

Non-invasive corrosion diagnosis of reinforced concrete structures: A sensitivity analysis using a multi-channel resistivity approach

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Abstract

Non-Destructive Electrical Methods (NDEM) using a four-electrode configuration are being developed for the corrosion monitoring of reinforced structures without altering their integrity [1]. Indeed, unlike conventional techniques based on a three-electrode configuration that requires a connection to the rebar, the measurement is performed directly on the concrete surface: two probes A and B inject a direct current while two other probes M_n and N_n measure an induced potential difference. However, despite the practical relevance of NDEM, their use is still at the margin. To promote such techniques, whose measured apparent resistivity ρ_{app} depends on both concrete resistivity and corrosion rate, a better definition of their sensitivity domain is required, along with a detailed sensitivity analysis to concrete and rebar properties.

This work reports a methodology designed to characterize the sensitivity domain for resolute corrosion rate determination from ρ_{app} measurements using five Wenner-Schlumberger-Reciprocal (WSR) configuration (Figure 1). Specifically, in this work, models were computed to establish the sensitivity domain of the novel Corlmager®-device developed by IRIS Instruments. The extensive modeling of synthetic data – considering several corrosion current densities j_{corr} , concrete resistivity ρ_c , effective depth c_{eff} and rebar diameter Φ – provided abacus showing three distinct regions: two regions for extreme j_{corr} values in which ρ_{app} is almost constant, and one region for intermediate j_{corr} values in which ρ_{app} significantly decreases with increasing j_{corr} (Figure 2a). The latter region, defined as the sensitivity domain, depends on ρ_c , c_{eff} , Φ , and the geometry of the chosen observation channel (Figure 2b). Within this domain, the amplitude of the sensitivity increases with the decrease in c_{eff} or the increase in Φ ,

while increasing ρ_c by one order of magnitude shifts the domain of j_{corr} by one order of magnitude to lower values.

The use of abacus allows quantifying the expected uncertainty on j_{corr} , according to the electronic noise of the monitoring device and to measurement uncertainties on C_{eff} or Φ . The interpretation of overall results allow providing good practices to limit the impact of potential errors for corrosion diagnosis in field application.

While developed specifically for the CorImager®-device in WSR configuration, the methodology can easily be adapted to any four-point configuration with apparent resistivity measurements. As a perspective, the data acquired with a multi-channel configuration open the way to inversion processes to determine the distribution of concrete resistivity and corrosion current density within the investigated volume.

References

[1] R. Rodrigues, S. Gaboreau, J. Gance, I. Ignatiadis, S. Betelu, Reinforced concrete structures: A review of corrosion mechanisms and advances in electrical methods for corrosion monitoring, Construction and Building Materials. 269 (2021) 121240. <https://doi.org/10.1016/j.conbuildmat.2020.121240>.

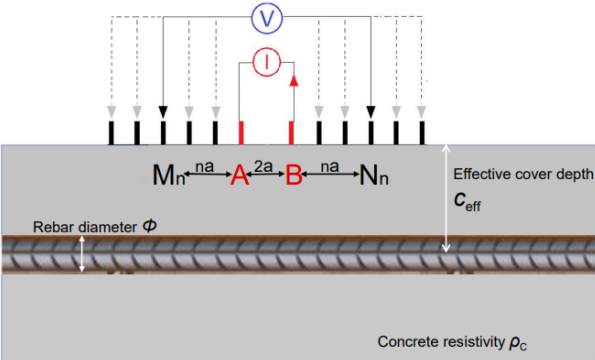


Figure 1. Schematic representation of WSR configuration and the different parameters of the model.

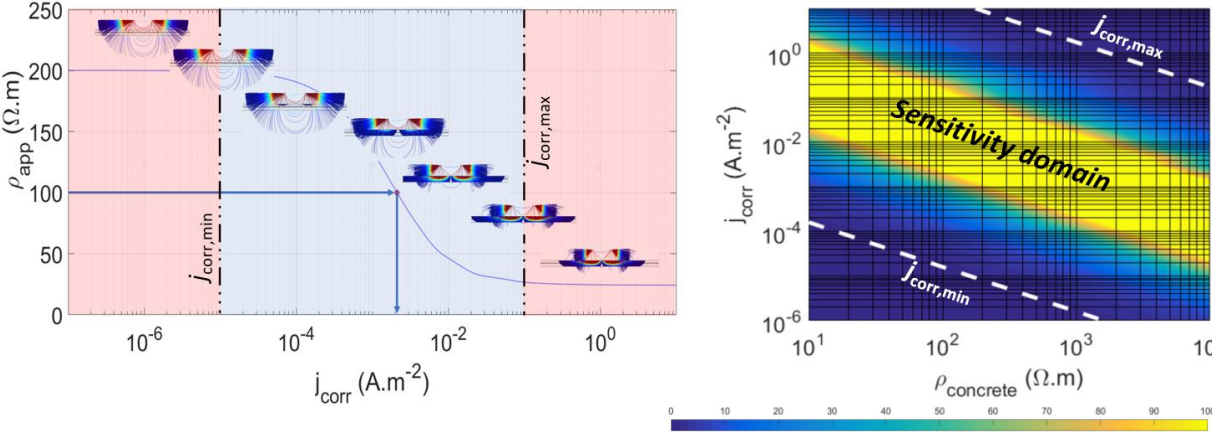


Figure 2. (a) Example of an abacus showing the evolution of ρ_{app} as a function of j_{corr} , with the three regions, (b) Example of a sensitivity diagram showing the evolution of j_{corr} as a function of ρ_c , with the color bar indicating the variation in sensibility. The limits $j_{corr,min}$ and $j_{corr,max}$ are defined relatively to a resolution of 1%.