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TESTING INFLUENCE OF SULFATE ON CORROSION RATE OF STEEL REINFORCEMENT IN CONCRETE CAUSED BY ACTION OF CHLORIDE

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ABSTRACT

This paper presents results of research influence of sulfate on corrosion rate of steel reinforcement in concrete caused by action of chloride. Cylindrical samples of cement mortar with steel reinforcement in middle, after preparation phase, were treated six months in following solutions: 5 % Cl^-, 2,1 % SO_4^{2-} + 5 % Cl^-, distilled water. Corrosion tests were conducted on samples after six months. Electrolyte used in this case is saturation solution $Ca(OH)_2$. Testing corrosion of reinforcing steel in cement mortar is carried on device which consists of an electrochemical cell and potentiostat/galvanostat (Princeton Applied Research, model 263A-2). Results of experiments are presented in form of anodic polarization curves of steel reinforcement in concrete, using potentiodynamic polarization method. Results indicate that sulfate reducing corrosion rate of steel reinforcement in concrete caused by action of chloride.

Keywords: sulfate, chloride, steel reinforcement, concrete, corrosion .

1. INTRODUCTION

Steel reinforcement in concrete has a natural protection against corrosion thanks to its high alkalinity of concrete , which steel reinforcement makes passive. Alkalinity in concrete generating alkaline oxide and calcium hydroxide formed in proces of cement hydration [1, 2]. Protective passive film of reinforcing steel in concrete can disrupt presence of chlorides in concrete.

Chlorides in concrete can enter during preparation of concrete or penetrating from environment [3]. It is believed that chlorides penetrate into concrete with mechanism of diffusion of chloride ions which follows Fick's second law [4].

Chlorides react with constituents of passive film, iron oxides, and also at pH> 9,5, which reactants (O_2 and H_2O) have direct access to steel reinforcement, and corrosion process begins [2]. Harmful effects on steel reinforcement, causing corrosion of concrete, cause and sulfates. Sulphate attack on concrete is a complex process that involves a set of different chemical reactions. There are mainly two reaction mechanism of sulfate attack on concrete: formation of calcium- hydrosulfoaluminate (ettringite) and formation of gypsum [5]. In absence of chloride in corrosion of concrete caused by sulfates can form a ettringite, in presence of chloride is formed gypsum, not ettringite [6].

However, there are different opinions when it comes to joint action chloride and sulphate in concrete.

A review of literature on role of chloride ions on sulfate attack in plain cements indicates three schools of thought: (a) chlorides tend to intensify sulfate attack, (b) presence of chlorides mitigates sulfate attack, and (c) effect of chlorides on sulfate attack is insignificant [7].

Due to its complexity it should be noted that studies mechanisms corrosion of concrete and steel reinforcement in concrete is always actually.

2. EXPERIMENTAL PART

Samples for testing corrosion rate (working electrodes) were prepared from cement mortar in which mass of cement and aggregates is equal to 1:3. Working electrodes is a cylindrical shaped body in which is embedded steel reinforcement. Samples were prepared by procedure prescribed by standard JUS U.M1.044 [8]. For above tests were used three classes of portland cement: PC 35, PC 45 and PC 55. Mineralogical composition of portland cements are shown in table 1.

Tabela 1. Mineralogical composition of portland cements

Class of cement	Content of cement minerals, ***mass percent***			
	C_3S	C_2S	C_3A	C_4AF
PC 55	63,9	14,4	3,7	14,9
PC 45	62,4	10,7	6,0	13,1
PC 35	65,8	6,4	7,2	9,4

Mineralogical (X-ray) analysis of portland cements done on device, "X-Ray Diffractometer Siemens D 5000. To test corrosion rate used is a steel reinforcement following chemical composition: C – 0,08%, Si – 0,12%, Mn – 0,32%, P – 0,019%, S – 0,016%, Cr – 0,03%, Cu – 0,07%, Ni – 0,04%, Mo < 0,01%. Aggregate used for preparation of cement mortar is standard sand per DIN EN 196-1. Samples prepared in molds were immediately placed in dryer at room temperature, in which relative humidity was about 90%. After 24 hours keeping in dryer, samples were extracted from mold and immersed in following solutions: 5% Cl^-, 2,1% SO_4^{2-} + 5% Cl^-, distilled water. Pure NaCl and Na_2SO_4 are used for preparation of above solution. In these solutions, samples were treated next 6 months, after which was followed by corrosion tests. Testing of corrosion of reinforcing steel in cement mortar was carried out in a corrosive cell containing three electrodes, on device potentiostat/galvanostat (Princeton Applied Research, Model 263A-2), with PowerCORR® software package. Testing was carried out in a saturated solution of $Ca(OH)_2$ at room temperature.

3. RESULTS AND DISCUSSION

Results of testing corrosion of steel reinforcement in cement mortar are shown in Figures 1, 2 and 3. Results of experiments are presented in form of anodic polarization curves of working electrodes, using potentiodynamic polarization method.

Assessing state of corrosion of steel reinforcement in cement mortar is carried out according to JUS U.M1.035. Standard provides measurement of current density at working electrode at 225 mV relative to a saturated calomel electrode[9].

