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Modification of four point method to measure the concrete electrical resistivity in presence of reinforcing bars

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ABSTRACT

Concrete resistivity is a material characteristic that can be related to its durability, as it indicates the amount and tortuosity of the pore network and also informs on the degree of water saturation. Its measurement is usually made in situ by the use of the four-point or Wenner method, but the accuracy of such measurements is affected by the presence of metallic reinforcement. In those cases, measurements should not be made on the surface immediately above the reinforcing bar. This paper examines the effects of rebar presence/absence on the resistivity measurements and the significance of a rebar presence factor, which is determined by means of numerical simulations using the COMSOL Multiphysics software package. The results indicate that the rebar presence apparently lowers the resistivity values in a proportion which is a function of the specimen geometry and the electrode spacing. Equations for its quantification are presented.

1. Introduction

The electrical resistivity of concrete is an indication of the volume of pores and also the degree of water saturation and therefore has a strong relationship with the concrete durability and in particular to the corrosion of reinforcements [1–5]. Andrade and d'Andrea [6] proposed a service life model based on the measurement of resistivity in saturated concrete.

There are several methods to measure the resistivity in concrete structures. In the classical or "direct" method using a regular geometry with electrodes placed face to face, the relation between the resistivity, ρ, and the electrical resistance, R, is given by the geometrical factor of ratio of the section, S, and the distance between electrodes, l.

$$\rho = R\frac{S}{l} \tag{1}$$

In a cylindrical arrangement, one electrode is centred and the other one surrounds the cylinder and the geometric factor depends on the distance between electrodes (the radius) and on the cross section. For irregular geometry there is several methods to obtain the geometrical factor, which are classified depending on the number of electrodes used.

One method is the disc-bar or one electrode method [7]. This method is based on measuring the resistance between a metal disc electrode placed on the concrete surface and the reinforcement. It requires a connection to the reinforcement cage and should avoid being near a rebar if the cover thickness is smaller than 2 times the diameter of the disc. In practice, this may require that the disc is not placed immediately above the rebars, but at some distance, for instance in the middle of the rebar mesh. The geometrical factor for the calculation of the resistivity is ($2\pi r$) where r is the radius of the disc.

$$\rho = 2\pi r R \tag{2}$$

Another method is based on the use of two parallel electrodes or rebar which are placed in the concrete surface, but this arrangement needs calibration for each electrode size and shape as there is not a unique expression that could be generally applied. Finally the most common method used is the Wenner or four-point method [8–10]. This method consists of four equally spaced electrodes that are pressed onto the concrete surface. The two outer electrodes serve to apply the current and the two inner electrodes measure the difference in potential drop. The resistance is the ratio of the voltage and the current (Fig. 1). This method has long been known and used for determining soil resistivity [8] and the resistance calculated from the four-point measurement can be converted to resistivity using a similar geometrical factor to the disc method but in which a is the electrode spacing:

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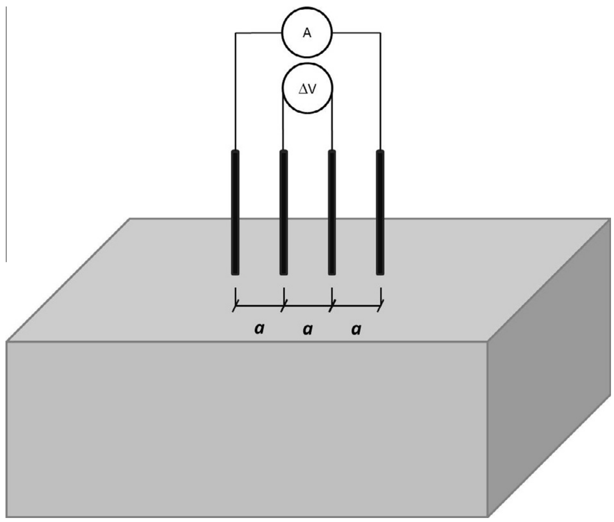

Fig. 1. Setup of four – electrode measurement.

$$\rho = 2\pi a R \tag{3}$$

Eq. (3) is applied for homogeneous semi-infinite volumes of concrete and infinitely small electrode points [11,12]. If the medium is finite (a specimen of limited size) it has to be considered an additional factor which will depend on the size and shape of the specimen [12]. The shape factor was studied by Morris et al. [12] and expressions were given for different types of specimen shapes and distance between the electrodes.

