Cathodic protection for reinforced concrete revisited: effects and side effects studied in lab conditions and a 45 years-old structure

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Chloride-induced localized corrosion of reinforcing steel is one of the most hazardous types of reinforced concrete degradation. It has impact not only on structural safety, but also imposes environmental and health risks. Next to that, infrastructure-related economic costs for corrosion control, maintenance and repair are a significant burden for national economies worldwide.

Impressed current cathodic protection (ICCP) is the only electrochemical technique, able to minimize or stop corrosion in highly aggressive environment. The conventional basis of ICCP lies in inducing a negative steel polarization i.e. cathodic potential shift to at least -850 mV SCE, where corrosion is thermodynamically impossible to occur. The main reason for the effective performance of ICCP is actually fundamentally justified - ICCP works using the same, but “reversed” electrochemical principles, which otherwise actually cause the steel corrosion process itself. As every technique, however, positive and negative effects are related to ICCP applications.

Except the main purpose of ICCP i.e. to maintain steel in a thermodynamic state where corrosion is not occurring (or minimized, where more noble potentials are aimed in certain conditions), positive secondary effects as known. These involve: chloride withdrawal from the steel surface and migration towards the external anode; stabilization of initially formed product layer on the steel surface, as consequence of OH^- and alkali ions accumulation; the so-called “imperfect steel passivity”, denoted to the improved steel surface layer properties. The latter phenomenon is related to steel potential ennoblement upon ICCP interruption with respect to previous readings in time. Additionally, negative (side) effects are well known as well e.g. steel/concrete bond strength degradation, anode/concrete de-bond, alkali-silica reaction, etc. In recent years, the effect of ICCP current on the bulk cement-based microstructural properties was also studied and justified. The ICCP current flow was proved to exert both positive and negative effects, the level of which depend on the current density and hydration age of the concrete matrix. As an alternative of the conventional ICCP, a pulse regime was investigated and proved to result in more pronounced positive effects, along with significantly reduced side effects. The pulse ICCP is a pulsed protection regime which uses lower current density (i.e. 50% lower than the usually recommended range of 5 to 20 mA/m^2) and can achieve the required steel polarization effectively with reduced anode surface area.

To this end, the paper will discuss main outcomes from the application of both ICCP regimes in lab conditions with respect electrochemical performance and bulk matrix microstructural properties. Next, an illustration for the indeed modified concrete material properties due to ICCP current flow will be presented for already significantly aged concrete (an existing 45-years old residential building under running ICCP for 15 years), thus justifying the previously obtained lab results.