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EXAMINATION OF THE INFLUENCE OF TENSILE STRESS ON CORROSION RATE OF REINFORCING STEEL COVERED WITH POLYMERIC SULPHURIC COATING

In paper presents investigation results of corrosion rate for steel reinforcement bars that have been covered with polymer coating and have been exposed to tensile stresses in a solution simulating pore-liquid of concrete. Experimental investigation of tendencies that occur during corrosion process of reinforcing steel covered with polymer and exposed to tensile stress has been attempted. To determine an effect of tensile stress on corrosion rate for St3S-b steel that has been covered with sulphuric coating and exposed to aqueous environment that was to simulate pore-liquid of concrete contaminated with chloride ions was an aim of the investigation. The samples underwent loading in an one-axial state of the stress including varied values of tensile stress, at the same time corrosion rate was determined potentiostaticaly. Potentiostatic investigation has been carried out in order to determine parameters describing corrosion rate of samples tested. Corrosion rate for the steel has decreased by orders of magnitude when covered with protective coating even though this latest became unseal at load exceeding. A small decrease of corrosion rate has been found for the steel that has not been covered with polymer coating when placed in model pore-liquid of concrete and exposed to tensile stress increasing. The aim of investigation that has been led was to evaluate tendencies of the corrosion process for St3S-b reinforcing steel when covered with polymer sulphuric coating and exposed to tensile stress. Steel samples were loaded in a way that their yield points were much exceeded; in the same time these samples were exposed to an action of the solution the composition of which is similar to that of pore-liquid of concrete is and additionally contaminated with chloride ions (pH = 9.14). The composition said was as follows: -0.015M $NaHCO_3$ + 0.005M Na_2CO_3 + 0.001M NaCl. Corrosion rate for the steel has decreased by 2-3 orders of magnitude when covered with protective coating even though this latest became unseal at load exceeding 88.5 MPa.

Keywords: **corrosion, reinforcing steel, tensile stress, polymeric sulphuric coating, polarization, corrosion, reinforcing steel**

BADANIE WPŁYWU NAPRĘŻEŃ ROZCIĄGAJĄCYCH NA INTENSYWNOŚĆ PROCESÓW KOROZJI STALI ZBROJENIOWEJ POKRYTEJ POLIMEROWYM KOMPOZYTEM SIARKOWYM

Przedstawiono rezultaty badań polaryzacyjnych prętów zbrojeniowych rozciąganych, pokrytych warstwą polimerowego kompozytu siarkowego, umieszczonych w modelowym roztworze odwzorowującym ciecz porową betonu skarbonatyzowanego, skażonego jonami chlorkowymi. Dążąc do określenia tendencji występującej w procesie korozji stali zbrojeniowej pokrytej powłoką polimerową wskutek działania naprężeń rozciągających, przeprowadzono badania eksperymentalne. Celem badań było określenie wpływu naprężeń rozciągających na szybkość korozji stali zbrojeniowej gatunku St3S-b pokrytej polimerową powłoką siarkową w środowisku wodnym odwzorowującym ciecz porową betonu skażonego jonami chlorku. Próbki obciążano w jednoosiowym stanie naprężenia, uwzględniając zmienne wartości siły rozciągającej, natomiast szybkość procesu korozyjnego określono na podstawie badań potencjostatycznych. Podczas badań określono szybkość korozji stali zbrojeniowej niepokrytej warstwą polimerowego kompozytu siarkowego, znajdującej się w modelowej cieczy porowej betonu pod wpływem wzrastających naprężeń rozciągających, a następnie stwierdzono kilka rzędów mniejsze szybkości korozji po zabezpieczeniu stali warstwą polimerowego kompozytu siarkowego. Przeprowadzone badania miały na celu oszacowanie tendencji przebiegu procesów korozyjnych stali zbrojeniowej gatunku St3S-b pokrytej polimerowymi powłokami siarkowymi pod wpływem działania naprężeń rozciągających. Próbki stalowe obciążono siłami powodującymi znaczne przekroczenie ich granicy sprężystości oraz poddano działaniu modelowego roztworu zbliżonego składem do cieczy porowej betonu skarbonatyzowanego i skażonego dodatkowo jonami chlorku (pH = 9,14), o składzie: 0,015 M $NaHCO_3$ + 0,005 M Na_2CO_3 + 0,001 M NaCl. W niniejszych badaniach zaobserwowano niewielkie zmniejszenie się szybkości korozji stali zbrojeniowej niepokrytej powłoką polimerową,\ w modelowej cieczy porowej betonu pod wpływem wzrastających naprężeń rozciągających, a o 2 do 3 rzędów mniejsze szybkości korozji po naniesieniu na stal powłoki ochronnej, pomimo jej rozszczelnienia, przy obciążeniu powyżej 88,5 MPa.

