

TESTING THE DURABILITY OF ECOLOGIC COATS IN THE PROTECTION OF METALS FROM CORROSION

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Preliminary notes

The paper describes the investigations into the durability of ecologically acceptable coats. With regard to standard coatings these contain a smaller part of solvents with reduced content of volatile organic compounds the same as the waterborne coatings. The test pieces were protected by waterborne and multi-layered coatings, tested in salt chamber and the results compared with the results obtained by testing in standard laboratory conditions. The obtained results show that the multi-layered coatings and the waterborne coatings can be used in the protection of structural materials from corrosion.

Key words: corrosion, ecology, organic paints, waterborne coatings

Analiza izdržljivosti ekoloških premaza u zaštiti metala od korozije

Prethodno priopćenje

U radu su opisana istraživanja postojanosti premaza koji su napravljeni po ekološki prihvatljivim recepturama. U odnosu na klasične premaze ovi premazi imaju manji udio otapala s reduciranim sadržajem hlapivih organskih spojeva kao i premazi s vodotopivim otapalima. Uzorci su zaštićeni s vodotopivim i debeloslojnim premazima i ispitani u slanoj komori te uspoređeni s dobivenim rezultatima koji su dobiveni testiranjem u standardnim laboratorijskim uvjetima. Dobiveni rezultati upućuju na mogućnost primjene debeloslojnih i vodotopivih premaza za zaštitu konstrukcijskih materijala od korozije.

Key words: korozija, ekologija, organske boje, vodotopivi premazi

1 Introduction Uvod

Anti-corrosion procedures protect environment but on the other hand they often have a detrimental effect on it as well. Application of coats to the surface of steel structures is the most widely used method of corrosion protection [1, 2]. The purpose of protective coats and paints is to long enough protect the structural material from detrimental effects of environment. This includes the preparation of the substrate previous to coating, the deposition of metal and non-metal coats and the removal of the worn out metal inorganic and non-metal coats.

There are restrictions regarding both the type and the maximum content of volatile organic solvents (VOC) in some products. The imposed limitations cause difficulties for paint manufacturers in the design and development of new products as the achievement of the desired technical properties of paints demands tremendous efforts and long time of research [3].

As the regulations governing environment protection are becoming stricter every day the paint producing industry is forced to develop and use the coatings that are the least detrimental to our environment. The coatings most examined today and considered as ecologically friendly are: high solid coatings, powder coatings, radiation curing coatings and waterborne coatings [3, 4, 5].

If the variety of technological application conditions, variety of structural features of the articles they are applied on and other specific qualities are considered, the choice is reduced to the new systems of coatings, in conformity with the existing regulations, that provide the same quality of performance and durability as the systems they replace [5, 6].

2 Experiment Eksperimentalni dio

The coating systems were applied to the P265GH (Č1204) non-alloyed structural steel in the form of the 100 × 50 × 0,48 mm test plates, previously cleaned to the Sa 2,5 cleanliness degree, the coating systems deposited according to the testing plan.

A 5 cm notch was made by a knife on all test pieces before testing. The test pieces thus prepared were subjected to 1008 h testing in salt chamber.

The laboratory testing of corrosion in seaside atmosphere is carried out in *salt chambers* in which the solution of NaCl or other salts is sprayed forming an aggressive fog.

The spray solution is prepared from common salt and distilled (deionized) water. The NaCl ($w = 3$ or 5 or 20 %) solutions with pH value 6,5 to 7,2 are used. The testing is usually performed at 35 °C, the work space being heated through the water layer between the chamber double walls, by preheating the spray air or by direct heating of that space i.e. the room the chamber is in.

Six commercial coatings in four systems formulated for steel corrosion protection were tested. They include three basic two component coatings: one coating based on epoxy binder and polyamide-amine solidifier enriched by zinc-phosphate as active anti-corrosion pigment (Volatile Organic Compounds VOC = 500 g/l), one multi-layered high solids coating based on epoxy binder and polyamide-amine adduct which contains zinc-phosphate and has a low content of organic solvents (VOC = 160 g/l), one coating based on epoxy dispersion and polyamine adduct with zinc-phosphate and low content of solvents (VOC < 5 g/l), and three cover two-component polyurethane coatings: one coating based on acrylic binder and aliphatic isocyanate solidifier (VOC = 500 g/l), one multi-layered coating based on acrylic binder and aliphatic isocyanate solidifier (VOC = 300 g/l), and one water based coating made on the basis of

acrylic binder and aliphatic isocyanate solidifier with a low content of organic solvents (VOC = 70 g/l).

