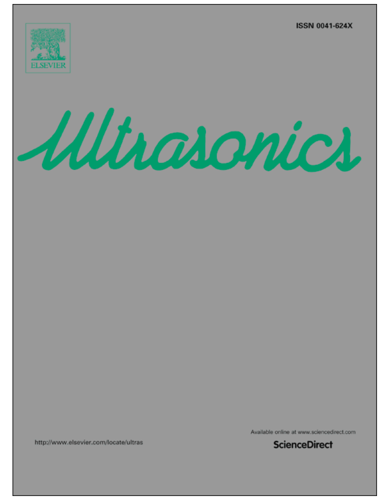

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Simulations of ultrasonic wave propagation in concrete based on a two-dimensional numerical model validated analytically and experimentally

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Abstract

Several non-destructive evaluation techniques to characterize concrete structures are based on ultrasonic wave propagation. The interpretation of the results is often limited by the scattering phenomena between the ultrasonic wave and the high concentration aggregates contained in the cement matrix. Numerical simulations allow for further insights. This study aims to build a two-dimensional numerical model in order to reproduce and interpret ultrasonic wave propagations in concrete. The model is built in a spectral-element software package called SPECFEM2D. The validation of the numerical tool is based on the use of resin samples containing different amount of aluminum rods from low (5%) to high concentration (40%), the last one being representative of aggregate concentration in concrete. These samples are characterized using an ultrasonic testing bench (ultrasonic water tank) from 150 kHz to 370 kHz. The measured results are analyzed in terms of phase velocity and attenuation which are the main parameters of coherent waves. As homogenization models such as the Waterman-Truell or Conoir-Norris models are usually used to model coherent waves in two-phase systems, we also compare the experimental and numerical results against them. We confirm that the use of these homogenization models is limited to low concentration of scattering phase, which is not adapted to applications to concrete. Finally, we use our numerical tool to carry out a parametric study on scatterer concentration, shape, orientation and size distribution of aggregates in concrete. We show that aggregate orientation has an influence on coherent wave parameters, but aggregate shape has not.

1. INTRODUCTION

Concrete has been used in buildings for many decades and is nowadays one of the most common materials in civil engineering. To optimize the durability and the maintenance of these structures, owners must be able to use experimental techniques to control that their realization conforms to the standards and to assess possible degradation of the materials with time. This is the reason why many Non Destructive Evaluation (NDE) techniques have been developed. Among them, several are based on ultrasonic wave propagation [1].

One phenomenon that is common to any wave propagation study has to be considered: wave scattering in a heterogeneous medium. Three regimes are distinguished, considering the ratio between the wavelength λ and the scatterer size a: Rayleigh, stochastic and geometric regimes. They are commonly characterized by the value of ka, where k is wave number defined by $k = 2\pi/\lambda$. When the wavelength is shorter than the geometric size of the structure but much longer than the aggregate size ($ka \ll 1$, 20 kHz to 150 kHz for concrete), wave propagation is in the so-called Rayleigh regime and the coherent wave dominates. While the frequency increases, the wavelength is of the order of the aggregate size ($ka \approx 1$ for the frequency range 150 kHz up to 1 MHz for concrete) and wave