Słowa kluczowe: **korozja, stal zbrojeniowa, naprężenia rozciągające, polimerowy kompozyt siarkowy, badania polaryzacyjne**

INTRODUCTION

Some specific environments with varied corrosivity occur in agriculture and in food- and beverage-industries. Soil with varied composition, structure and corrosivity, fertilizers, organic environment of live-stock buildings, and the atmosphere of chemical industries manufacturing plant protectives and fertilizers are among the most significant. As far as construction made of reinforced concrete is concerned the corrosivity of live-stock building environment is much higher than that typical for rural one and it may be compared to that of atmosphere of chemical industry [1-3]. It depends on humidity [4, 5] and on concentration of compounds which make electrical conductivity of the condensate to increase and react chemically with after that they have dissolved in it.

There are several ways possible of protecting ferro-concrete constructions: pre-galvanizing steel, using alloy steel, cathodic protection, electrochemical extraction of chlorides, re-alkalizing carbonated concrete [6-10]. Protective coating, if needed, can be used to prevent corrosion of reinforcing steel, e.g. when concrete lagging may not to be tight, too thin or none, on connecting parts of precast concrete units. Sulfuric polymeric coating may be an example.

Experimental investigation of tendencies that occur during corrosion process of reinforcing steel covered with polymeric sulphuric coating and exposed to tensile stress has been attempted.

To determine an effect of tensile stress on corrosion rate for St3S-b steel that has been covered with sulfuric coating and exposed to aqueous environment that was to simulate pore-liquid of concrete contaminated with chloride ions was an aim of the investigation. The samples underwent loading in an one-axial state of the stress including varied values of tensile stress, at the same time corrosion rate was determined potentiostaticaly.

SAMPLES AND METHODS

In paper presents investigation results of corrosion rate for steel reinforcement bars that have been covered with polymer coating and have been exposed to tensile stresses in a solution simulating pore-liquid of concrete. Experimental investigation of tendencies that occur during corrosion process of reinforcing steel covered with polymer and exposed to tensile stress has been attempted. To determine an effect of tensile stress on corrosion rate for St3S-b steel that has been covered with sulphuric coating and exposed to aqueous environment that was to simulate pore-liquid of concrete contaminated with chloride ions was an aim of the investigation. The samples underwent loading in an one-axial state of the stress including varied values of tensile stress, at the same time corrosion rate was determined potentiostaticaly. Potentiostatic investigation has been carried out in order to determine parameters describing corrosion rate of samples tested. Corrosion rate for the steel has decreased by orders of magnitude when covered with protective coating even though this latest became unseal at load exceeding. A small decrease of corrosion rate has been found for the steel that has not been covered with polymer coating when placed in model pore-liquid of concrete and exposed to tensile stress increasing. The aim of investigation that has been led was to evaluate tendencies of the corrosion process for St3S-b reinforcing steel when covered with polymer sulphuric coating and exposed to tensile stress. Steel samples were loaded in a way that their yield points were much exceeded; in the same time these samples were exposed to an action of the solution the composition of which is similar to that of pore-liquid of concrete is and additionally contaminated with chloride ions.

Samples of St3S-b reinforcing steel covered with sulfuric coating of 0.5 and 1.5 mm of thickness have undergone investigation. The samples have been taken from rods with 10 mm of diameter. A measurement position that had been specially prepared for that purpose was used. It enabled to load axially samples which were in contact with aqueous solution.

Samples of St3S-b reinforcing steel with diameter of 10 mm were used for investigation. The surface of samples was in natural state, i.e. it has not been polished nor degreased (non-polished rods with tarnish).

In order to simulate the environment of the pore-liquid of carbonized concrete a model solution was used, and namely that with composition as follows: 0.015M $NaHCO_3$ + 0.005M Na_2CO_3 + 0.001M NaCl, pH of which was 9.14. The solution was prepared at 20ºC + 2ºC according to [1, 4-6, 9, 10] and in which all potentiostatic investigation was carried out.

