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THE MULTIFUNCTIONAL ADMIXTURE FOR CONCRETE

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One of the most important requirements of concrete is that it should be durable under exposure conditions. Various forms of deterioration can occur due to different exposure condition. The corrosion of reinforcement is considered to be one of the most frequent causes of such premature degradation. Addition of multifunctional admixtures may control these deleterious effects.

Migrating corrosion inhibitors (MCI) are admixtures that delay the onset of corrosion and lower the corrosion rate. Superplastisizers are used to increase the flowability of concrete. Both types of admixtures are very important in concrete technology.

In this paper are presented the results of the combination of migrating corrosion inhibitor and superplasticizer in common dosage as one admixture. This new admixture synergistically improves both the physical properties of concrete on rapid freezing and thawing and corrosion protection of the reinforcing steel.

INTRODUCTION

MCIs are a mixed (anodic/cathodic) amino-carboxylate based inhibitor system. MCI mixed inhibitors contain molecules in which electron density distribution causes the inhibitor to be attracted to both anodic and cathodic sites. They are secondary electrolyte-layer inhibitors. Substances dispersed or dissolved in the electrolyte-layer cause electrolyte-layer inhibition. MCIs possess appreciable saturated vapour pressures under atmospheric conditions, thus allowing significant vapour phase transport of the inhibitive substance [1]. MCI admixtures migrate to the reinforcement through diffusion (both liquid and vapour). The first commercial use of mixed inhibitors was in 1986, as shown in Table 1. Migrating corrosion inhibitors generally double the time to the onset of corrosion [2-10], and once corrosion starts, slow the corrosion rate to four times or more less than that of a control. Superplasticizers modifies the properties of fresh and hardened concrete by increasing its workability, which can be used to reduce the water/cement ratio, reduce the cement content or increase the flowability of the concrete. Water-reducing admixtures were first introduced in 1935 as plasticizers based on ligno-and naphthalene sulfonates. In the early 1960's the first high range, or "super"-plasticizers, based on melamine and naphthalene formaldehyde, were introduced [11]. Over the last 10 years a new generation of polyacrylate and polycarboxylate-based superplasticizer has been developed, Table 2. The dispersion mechanism of these superplasticizers in cement paste is best explained in terms of electrostatic repulsion between cement particles, which are negatively charged by the adsorption of the polymer molecule onto the cement surface. Superplasticizing admixtures, when added in concrete mix, are capable of reducing water requirement by 20 to 30% depending on the formulation [12, 13].

Both superplasticizers and migrating corrosion inhibitors are very important admixtures in concrete technology today.

In order to test the compatibility of migrating corrosion inhibitors in combination with superplasticizers, the three types of migrating corrosion inhibitors and three types of superplasticizers were tested in the combinations of separate dosages of migration corrosion inhibitors and superplasticizers during the preparation of the specimens and in the common dosage as one product [14]. The three types of migrating corrosion inhibitors investigated were based: on alkanol amine, on aminocarboxylates and salts of oxycarbonic acids and on aminocarboxylates and non-organic inhibitors. The three types of superplasticizers investigated were based: on lignosulfonate salt, on melamine salt and on salts of sulfonated napthalene.

The compatibility testing on fresh micro concrete consisted of setting time of the cement paste at 20°C and 30°C (according to ASTM C 403), porosity of the micro concrete (according to ASTM C 231) and flowability of the micro concrete (according to ASTM C 143) and the results are shown in Reference 14 and 15. The same combination of admixture combination as on the fresh concrete was also tested on the hardened concrete on compressive strength, flexural strength, gas permeability and chloride diffusion [14,15].

The aim of the investigation in this paper was to show how the combination of migrating corrosion inhibitor and superplasticizers in common dosage as one admixture synergistically improves both the physical properties of concrete on rapid freezing and thawing and corrosion protection of the reinforcing steel.

EXPERIMENTAL DETAILS

The best combination of common dosage of migration corrosion inhibitor and superplastisizer (MCI + S) that was given from the previous investigation [14,15] was tested on the additional properties such as the resistance of concrete to rapid freezing and thawing and corrosion resistance. The testing procedure for rapid freezing and thawing are not described here because this is the standard ASTM C 666 (A) testing procedure. Only the corrosion testing on mortars specimens is described below.

The effect of the new admixture "MCI + S", on the corrosion of reinforcing steel was studied using electrochemical impedance. Electrochemical measurements on rebar were carried out on mortar specimens without and with the addition of 2% of admixture "MCI + S" by the weight of cement.

The reinforcing steel bars were cleaned with a wire brush and wiped with methanol then air-dried. The tip of the rebar and the interface area where the atmosphere and concrete meet were isolated with epoxy, (Figure 1). Approximately 2.5 cm of the reinforcing steel was exposed in the mortar sample (Figure 2). The distance from the top of the surface of the mortar to the exposed steel is approximately 2.5 cm. The exposed steel area is the working electrode for the impedance study. The mould used for the concrete samples was 400 ml plastic beakers.

