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INFLUENCE OF SURFACE ROUGHNESS ON THE RATE OF CORROSION PENETRATION INTO THE STEEL

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This research analyses the influence of surface roughness on the rate of corrosion penetration into the steel. The test specimens were mechanically treated with fine abrasive jet to make their surface slightly rougher than it was in the initial state. The test specimens were then kept in conditions of atmospheric corrosion for 90 days to be tested afterwards by weighing, i.e. by the mass loss method. The analysis showed that a slight increase in surface roughness facilitated faster development of corrosion mechanisms, thus drastically increasing the rate of corrosion penetration into the material. Changes in surface roughness can be also caused by abrasion or erosion damage, so it is important to choose adequate surface protection technologies for prevention of unwanted wear of the steel.

Key words: steel, corrosion, rate of corrosion, roughness, weighing

INTRODUCTION

Development of corrosion on construction materials happens because of various factors, such as environmental conditions, materials in contact, characteristics of materials themselves, and many others [1]. Corrosion mechanisms can be also triggered by abrasion or erosion damages on the material, which results in changed surface profile of the observed material [2, 3]. Such changes increase surface roughness, due to which it becomes more prone to corrosion [4]. Roughness enables retaining of moisture and condensates on the surface of damaged material. This research intends to emphasise the importance of preventing such damages and changes of the surface profile of structural material. The research objective was to increase the roughness of material surface by applying fine abrasive jet and then to analyse the extent to which increased surface roughness influences the rate of corrosion development on the material. When knowing the characteristics of the material, the data on corrosion development rate can be calculated to obtain the rate of corrosion penetration into the material.

EXPERIMENTAL PART

The experiment was carried out on specimens prepared in dimensions 50 x 50 x 3 mm (Figure 1).

Table 1 presents chemical composition of the base material from which test specimens were cut out.

Measuring of roughness was performed after treating all test specimens with abrasive jet. Roughness was measured both on jet-treated and untreated specimens in their initial state, as having in mind the fact that each surface has a certain degree of roughness. Table 2 overviews data of roughness measured on test specimens. Test specimens labelled by numbers from 1-1 to 1-10 were not treated, while specimens with changed surface profile were labelled by numbers from 2-1 to 2-10. The values referring to roughness represent the mean value of five repeated measurements on each specimen.

After measuring the roughness, test specimens were weighed and then exposed to atmospheric conditions. Specimens were weighed on Scaltec SPB32 laboratory scale with a measuring range of up to 120 grams and a precision of four decimal places. The test specimens were exposed to atmospheric conditions for 90 days, during which they were affected by different weather conditions and changes, as well as different reactants that facilitated development of corrosion mechanisms. As the analysis was performed by weighing, i.e. by the

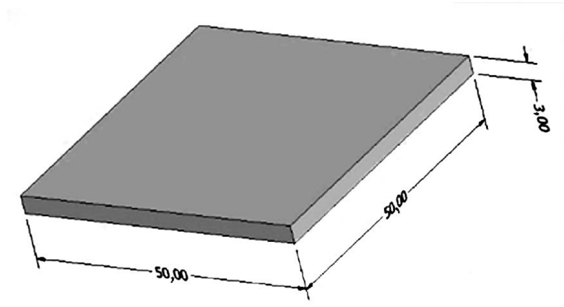

Figure 1 Test specimen

Table 1 **Chemical composition of the base material / mas. % [5]**

C	Si	P	S	N
0,17	+	0,05	0,05	≤ 0,007

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Table 2 **Roughness of test specimens**

Test specimen	Roughness / μm
1-1	6,1
1-2	5,42
1-3	5,04
1-4	6,02
1-5	5,12
1-6	5,31
1-7	6,08
1-8	5,94
1-9	5,73
1-10	5,24
2-1	11,42
2-2	11,63
2-3	11,07
2-4	11,21
2-5	11,48
2-6	11,13
2-7	11,52
2-8	11,57
2-9	11,29
2-10	11,33

mass loss method, it was necessary to determine the difference in the specimen mass at the start of experiment and after the testing period. In order to calculate the mentioned difference, it was necessary to remove the loose corrosion product from specimens and then to weigh them again. Figure 2 shows an untreated test specimen after being exposed to atmospheric conditions before removal of corrosion products.

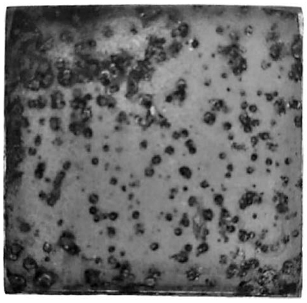

Figure 2 Untreated test specimen before removal of corrosion products

Figure 3 presents the test specimen treated by abrasive jet as it changed the surface profile and developed corrosion products to a greater extent.

