

INFLUENCE OF TYPES OF MAGNESIUM SALTS ON THE CORROSION RATE OF REINFORCEMENT STEEL IN CONCRETE

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ABSTRACT

This paper presents the investigation results of the influence of types of magnesium salts on the rate of corrosion of steel reinforcement in concrete. The cylindrical samples of cement mortar, with reinforcement steel in the middle, measuring 80 × 40 mm of varying water-cement ratio 0.5 and 0.7 (kg H₂O / kg of cement) were prepared for implementation of planned research. The samples were immersed and treated for nine months in following solution: 1% MgCl₂, 1% MgSO₄, 5% MgCl₂, 5% MgSO₄, distilled H₂O. Using the electrochemical method potentiodynamic polarization it was proved that in solutions of magnesium salts with higher concentrations (5%) are more aggressive salt MgCl₂ at reinforcement steel in both water - cement ratios, while in solutions with lower concentrations (1%) more aggressive salt is MgSO₄ at reinforcement steel in both water - cement ratios.

Keywords: magnesium salts, cement mortar, corrosion of reinforcement steel, potentiodynamic polarization.

1. INTRODUCTION

A great threat for reinforced concrete structures are magnesium salts, mainly sulphates and chlorides of magnesium. The basic processes that occur in cement stone in the presence of magnesium salt solution are based on their reaction with calcium hydroxide [1]:



The product of reaction (1) and (2) is magnesium hydroxide, with low solubility, 18.2 mgdm⁻³ at room temperature, and it will precipitate from the solution. Binding of OH⁻ ions in the magnesium hydroxide is accompanied by reduction of pH value of the solution in the pores of the cement stone to pH = 10 [1]. Otherwise, the pH of the solid concrete pores is in the interval from 12.5 to 13.5, thanks to the calcium hydroxide generated through the process of cement hydration [2]. Reduction of pH of concrete leads to increased corrosion intensity of concrete and steel reinforcement. Reinforcement steel in concrete with pH 12,5 to 13,5 is protected with layer oxidized iron (FeO.OH) ili Fe₂O₃, which in normal conditions causes passivation of reinforcement steel [3]. Depolarization of steel reinforcement in concrete, or activate corrosion on the reinforcement steel causes presence of chloride on its surface. Chlorides dissolve the protective film on the steel reinforcement and thereby create conditions for further corrosion destruction reinforcement.

2. EXPERIMENTAL PART

The cylindrical samples of cement mortar, with ratio of mass of cement and aggregate 1: 3, with dimensions of 80 × 40 mm, in which is embedded steel reinforcement with a diameter of 6 mm, were prepared for testing of corrosion rate. Cement mortar was prepared with distilled H₂O, varying water-cement ratio 0.5 and 0.7 (kg H₂O / kg of cement). The samples were prepared by the process that prescribes the standard HRN U.M1.044. [4]. For sample preparation the Portland cement class PC 42.5 with following clinker mineralogical composition was used: alit, tricalcium silicate (C₃S) - 66.37%; belit, dicalcium silicate (C₂S) - 8.32%; tricalcium aluminate (C₃A) - 9.62%, celite, and tetracalcium aluminoferrite (C₄AF) - 10.77%. Mineralogical analysis of cement clinker was performed on "X-Ray Diffractometer SIEMENS D 5000" device. To test the rate of corrosion of steel reinforcement in concrete, used the smooth steel reinforcement, whose chemical composition is given in table 1.

Table 1. Chemical composition of steel reinforcement

Element	C	Si	Mn	S	P	B	Zn	Cr	Mo	Cu	Ni
Mas. %	0,11	0,12	0,38	0,012	0,021	<0,001	0,002	0,02	<0,01	0,09	0,04

The aggregate used for the preparation of cement mortar is the standard sand DIN EN 196-1. After preparation, the samples were placed in molds and in the drying oven with relative humidity of at least 90%. The molds were held in such state for 24 hours. After 24 hours keeping in a drying oven, the samples were removed from the mold and then immersed in the following solution: 1% MgCl₂, 1% MgSO₄, 5% MgCl₂, 5% MgSO₄, distilled H₂O. In this solutions, samples were immersed to 2/3 of its height and left in contact with the electrolyte at room temperature for the next 9 months. Testing of corrosion of reinforcing steel in cement mortar was performed on the measuring device potentiostat/galvanostat EG&G/PAR Model 263A in a corrosive cell which contains three electrodes. Testing was carried out in saturation solution Ca(OH)₂ at room temperature. Potentiodynamic polarization technique was used for testing of corrosion of reinforcement steel in cement mortar.

3. RESULTS AND DISCUSSION

Figures 1, 2, 3 and 4 show results analysis influence of magnesium salts on the corrosion rate of reinforcement steel in concrete mortar.

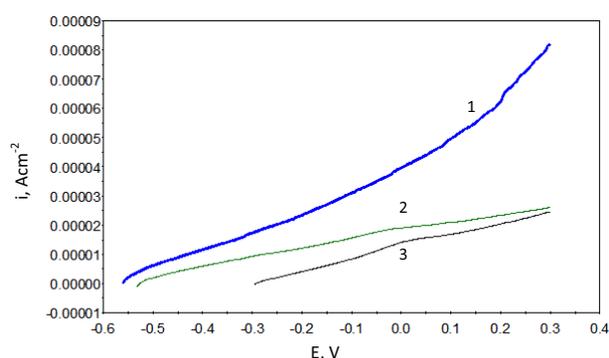


Figure 1. Anodic polarization curves of samples treated in solutions of: 1 - 5% MgCl₂ v/c=0,5; 2- 5% MgSO₄ v/c=0,5; 3 - H₂O v/c=0,5