Investigation was led with a 3-electrode circuit together with a computer operated set from Zahner designed for polarization measurement. Steel sample covered with polymer sulfuric coating was a specimen, saturated calomel electrode as a reference electrode was used, and platinum wire was an auxiliary electrode. In each case measuring electrode was polarized within a range ±100 mV off the stationary potential. A potential of a measuring electrode that became stable after that it had been immersed in the solution and had not changed within 30 min was considered as a stationary potential. Measurements were made without any loads and then each sample was loaded with 88.5 MPa (2.5 kN) and 194.5 MPa (5.0 kN), each time after that it had reached a stationary potential.

INVESTIGATION RESULTS AND CONCLUSION

Investigation results have been obtained as standard computer diagrams with stationary potentials E_0 and corrosion currents I_0 indicated.

And overview of all corrosion current densities i_0, stationary potentials E_0, at loads P, tensile stresses σ_0 and corrosion rates H_t is presented in Figures 1-8. Corrosion rate H_t has been calculated basing on current densities i_0 measured prior and with using a formula

$$H_t = 1.123 \cdot k \cdot i_0$$

where k = 1.042 g/Ah means the electrochemical equivalent for iron.

The aim of investigation that has been led was to evaluate tendencies of the corrosion process for St3S-b reinforcing steel when covered with polymeric sulphuric coating and exposed to tensile stress. Steel samples were loaded in a way that their yield points were much exceeded; in the same time these samples were exposed to an action of the solution the composition of which is similar to that of pore-liquid of concrete is and additionally contaminated with chloride ions (pH = 9.14). The composition said was as follows:

$$0.015\text{M } NaHCO_3 + 0.005\text{M } Na_2CO_3 + 0.001\text{M } NaCl$$

It was found that a stress increased resulted as the stationary potential for the reference sample slightly decreased, i.e. by some tens of milivolts only compared to that potential for a sample without loads. However for samples, which had been covered with polymeric sulphuric coating, fluctuating potential was found. Yet the results measured match those reported by other authors.

Even though stationary potential E_0 was lowered tensile stresses did not cause corrosion process to increase that was expected when a sample without coating was exposed. Comparing a value for corrosion current density i_0 (Fig. 5) makes evident that within all over the range of loads applied corrosion rate was of the same order of magnitude as that value of corrosion rate was when the sample was without any load; also it tended to decrease when tensile stress grew.

Together with an increase of the tensile stress corrosion current density decreasing was observed which was followed by corrosion rate reduced if compared with that calculated from polarization measurement results. Any significant differences between corrosion rates at particular levels of loading have not been found. It is to assume that these rates have always been of the same order of magnitude for the reference sample (means, without polymeric sulphuric coating), independently on the value of tensile stress. Covering samples tested with protective polymeric sulphuric coating caused significant reduction of corrosion rate, i.e. by 2-3 orders of magnitude (Fig. 7) which means that coating ensures good corrosion prevention in the environment investigated.

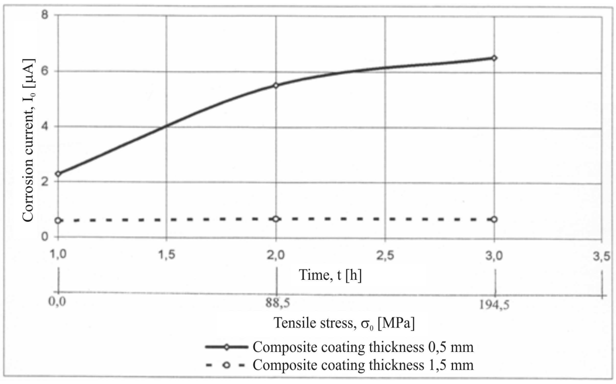

Fig. 1. Polarization investigation results for samples of St3S-b reinforcing steel covered with polymer sulphuric coating and exposed to tensile stresses

Rys. 1. Zależność natężenia prądu korozyjnego dla prętów zbrojeniowych gładkich o średnicy 10 mm, pokrytych warstwą polimerowego kompozytu siarkowego, w funkcji czasu i rosnącego naprężenia rozciągającego

