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Electrochemical Protection of Steel in Concrete to Enhance the Service Life of Concrete Structures

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Abstract

Corrosion of steel in concrete is a major threat to the construction industry. Ingress of chloride is the main cause of reinforcement corrosion. To prevent corrosion many protection methods are adopted viz, coating to concrete, coating to rebar, adding inhibitors, using supplementary cementations materials and electrochemical protection of steel, etc., Electrochemical protection of steel is one of the method adopted to protect and minimize the rebar corrosion both for existing and new concrete structures. In the present investigation an inhibitor injection was formulated to mitigate reinforcement corrosion in chloride contaminated concrete. In the first stage, the efficiency of the inhibitor injection was tested in different cement environments. In the second stage, the inhibitor formulation was injected into Ordinary Portland Cement (OPC) and Portland Slag Cement (PSC) with different concentrations of chloride. The efficiency of the electro injection process was evaluated by electrochemical techniques. Electrochemical measurements show that the EI process has a high inhibition efficiency than migration process. Electro injection process showed a remarkable decrease in the corrosion rate of embedded in concrete steel even in the presence of aggressive chloride ions when compared to systems without electro injection. In the third, the long term performance of the effectiveness of the electro injection process was studied in concrete slab for an exposure period of 3 months. EI process not only enhanced the inhibition property but also removes the free chloride ions from the chloride contaminated concrete. FT-IR results confirmed that the inhibitor formulation has formed a passive layer on the surface of the steel rebar even in the presence of chloride through the electro injection process.

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Keywords: Reinforcement corrosion; Electro injection; inhibited injection solution; passivity

1. Introduction

Corrosion of steel in concrete is a worldwide problem. It is influenced by various factors such as carbonation, chloride ingress, etc., One of the early deterioration mechanisms is chloride-induced steel corrosion in concrete. Among them chloride ingress plays an important role in decreasing the durability of concrete structures.

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Several researchers protected the steel in concrete by various methods such as coatings to steel, coatings to concrete, cathodic protection (CP), addition of super plasticizers, electrochemical removal of chloride, desalination, electrochemical re-alkalization and corrosion inhibiting admixtures have been reported [1-7]. The method of partial replacement is considered the conventional option, for repair and rehabilitation but it can be time-consuming, expensive and inconvenient, often associated with noise, dust and general disruption during the repair process. As far as electrochemical re-alkalization is concerned, criteria for determining completion of a successful treatment and its long-term durability have been somewhat unclear [8] and, desalination is the established method used for extracting chloride ions from concrete [9,10]. This technique has an advantage of being a fast and temporary treatment, although chloride ions cannot be completely removed in the treatment [11,12]. Therefore, it is important to improve the chloride removal and simultaneously protect the steel by electro injection techniques. Two organic migrating inhibitors (amine- and alkanolamine based) were applied on the surface of concrete and the results showed that migrating inhibitors were not effective in reducing the corrosion rate, either for chloride or carbonation induced corrosion, although some effect was observed on delaying the initiation of corrosion in the case of chloride penetration. The effectiveness of the inhibitors was evaluated by long-term rebar corrosion monitoring in reinforced concrete, and by visual inspection of rebars after five years of testing. The results provide useful information on the corrosion prevention ability of the inhibitors, both on time-to-corrosion and on corrosion propagation.

The objective of the present investigation is directed towards the evaluation of a designed multi component inhibitor injection solution consists of thiosemicarbazide, tri-ethanolamine, guanidine and ethyl acetate were used as electrolyte formulation for the corrosion of steel in different types of concrete (OPC, PPC & PSC) with varying chloride levels through the electro injection process. In the first stage, the efficiency of the inhibitor formulation is tested in the different cement extract medium. Long term performance of the electro injection process is also monitored for an exposure period of 12 months.

2. Materials and Methods

2.1. Materials

The various types of cement namely ordinary Portland cement (OPC) (IS: 8119-1989), Portland pozzolana cement (PPC) (IS: 1489 (part-1) 1991- fly ash based and Portland slag cement (PSC) (IS: 455-1989) were used. The chemical composition of OPC, PPC and PSC is given in Table 1. Local clean river sand (fineness modulus of medium sand equal to 2.6) conforming to grading zone-III of IS: 383–1970 was used. The specific gravity of fine aggregates is 2.4. Water absorption of fine aggregates is 0.5%. All the solutions were prepared using distilled water. Inhibited injection solution consists of 0.1M guanidine, 0.1M thiosemicarbazide; 2M triethanolamine and 2M ethyl acetate. Sodium chloride (3%) by weight of cement was added to the concrete during casting. Thermomechanically treated (TMT) rebar of size 12 mm diameters was used. The composition of PC-TMT (wt. %) are as follows: C=0.17; Mn=0.88; P=0.023; Si=0.075; S=0.038 and Fe remainder with carbon equivalent= 0.32%.

Constituent	Wt(%)		
	OPC	PPC	PSC
SiO_2	20-21	28-32	26-30
Al_2O_3	5.2-5.6	5.0-8.0	9.0-11.0
Fe_2O_3	4.4-4.8	4.9-6.0	2.5-3.0
CaO	62-63	43-45	44-46
MgO	0.5-0.7	1.0-2.0	3.5-4.0
SO_3	2.4-2.8	2.4-2.8	2.0-2.4
LOI	1.5-2.5	3.0-3.5	1.5-2.5

Table 1: Chemical composition of OPC, PPC and PSC cements