Aspects of corrosion in reinforced concrete structures and its influence on structural safety (Stage B)

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Abstract

Stage A of this research project concentrated on the influence of corrosion on the behavior of reinforced concrete structures made with ordinary Portland cement and black unprotected reinforcing steel. Results of the Stage A of the research indicated that for reinforced concrete structures in extremely aggressive marine environments such as the splash zone measures like the reduction of water-cement ratio and the increase in the concrete cover, which are usually employed for the protection of reinforced concrete structures against corrosion, may be not sufficient. Therefore, for such exposure conditions other protective measure like the use of supplementary cementitious materials and/or epoxy or galvanic coating of reinforcing steel may be necessary.

According to available experimental results, the use of cements with supplementary cementitious materials such as fly ash, granulated blast-furnace slag, and silica fume allows to reduce the rate of chloride ingress into concrete. At the same time, this decreases alkalinity of the concrete pore solution and, subsequently, the threshold chloride concentration (i.e., the level of chloride concentration near reinforcing steel which leads to corrosion initiation). Additional factor that may influence the corrosion propagation is that according to experimental results the corrosion rate in concretes with the supplementary cementitious materials is usually lower compared to that in concretes with ordinary Portland cement. Eventually, it may be concluded that the proper use of supplementary cementitious materials can significantly improve the resistance of reinforced concrete structure to corrosion.

Another way to protect reinforced concrete structures against corrosion is via improving the corrosion resistance of reinforcing bars by using epoxy or galvanic coating. Based on practical experience gained over decades and also from numerous experiments reinforcing bars with epoxy or galvanic coating show better resistance to corrosion than uncoated rebars. At the same time, for a number of reinforced concrete structures the use of epoxy coating did not bring any significant improvement in their performance and signs of corrosion were discovered in these structures just in a few years after the completion of their construction. There are also some doubts concerning the efficiency of galvanic

coating comparing the limited improvement it provides with the additional cost associated with its use. Thus, there is no general agreement concerning the efficiency of coatings on reinforcing steel as a protective measure against corrosion.

Results of this research indicate that the requirements of IS 466 concerning the concrete grade and the thickness of the concrete cover are not sufficient to provide sufficient protection of reinforced concrete structures built right on the coast or in the splash zone. The use of supplementary cementitious materials allows improving the resistance of reinforced concrete structures against corrosion. The research provides recommendations for selection of design specifications (i.e., concrete grade, type of cement, thickness of the concrete cover) that should provide sufficient protection of reinforced concrete structures built right on the coast and in the splash zone against corrosion. Based on the presented results it can be concluded that among different cements considered in this study, the cement with 10% of silica fume provides the best protection against corrosion caused by the ingress of chloride ions.

Results presented in this study also demonstrate that the use galvanized reinforcing steel improves the corrosion resistance of reinforced concrete structures. At the same time, it has been shown that in many cases the use of galvanized reinforcement alone is not able to provide sufficient protection against corrosion. Therefore, it is very important for reinforced concrete structure in aggressive marine environments to have an appropriate concrete cover. Within the protective measures that have been considered in this study the use of galvanized reinforcement in combination with cement containing 10% of silica fume was the most efficient one. It has been also demonstrated that cracks in the concrete cover may lead to significant reduction of the corrosion resistance of a structure. Therefore, it is extremely important to ensure good quality of the concrete cover for reinforced concrete structures in marine environments.