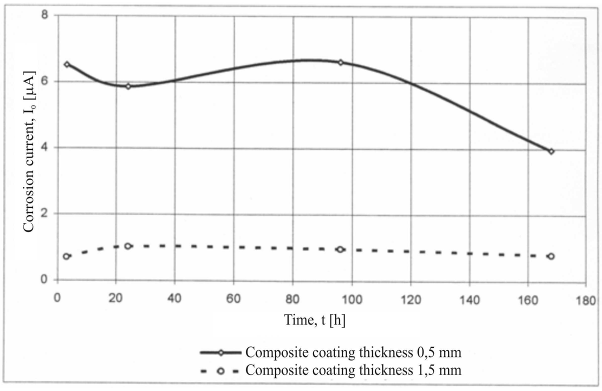

Fig. 2. Polarization investigation results for samples of St3S-b reinforcing steel covered with polymer sulphuric coating and exposed to tensile stresses σ_a = 194.5 MPa

Rys. 2. Zależność natężenia prądu korozyjnego dla prętów zbrojeniowych gładkich o średnicy 10 mm, pokrytych warstwą polimerowego kompozytu siarkowego, w funkcji czasu i stałego naprężenia rozciągającego σ_a = 194,5 MPa

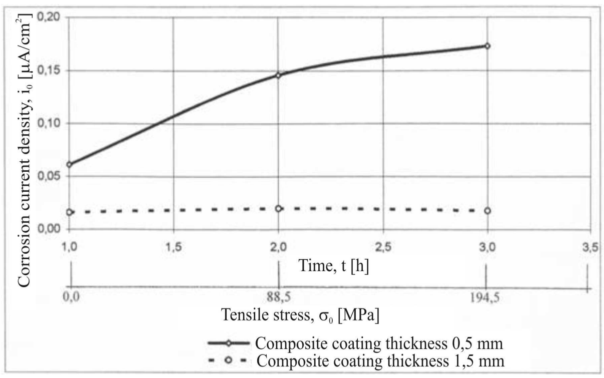

Fig. 3. Polarization investigation results for samples of St3S-b reinforcing steel covered with polymer sulphuric coating and exposed to tensile stresses

Rys. 3. Zależność gęstości prądu korozyjnego dla prętów zbrojeniowych gładkich o średnicy 10 mm, pokrytych warstwą polimerowego kompozytu siarkowego, w funkcji czasu i rosnącego naprężenia rozciągającego

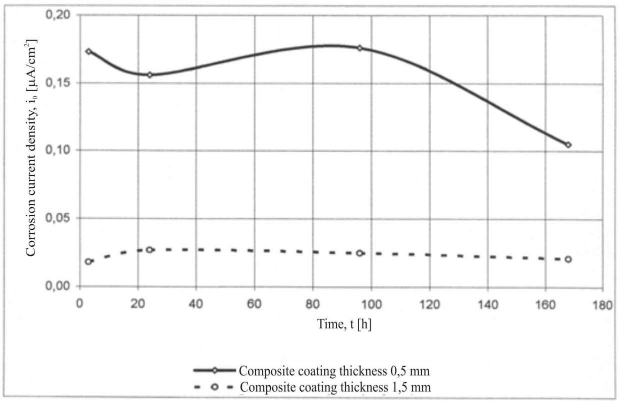

Fig. 4. Polarization investigation results for samples of St3S-b reinforcing steel covered with polymer sulphuric coating and exposed to tensile stresses σ_a = 194.5 MPa

Rys. 4. Zależność gęstości prądu korozyjnego dla prętów zbrojeniowych gładkich o średnicy 10 mm, pokrytych warstwą polimerowego kompozytu siarkowego, w funkcji czasu i stałego naprężenia rozciągającego σ_a = 194,5 MPa

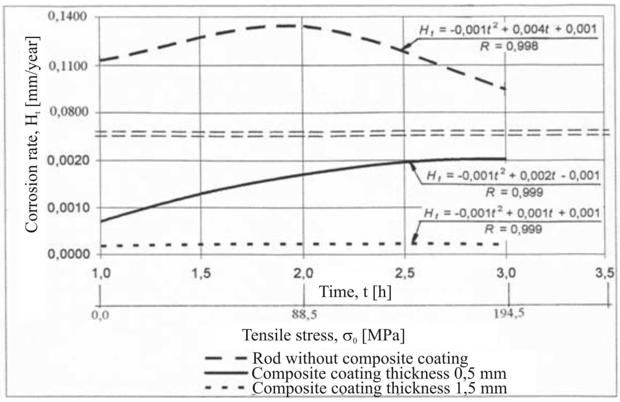

Fig. 5. Polarization investigation results for samples of St3S-b reinforcing steel covered with polymer sulphuric coating and exposed to tensile stresses