Comparing corrosion rate of samples prepared from cements PC 35, PC 45 and PC 55 and treated 6 months at above solutions, Figures 1, 2 and 3, results show that most active corrosion of steel reinforcement in samples treated in a 5% solution of chloride. Results are consistent with known facts that chlorides activated corrosion processes in steel reinforcement in concrete.

Results in Figures 1, 2 and 3 show that intensity of corrosion of steel reinforcement in samples treated in common solutions with chloride and sulfate lower than intensity of corrosion of steel reinforcement in samples treated in solutions of chlorides.

Sulfates obviously reduce corrosion on steel reinforcement in concrete caused by action of chloride. Reason of reducing corrosion rate can be formation of calcium sulfate from SO_4^{2-} and $Ca(OH)_2$.

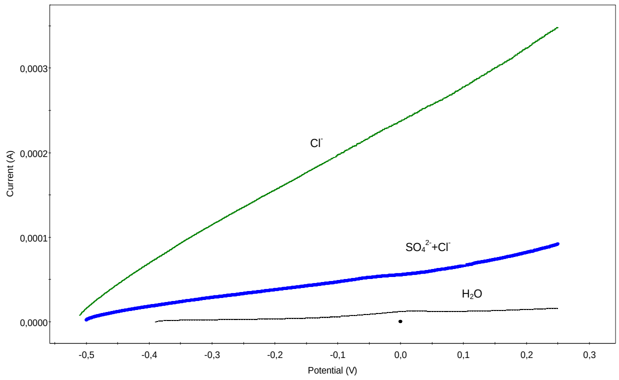

Figure 1. Anodic polarization curves samples of PC35

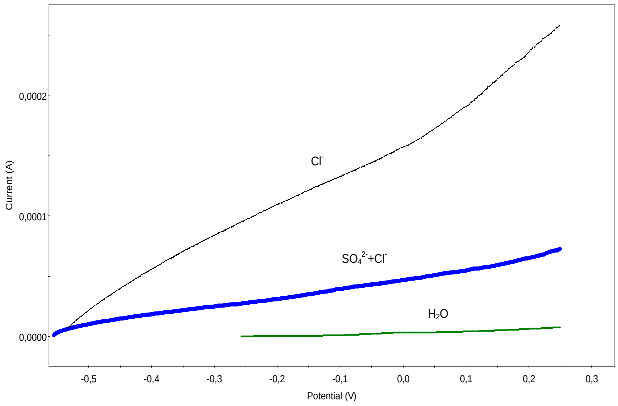

Figure 2. Anodic polarization curves samples of PC45

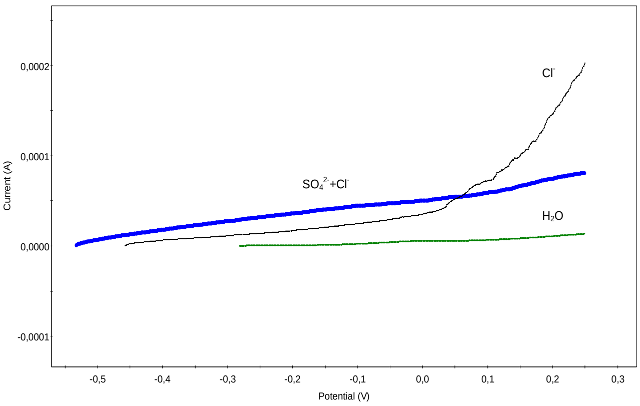

Figure 3. Anodic polarization curves samples of PC55

According to literature data in case of small concentrations of sulfate in solution, concrete becomes denser and its throughput capacity is reduced due to accumulation of calcium sulphate from SO_4^{2-} and $Ca(OH)_2$. When is concrete denser structure then is less depth of penetration of chloride, or less chance of corrosion on steel reinforcement in concrete. In absence of chloride in corrosion of concrete caused by sulfates can form a ettringite, in the presence of chloride is formed gypsum, not ettringite [6].

Chlorides and sulfates react with Ca $(OH)_2$ in concrete but chlorides are active than sulfate. Chlorides penetrate in concrete forming $CaCl_2$ in reaction with $Ca(OH)_2$. Very soluble $CaCl_2$ increases porosity of concrete and conductivity in pore at concrete. Chlorides destructive formed oxide and hydroxide films on steel reinforcement which activates corrosion of steel reinforcement. In case when concrete is treated in solution with a common $SO_4^{2-}$and Cl^-ions, sulfates react with $Ca(OH)_2$ to form $CaSO_4$.

Formed $CaSO_4$ increases density of pores in concrete in relation to density of pores in concrete treated only with a solution of chloride. Increasing density of concrete due to formation of $CaSO_4$ reduces conductivity of concrete which directly affects reduction of corrosion in steel reinforcement in concrete caused by action of chloride.

4. CONCLUSION

Results of research indicate that sulfate reducing corrosion rate of steel reinforcement in concrete caused by action of chloride. Reason of reducing corrosion rate can be formation of calcium sulfate from SO_4^{2-} and $Ca(OH)_2$. Formed $CaSO_4$ increases density of pores in concrete in relation to density of pores in concrete treated only with a solution of chloride. Increasing density of concrete due to formation of $CaSO_4$ reduces conductivity of concrete which directly affects reduction of corrosion in steel reinforcement in concrete caused by action of chloride.

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