The specimens were kept in the laboratory for 2 days after concreting. After opening the moulds the samples were then cured for 28 days in a high humidity chamber (100% RH and 40^0C). Once they were removed from the humidity chamber epoxy was applied to both top and bottom of the exterior of the mortar sample to prevent "end effects" from occurring. The coating of the top portion of the mortar sample extended to the reinforcing bar to prevent any interface effects from occurring.

The cement mortar used for the samples was a commercially available Ready Mix Mortar. The prepared specimens were exposed to 14 cycles in the salt spray chamber. The specimens were kept for 8 hours in a salt spray room and 16 hours in the laboratory condition (20°C and 65% RH) during one cycle. The impedance spectra were produced through the use of a potentiostat "Fermostat" with EIS 900 Software produced by Gamry Instruments Inc. A three-electrode arrangement was utilized for the measurements in $Ca(OH)_2$ saturated solution. This arrangement included a working electrode (steel reinforcing bar), a counter electrode (high density graphite), and a reference (saturated calomel electrode). Impedance spectra were obtained in the potentiostatic regime. A small amplitude (10 mV rms) sinusoidal wave was applied via the working electrode. The range of frequencies was 10^{-3} to 10^6 Hz.

RESULTS

The results of the resistance of concrete to rapid freezing and thawing are shown as relative durability factor in %. The average relative durability factor for tested specimens was > 93.1 which is much better than required to be > 80%, (Figure 3). These results indicate very good resistance to freezing and thawing cycles for the tested combination.

The results of the electrochemical measurements are presented in the (Figure 4). The results showed that the new admixture consisted of one migration corrosion inhibitor and one superplasticizer provided very good corrosion protection to reinforcing steel after 14 cycles in salt spray chamber.

The provided corrosion investigation could be considered as the preliminary testing and further investigation should be done as suggested in [16]. It means that it would be necessary to do the investigation on concrete specimens according the standard ASTM procedure for the assessment of the corrosion protection effectiveness of the new admixture that is the combination of one migration corrosion inhibitor and one superplasticizer.

CONCLUSIONS

Based on previous and presented study it could be seen that using a combination of migrating corrosion inhibitors and superplasticizer synergistically improves both corrosion protection of the reinforcing steel and the physical properties of concrete. The improvement of the durability properties was found when concrete contain the admixture which is the combination of one migrating corrosion inhibitor and one superplastisizer. It was also found that this final version of admixture "MCI + S" lowers the corrosion current when testing in salt spray chamber was done. The additional long lasting investigation on concrete specimens is suggested for the assessment of this new type of admixture as good corrosion protection substance with synergetic effect.

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TABLE 1
DEVELOPMENT OF REINFORCEMENT CORROSION INHIBITOR TECHNOLOGY AND APPLICATION METHODS

Year	Type of inhibitor	Chemical composition	Application
1979	Anodic	Calcium nitrite	Admixture
1986	Mixed	Alkanolamines	Admixture
1990	Mixed	Water based amine carboxylate	Surface applied
1990	Mixed	Water based, organic (amines and esters	Admixture
1993	Anodic	Calcium nitrite	Surface applied
1994	Anodic	Organic and inorganic	Admixture
1996	Mixed	Water based, organic	Surface applied
1997	Mixed	Amino alcohol	Admixture, surface applied
1997	Anodic	Sodium mono-fluorophosphate	Surface applied
1998	Mixed	Ethanolamine	Pellets into predrilled holes

TABLE 2
DEVELOPMENT OF SUPERPLASTICIZER AS ADMIXTURE IN CONCRETE

Year	Admixtures
1885	Calcium chloride
1924	Water-tightness admixtures
1930	Alumina powder
1932	Naphthalene-formaldehyde condensate
1938	Air entraining admixtures
1938	Accelerator and retarder
1939	Ligno-sulphonates
1950	De-foaming agent
1955	Freezing point lowering admixtures
1960	Melamine-formaldehyde condensate
1993	Polyacrylate
1997	Polycarboxylic ether

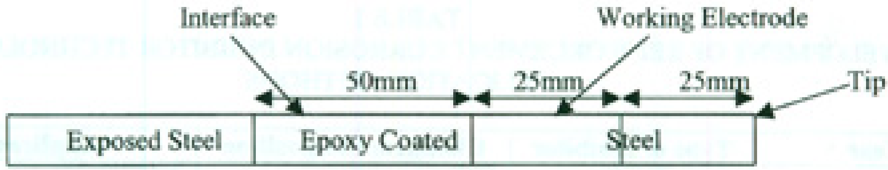

FIGURE 1 - Reinforcing steel bar used for impedance measurements.