Rys. 5. Zależność szybkości korozji dla prętów zbrojeniowych gładkich o średnicy 10 mm, pokrytych warstwą polimerowego kompozytu siarkowego, oraz dla prętów niepokrytych warstwą tego kompozytu, w funkcji czasu i rosnącego naprężenia rozciągającego

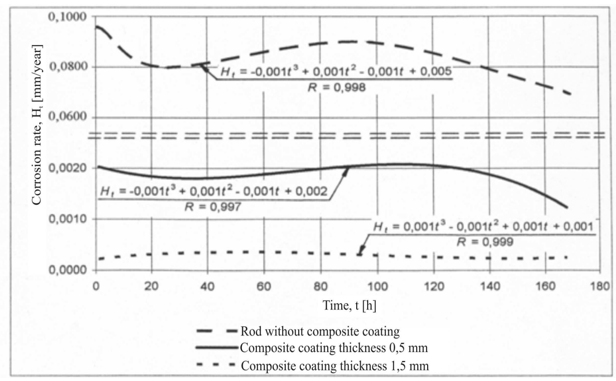

Fig. 6. Polarization investigation results for samples of St3S-b reinforcing steel covered with polymer sulphuric coating and exposed to tensile stresses σ_a = 194.5 MPa

Rys. 6. Zależność szybkości korozji dla prętów zbrojeniowych gładkich o średnicy 10 mm, pokrytych warstwą polimerowego kompozytu siarkowego, oraz dla prętów niepokrytych warstwą tego kompozytu, w funkcji czasu i stałego naprężenia rozciągającego σ_a = 194,5 MPa

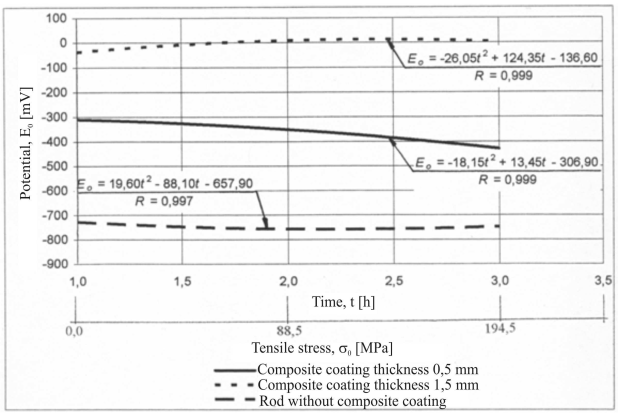

Fig. 7. Polarization investigation results for samples of St3S-b reinforcing steel covered with polymer sulphuric coating and exposed to tensile stresses

Rys. 7. Zależność potencjału stacjonarnego dla prętów zbrojeniowych gładkich o średnicy 10 mm, pokrytych warstwą polimerowego kompozytu siarkowego, oraz dla prętów niepokrytych warstwą tego kompozytu, w funkcji czasu i rosnącego naprężenia rozciągającego

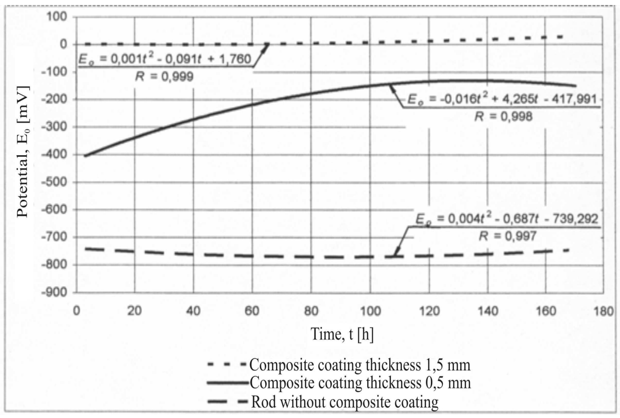

Fig. 8. Polarization investigation results for samples of St3S-b reinforcing steel covered with polymer sulphuric coating and exposed to tensile stresses σ_a = 194.5 MPa

Rys. 8. Zależność potencjału stacjonarnego dla prętów zbrojeniowych gładkich o średnicy 10 mm, pokrytych warstwą polimerowego kompozytu siarkowego, oraz dla prętów niepokrytych warstwą tego kompozytu, w funkcji czasu i stałego naprężenia rozciągającego σ_a = 194,5 MPa

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