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Multi-scale marco to nano FEM modeling for corrosion of RC structures and its experimental verification

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Corrosion of RC (reinforced concrete) structures is a major durability concern throughout the world. Chloride attack is the main cause of deterioration in steel reinforced concrete structures. Chloride ions break the passive film developed on steel bar embedded in concrete protecting the steel from corrosion. This situation is further aggravated by the hot weather conditions. The passive layer is believed to be a few nanometers in thickness and primarily composed of iron oxides; however, little is known about its chemical composition and structure as well as the passive film breaking process. This makes it difficult to characterize corrosion which is highlighted by the fact that the chloride threshold value of steel reinforced concrete measured by conventional electro-chemical techniques can vary greatly. While these techniques measure corrosion in a macro scale, the growth and deterioration of passive film actually take place at the nano-scale and is governed by the elemental compositions and nano-microstructure of the steel as well as the chemistry of the concrete and the environment around the rebar which has been incorporated in this paper. This research paper focuses on characterization of passive layer at the nano-scale as well as on finding out what happens when the film breaks down especially due to chloride attack under hot weather. To address these key issues, advanced nano-techniques (such as SEM, FEG-SEM, XRD, EDS/EDX, XRF, XPS, AFM, Raman Spectroscopy, Photo Electron Spectroscopy etc.) and electrochemical measurements have been used. Electro-chemical techniques have been used to conduct research on the growth and breakdown mechanisms of passive film in aggressive environments, particularly chloride contaminated environments and hot weather conditions prevailing around the world. It was found that the chemical composition and surface treatment of various steel bar sources available differ considerably from each other and also have significant difference in the development of passive layer as well as the corrosion rates respectively. An interesting sequence of reactions taking place during the formation of passive film on steel rebars is revealed. Role of changes in parameters surrounding the steel reinforcement bars exposed in concrete pore solution on nature of passive film is established. A wide variation in corrosion and pitting tendency of rebars in different conditions is caused due to changes in nature of the passive film on steel surface. A subtle change in nature of film in contact with chloride ions occurs before its complete breakdown. A rise in temperature transforms the nature of the passive film resulting in acceleration in corrosion rate. Presence of lime in pore solution significantly improves the protective properties of the film. Comparison of multi-scale experimental analysis shows a direct relationship among the macro, micro and nano scale results obtained in this project. A nano-scale model for the transformation, breakdown of passive film, initiation and propagation of corrosion under severe environment has been suggested and experimentally verified in this paper.

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