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ScienceDirect

Procedia Environmental Sciences 37 (2017) 647 – 654

Procedia Environmental Sciences

International Conference – Green Urbanism, GU 2016

Experimental characterisation of concrete containing different kinds of dielectric inclusions through measurements of dielectric constant and electrical resistivity

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Abstract

This paperis aimed at the experimental characterization of a two- phase composite material namely concrete containing different kind of inclusions by measuring the electric resistivity and the dielectric constant. The model of composite consists of cylindrical samples of concrete in which are introduced different types of cylindrical inclusions. Later are embedded in the centre of the host matrix. The measurements are achieved thanks to an impedance-meter. The effective dielectric constant and resistivity characteristics are investigated versus the concentration and the type of inclusions. The inclusions we consider are cavities (air), cavities filled with water. It's shown that the effective dielectric constant of composite material increases with the water content while the effective resistivity decreases due to the fact that the dielectric constant of water is too higher than that of concrete and the resistivity of water is lower than that of concrete. While the dielectric constant of concrete decrease when increasing the concentration of cavities; the resistivity of heterostructure increases with the concentration of air. This technique can constitute a good tool to follow, for instance, the humidification or the drying of a given heterostructure.

Peer-review under responsibility of the organizing committee of GU 2016

*Keywords:*Heterostructures, Dielectric constant, Resistivity, Voids, Water Content, inclusions

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Peer-review under responsibility of the organizing committee of GU 2016

doi:10.1016/j.proenv.2017.03.051

1. Introduction

The knowledge of the cavities (porosity and fissures) andwater contents of a given medium or any heterostructure consisting of a host matrix containing different kinds and concentrations of inclusions (steel, glass …) is of a great interest for different application domains among which civil engineering. It enables to evaluate the ability of the medium to absorb water (or other fluids), or to place in a prominent position the presence of cavities and/or fluids, or to evaluate its resistance to given constraints. Thus, depending on the application, one can evidence for instance the presence of water in a given site or appreciate the penetration degree of moisture and thence the quality and/or the ageing of heterostructure such as the structural concrete. Also, the knowledge of the presence of fissures, their size and concentration could inform us about the fragility of heterostructures (building, floor-tiles, beams, pillars, …) resulting of different stresses such as an excessive heating or earthquakes, or due to hostile chemical environments or to a bad proportioning of construction materials.

Different methods are used to evaluate the water content in a given medium. One can cite the thermal method[1], the nuclear methods[2], the method based on the measurement of the resistivity called “electrical method”[3,4,5] and the methods based on the measurement of the dielectric constant called “dielectric methods” [6,7,8].

During the last decade, nondestructive methods using ultra wideband radar have been developed to visualize variations of cracks, voids, and rebars within the concrete and to determine the structural properties[9,10].
These methods enable, through the measurement of dielectric property, to evaluate the performance of cement concrete or new construction materials, such as polymer concrete developed to reduce the high cost of rehabilitation of structural concrete[11].

This paper presents results of an experimental study consisting in the characterization of a two- phase composite material namely concrete originated from a specific region in Algeria, containing different kinds of inclusions by measuring the electric resistivity (ρ) and the dielectric constant (ε). The inclusions we consider are cavities, cavities filled with water.

2. Experimental Technique

The experimental model of composite we consider consists of a cylindrical sample of concrete of 40 mm diameter and 30 mm height in which we introduce different types of cylindrical inclusions namely air cavities, cavities filled with water (Figure 1).

This material which constitutes the host matrix is dried during 24 hours in an oven at 110°C. The inclusions are embedded in the centre of the host matrix.

Figure 2 gives a schematic view of the measurement system. It consists of two cylindrical cooper electrodes of 40 mm diameter. The electrodes are perpendicular to the axis of samples and inclusions (i.e. the electric field is parallel to the axes of inclusions).A spring placed on the upper electrode enables to assure a good contact between the electrodes and the sample; this allows us to avoid the parasite capacitance induced by the presence of air interstices at the interfaces between the sample and the electrodes.

The measurements of the dielectric constant ε as well as the resistivity ρ investigated versus the concentration and the type of inclusions as well as the frequency of exiting signal, were performed using a Hewlett Packard HP4284 A (20 Hz-1 MHz) impedance analyzer at frequencies ranging 100 kHz to 800 kHz. The choice of this range of frequencies (100 - 800 kHz) is justified by the fact that the measurements of the resistance R_p and the capacitance C_p from which we compute respectively ε and ρ are more stable at these frequencies than at lower frequencies.

All measurements were performed at room temperature. As the capacitances we measured are very small (in pF range), the tested samples can be represented by an equivalent electrical circuit consisting of a capacitance C_p in