Then, the four electrode method has been applied from long time ago but always preventing on the need to avoid be nearing the metallic rebars as, equally to the disc method, if they are in the zone of influence of the current applied, the resistivity will be shielded and then not representing the concrete bulk.

In this paper the disturbance is quantified experimentally and modelled by numerical analysis. The effect of this disturbance on resistivity is given in the form of a rebar presence factor, f_b. In addition to the shape factor and geometrical factor, the resistivity then becomes:

$$\rho = f_b f_s 2\pi a R \tag{4}$$

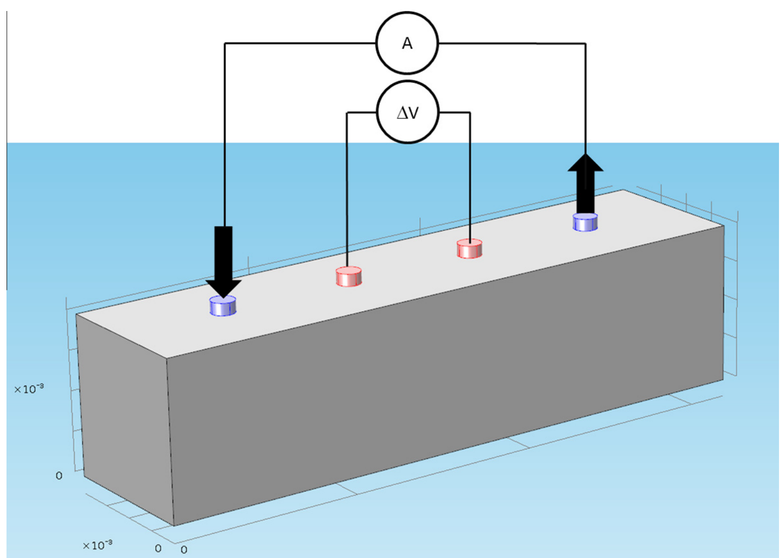

Fig. 2. Boundary settings. Prismatic geometry 4 × 4 × 16 cm without rebar in horizontal position.

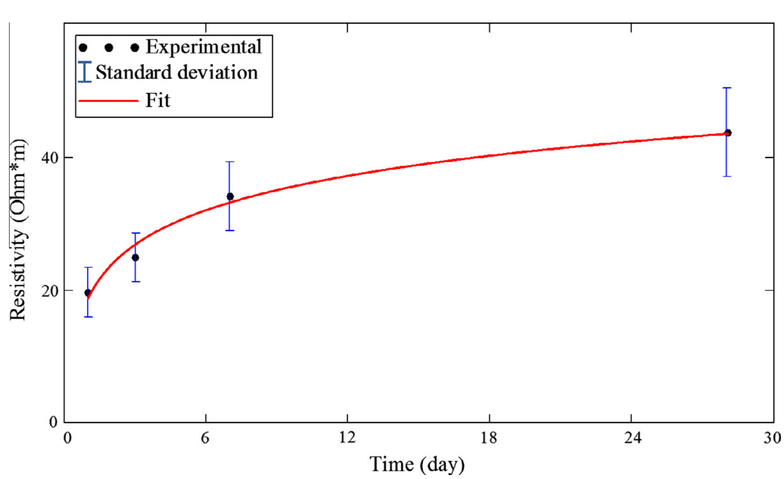

Fig. 3. Resistivity evolution during the concrete aged for specimens without rebar.