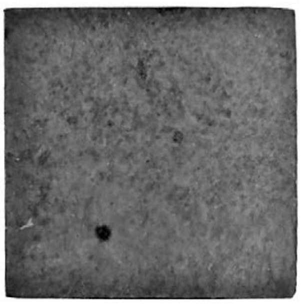

Figure 3 Specimen treated by abrasive jet prior to removal of corrosion products

Table 3 presents the results of measured mass loss that were used for further calculation of corrosion rate.

Table 3 **Mass loss after exposing test specimens to atmospheric conditions**

Test specimen	Mass loss Δm / g
1-1	0,0085
1-2	0,0101
1-3	0,0107
1-4	0,0094
1-5	0,0098
1-6	0,0103
1-7	0,0089
1-8	0,0102
1-9	0,0105
1-10	0,0096
2-1	0,0167
2-2	0,0192
2-3	0,021
2-4	0,0176
2-5	0,0183
2-6	0,0202
2-7	0,0169
2-8	0,0175
2-9	0,0198
2-10	0,0187

The above data were used in calculation of corrosion rate for all specimens by applying the following equation [6]:

$$v = \frac{m_1 - m_2}{S\left(t_2 - t_1\right)} = \frac{\Delta m}{S\Delta t} \qquad (1)$$

where: $_1$ specimen mass before testing, $_2$ specimen mass after testing, □ difference in masses before and after testing, S initial geometric surface of the exposed material, □ duration of testing.

Table 4 **Calculated values of the corrosion rate and of the rate of corrosion penetration into the steel**

Test specimen	v / g·mm^{-2}·d^{-1}	v_p / mm·a^{-1}
1-1	3,7778x10^{-8}	1,7678x10^{-3}
1-2	4,4889x10^{-8}	2,1006x10^{-3}
1-3	4,7556x10^{-8}	2,2254x10^{-3}
1-4	4,1778x10^{-8}	1,955x10^{-3}
1-5	4,3556x10^{-8}	2,0382x10^{-3}
1-6	4,5778x10^{-8}	2,1422x10^{-3}
1-7	3,9556x10^{-8}	1,851x10^{-3}
1-8	4,5333x10^{-8}	2,1213x10^{-3}
1-9	4,6667x10^{-8}	2,1838x10^{-3}
1-10	4,2667x10^{-8}	1,9966x10^{-3}
2-1	7,4222x10^{-8}	3,4732x10^{-3}
2-2	8,5333x10^{-8}	3,9931x10^{-3}
2-3	9,3333x10^{-8}	4,3676x10^{-3}
2-4	7,8222x10^{-8}	3,6602x10^{-3}
2-5	8,1333x10^{-8}	3,8059x10^{-3}
2-6	8,9778x10^{-8}	4,2012x10^{-3}
2-7	7,5111x10^{-8}	3,5148x10^{-3}
2-8	7,7778x10^{-8}	3,6396x10^{-3}
2-9	8,8x10^{-8}	4,1179x10^{-3}
2-10	8,3111x10^{-8}	3,8891x10^{-3}