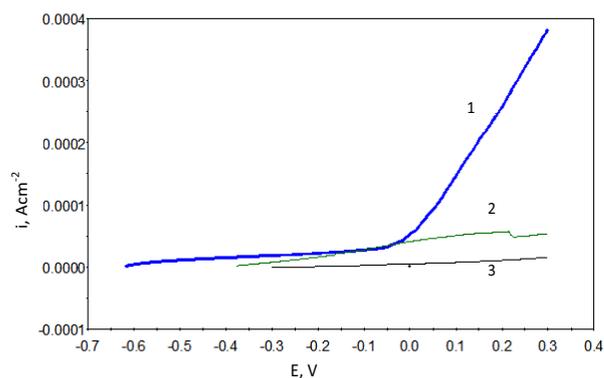


Figure 1. Anodic polarization curves of samples treated in solutions of: 1 - 5% MgCl₂ v/c=0,7; 2- 5% MgSO₄ v/c=0,7; 3 - H₂O v/c=0,7

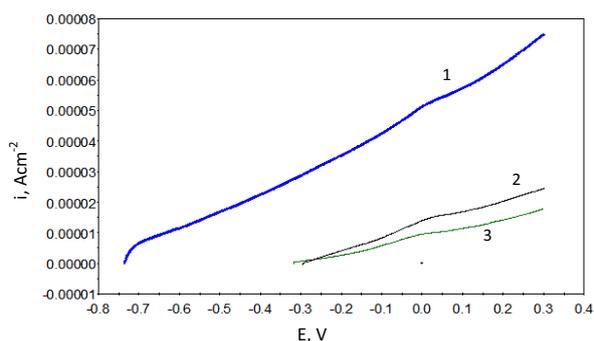


Figure 3. Anodic polarization curves of samples treated in solutions of: 1 - 1% $MgSO_4$ $v/c=0,5$; 2- H_2O $v/c=0,5$; 3 - 1% $MgCl_2$ $v/c=0,5$

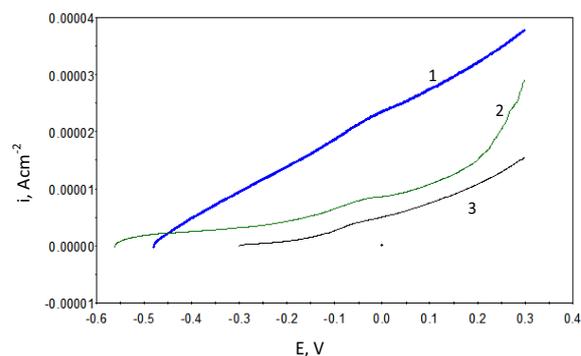


Figure 4. Anodic polarization curves of samples treated in solutions of: 1 - 1% $MgSO_4$ $v/c=0,7$; 2- 1% $MgCl_2$ $v/c=0,7$; 3 - H_2O $v/c=0,7$

By comparing the slope curve anodic polarization in the diagrams current density / potential (Figures 1, 2, 3 and 4) can be assessed corrosion activity on the working electrode. Since the current density is proportional to the concentration of corrosion products, curve with the greater slope shows the highest corrosion activity [5]. In solutions of magnesium salts with higher concentrations (5%), more aggressive salt is $MgCl_2$ at reinforcement steel in both water - cement ratios (Figure 1 and 2), while in solutions with lower concentrations (1%) more aggressive salt is $MgSO_4$ for reinforcement steel in both water - cement ratios (Figure 3 and 4). In solutions of higher concentrations of magnesium salts it is expected that $MgCl_2$ be more aggressive salt because chlorides are activators of corrosive reaction in the reinforcement steel. Chlorides dissolve the protective film on the reinforcement steel and thereby create conditions for further corrosion destruction reinforcement steel. However, at solutions with lower concentrations of magnesium salts, more aggressive salt is $MgSO_4$ at reinforcement steel, which was not expected. Aggressive effect of $MgSO_4$ in solutions of magnesium salts with lower concentration (1%) could be explain over the binding reaction of chloride and sulfate for hydrates cement minerals. With the binding of the chlorides for aluminate hydrate from samples of cement mortar, the same chlorides will be in a large extend binding from 1% solution $MgCl_2$ and they will not represent danger for reinforcement steel. Only free chlorides present in the concrete can cause corrosion of reinforcement steel. On the other side, sulphates, binding to aluminate hydrates formed expansive ettringite low concentrations. Ettringite insignificantly increase the capillary porosity of samples of cement mortar which results increase corrosion at reinforcement steel in samples treated 1 % solutions of $MgSO_4$, compared to the samples treated in a solution of 1% $MgCl_2$.

4. CONCLUSION

The results of the research show that the intensity of corrosion at reinforcement steel in samples of cement mortar, treated in solutions of magnesium salt with concentrations of 5% in both water-cement ratio, were higher at the reinforcement steel treated in solutions of $MgCl_2$. This result was expected because chlorides are activators of corrosive reaction at reinforcement steel. At lower concentrations, intensity of corrosion at reinforcement steel in samples of cement mortar treated in solutions of magnesium salt concentration of 1%, in both water-cement ratios, were higher at reinforcement steel treated in solutions of $MgSO_4$. This is explained by binding chlorides for aluminate hydrates from samples of cement mortar, and prevent arrival of chlorides at reinforcement steel. On the other side, sulphates, binding to aluminate hydrates formed expansive ettringite low concentrations which increase the capillary porosity of samples of cement mortar which results increase corrosion at reinforcement steel in samples treated 1 % solutions of $MgSO_4$, compared to the samples treated in a solution of 1% $MgCl_2$.

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