# Influence of Unsupported Concrete Media in Corrosion Assessment for Steel Reinforcing Concrete by EIS

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### Introduction

The assessment of the corrosion activity in reinforced concrete by Electrochemical Impedance Spectroscopy, EIS, is well-known. One of the most common environments, promoting corrosion, involves dry or partial dry-conditions especially, dry-wet cycles, which play a crucial role in what concerns corrosion activity. In such conditions concrete becomes an unsupported media and the obtained results are an expression of steel corrosion and concrete dielectric response. Theoretical studies proposed by Macdonald et al [1] explained this phenomenon by taking into consideration that the complexity of the impedance response of such system must be related with charge separation inside the film bulk.

For measurements carried out in partial dry conditions, particularly associated with dry-wet cycles, the results are affected by ionic, water and gases transport. This can occur by three mechanisms: permeability, diffusion and absorption [2]. These mechanisms are governed by the pore system, which is characterized by the porosity, connectivity between pores and pore size [3]. The main factor influencing the porosity is water-cement ratio [4]. However, other factors, like cement type, can also affect the porosity [5]. Nevertheless, the tests to assess the permeability coefficients are long and relatively complicated [6]. EIS technique is a very suitable technique to determine concrete properties, such as permeability. Several authors have already used this non-destructive technique to reveal the microstructure of concrete [7]. This work aims at studying the response of unsupported concrete media by EIS and its influence in the results obtained for reinforcing steel corrosion in concrete samples.

# Experimental

Cylindrical samples with 50 mm of thickness and a diameter of 150 mm were used. The top and bottom of the samples are cutting surfaces. Adequate variety of cement type and water/cement ratio was used to guarantee the representative of the results. The concrete specimens tested were the followings: C55/67 (CEM I [8]; w/c=0.39), C40/50 (CEM I; w/c=46), C30/37 (CEM I; w/c=0.60), C35/45 (CEM I; w/c=0.53), C30/37 (CEM II/A; w/c=0.51) and C25/30 (CEM IV/A; w/c=0.53).

For the saturation test a two-compartment cell with four-electrode arrangement was used. The concrete sample was held between the compartments, with two smaller platinum electrodes working as pseudo-reference electrodes and two larger platinum electrodes acting as counter electrodes. The transversal exposure area was  $50.12 \text{ cm}^2$ . For the dry tests, a two electrode arrangement cell was used, in which two plates of stainless steels (316L), with 100 cm<sup>2</sup> each, were compressed against the sample flat faces, operating each one simultaneously as counter and reference electrode.

These measurements were conducted using a Zanher Zennium Electrochemical Workstation. The frequency range, at the initial 20 minutes of samples saturation were between 2 kHz and 4 MHz, for longer times, the frequency range used were between 50 mHz and 4 MHz. The applied amplitude was 50 mV (rms). Numerical fitting of the impedance data was made using ZView® software.

The samples remain in controlled environment at 25°C during the saturation and drying processes.

#### **Results and Discussion**

Figure 1 depicts the EIS spectra evolution with time during saturation and drying. The obtained spectra are heavily dependent of the environmental conditions. For measurements carried out in full immersed samples concrete behaves as a typical electrolyte media, presenting only a resistive behavior, except at very high frequencies where the dielectric properties of concrete can be observed, thus rebar corrosion, which appears commonly at intermediate frequency region, can be assessed and easily interpreted. However, for samples in partial dry conditions the spectra are unexpected different, presenting several timeconstants distributed across the entire frequency region. Therefore spectra interpretation for concrete reinforced steel obtained in such conditions is guite challenging. In the high frequency region the time constant can be ascribed to dielectric properties of concrete, which appears also for immersed samples. At low frequencies the time constant can also easily be interpreted since the samples are not immersed, thus the continuous ionic displacement during measurements cannot be replaced and ionic depletion take place. The most difficult interpretation relates with time-constant present at intermediate frequency region. However, these results are present only in dry tests and are progressively relevant for longer times. That is an indicator that low water content is related with this phenomenon. Since in these conditions the concrete samples become an unsupported material, then the best interpretation for that result is given by Macdonald et al [1], in which charge separation inside the material bulk must occur during EIS measurements, thus causing the appearing of another time constant. That situation can occur either for media with low water concentration or for low ionic strength solutions.



Figure 1 – Evolution of |Z| and phase angle Bode diagram with time for CEM I sample with w/c=0.39: (a) fully immersed and (b) during drying.

## Conclusions

EIS results obtained for concrete specimens in partial dry conditions showed a dielectric response in the intermediate frequency region, which are related with charge separation typically of unsupported media.

Interpretation of the results obtained by EIS for concrete reinforced steel in partial dry conditions cannot be fully interpreted without considering the dielectric behavior of concrete.

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