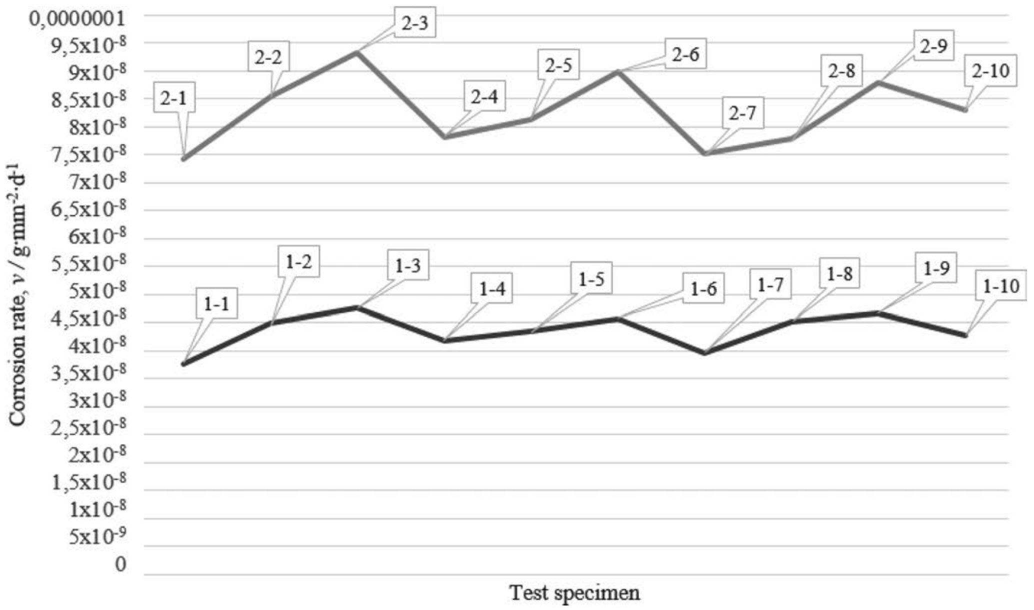

Figure 4 Graphical presentation of values referring to corrosion rate

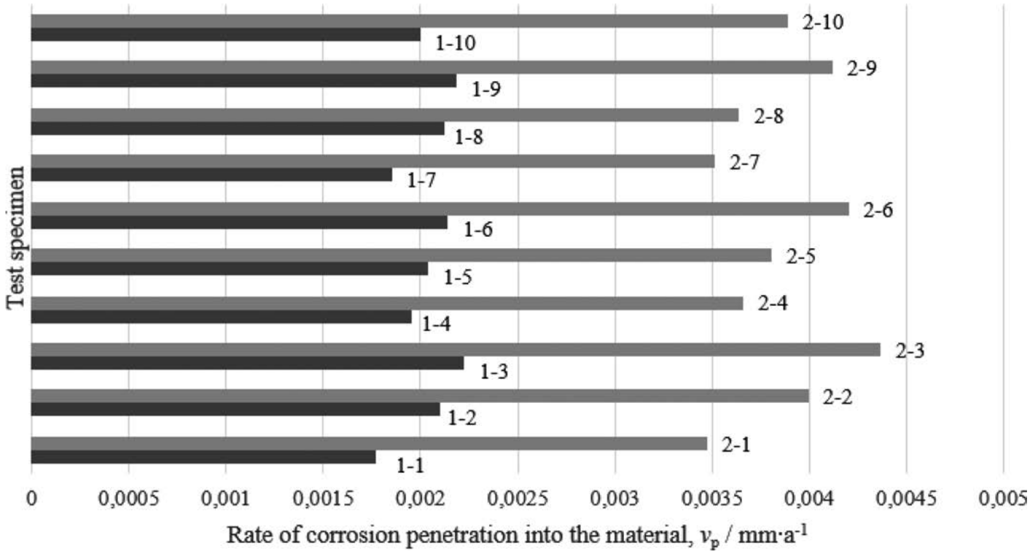

Figure 5 Graphical presentation of values referring to the rate of corrosion penetration into the steel

Afterwards, the corrosion rate was converted into the average rate of corrosion penetration into the material, by considering the known density of the base material, which was 7,80 g/cm^3, and by applying the following equation [6]:

$$v_p = \frac{\Delta m}{S \rho_m \Delta t} = \frac{v}{\rho m} \qquad (2)$$

Values obtained as results of calculations with the above-stated equations are overviewed in Table 4.

It is clear that slightly increased roughness of treated specimens' surfaces resulted in almost twice as high values of corrosion rate and of corrosion penetration than those of untreated surfaces. Figure 4 gives graphical presentation of corrosion rate for specimens in initial state and for those treated by abrasive jet, which then became more susceptible to corrosion mechanisms. Figure 5 presents results of measuring corrosion penetration into the steel.

As described above and as presented in Figure 4, the corrosion rate drastically increased, thus it was is concluded that the increase of corrosion rate was proportional to the increase of material surface roughness. Accordingly, there was also an increase in the penetration of corrosion into the material, which ultimately resulted in the decay of the material and in deviation from required dimensional properties of a structure.

CONCLUSION

Within this research, it is concluded that the corrosion rate, as well as the rate of corrosion penetration into the steel, significantly depend on the surface profile of the steel, i.e. on the surface roughness as a property of certain material. As surface roughness can get increased by abrasive or erosive actions, it is important to consider proper technology of surface protection to reduce and prevent such actions. If a damage occurs on the material surface, it will cause the increase in its roughness, and such increase, no matter how small, can influence significant development of corrosion mechanisms and subsequent decay, as well as impaired service life and weakened corrosion resistance of the steel.

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Note: Responsible person for English translation is Martina Šuto, MA, University of Osijek