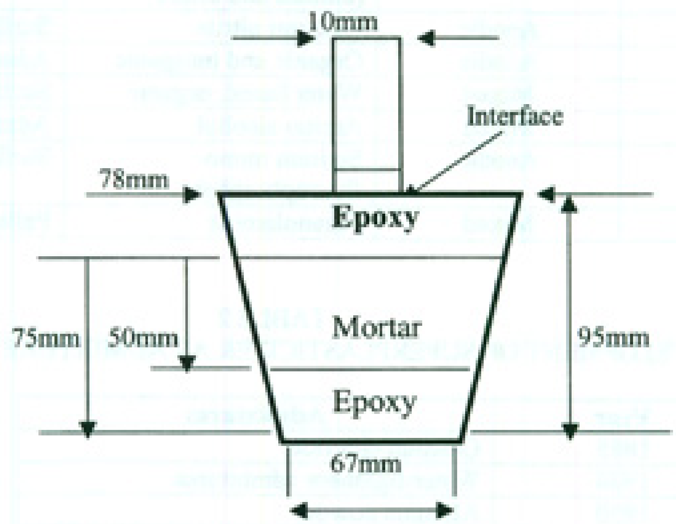

FIGURE 2- Geometry of concrete sample of impedance measurements

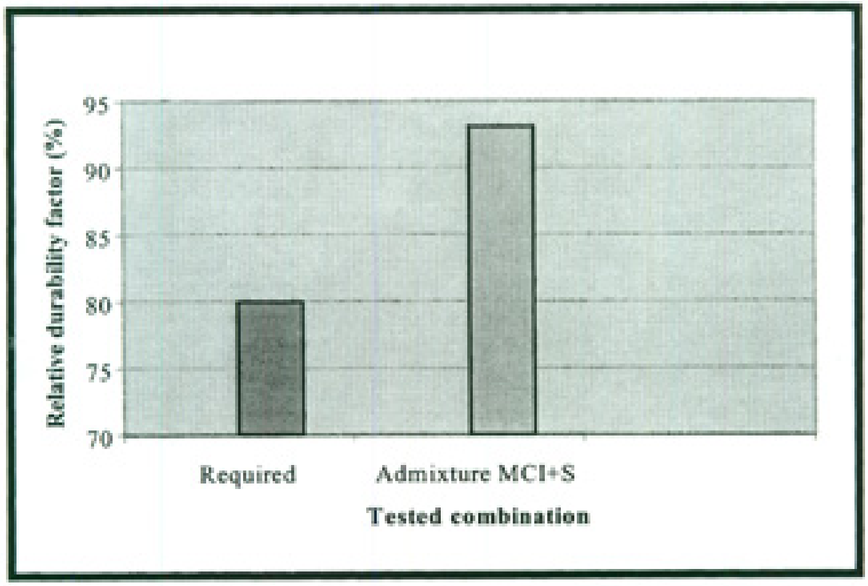

FIGURE 3 - The results of the resistance of concrete to rapid freezing and thawing

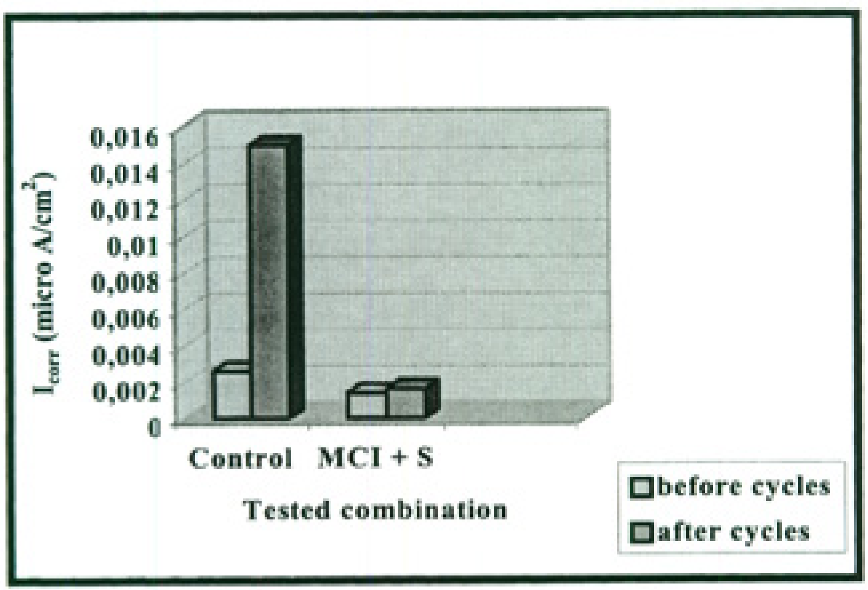

FIGURE 4 - The results of electrochemical investigation on mortar specimens