According to the testing plan the four coat systems applied to the steel plate prepared surface (Sa 2,5) were to be tested in salt chamber in conformity with HRN EN ISO 9227:2006.

Corrosion induced changes on the notch were used as the main parameter in comparing the durability of coats. After exposure to the influence of the moist and salty atmosphere the properties of coatings on the samples were tested. One set of test plates with samples was prepared for testing after 6 months in laboratory conditions.

2.1

Laboratory conditions of testing

Laboratorijski uvjeti ispitivanja

Subsequent to the application of coatings the test plates were left in the laboratory with controlled conditions. The average environment temperature was 22 °C with relative humidity varying from 43 to 72 % during 6 months. The samples were not subjected to a direct influence of the sun nor were they placed near a source of heat.

2.2

Corrosion testing in salt chamber

Korozijsko ispitivanje u slanoj komori

Four samples were selected for salt chamber testing i.e. one sample from each system. The testing lasted 1008 hours i.e. 42 days according to the HRN EN ISO 9227 standard. In the chamber the samples were exposed to salt spray mist i.e. to salt water dispersed by compressed air. The test pieces in the chamber were arranged in such a way that the face of the piece with applied coating was turned upwards, thus directly exposed to the salt spray. The double sprayer on top of the chamber dispersed the salt water on injection principle, the compressed air passing through the pressure moisturizer where it was being heated and moisture saturated before entering the chamber. The salt water flow in the chamber was constant, ranging from 500 to 600 cm³/h. The chamber temperature was 35 °C, pH between 6,5 and 7,2. The chamber was hermetically closed during testing.

Fig. 1 shows the arrangement of test pieces in salt chamber. The testing conditions in salt chamber are given in Tab. 1.

Table 1 Testing conditions in salt chamber

Tablica 1. Uvjeti ispitivanja u slanoj komori

Testing climate	Salt spray – Dry air
Duration of testing	1008 h
Test cycle	1 h salt spray/1 h dry air
Moist curing cycle	5 % NaCl at 35 °C
Dry air cycle	Environment temperature



- 1 - ZPE base/PU cover coat
 2 - ZPE base/PU water cover coat
 3 - ZPE multi-layered base /PU multi-layered cover coat
 4 - ZPE dispersion/PU water cover coat

Figure 1 Test pieces in salt chamber

Slika 1. Probni uzorci u slanoj komori

2.3

Testing the properties of samples

Ispitivanja svojstava uzoraka

Properties of samples were examined in conformity with the European standards: dry film thickness (HRN EN ISO 2808), hardness (HRN EN ISO 1522), elasticity (HRN EN ISO 1520), gloss (HRN EN ISO 2813), adhesion (HRN EN ISO 2409), evaluation of the surface degree of blistering (HRN EN ISO 4628-2), evaluation of the surface degree of rust (HRN EN ISO 4628-3), evaluation of the flaking and

Table 2 Results of testing the properties of samples after 6 months in laboratory ($\vartheta_a=22$ °C and $rH=68$ %)

Tablica 2. Rezultati ispitivanja svojstava uzoraka nakon 6 mjeseci u laboratoriju ($\vartheta_a=22$ °C i $rH=68$ %)

Properties STANDARD	Sample 1: ZPE base/PU cover coat	Sample 2: ZPE base/PU water cover coat	Sample 3: ZPE multi-layered base /PU multi-layered cover coat	Sample 4: ZPE dispersion/PU water cover coat
Dry film thickness HRN EN ISO 2808:2007	79-84 μm	111-145 μm	99-108 μm	91-119 μm
Hardness HRN EN ISO 1522:2006	163 s	106 s	112 s	80 s
Elasticity HRN EN ISO 1520:2006	1,5	1,8	1,5	5,5
Gloss 20°/60° HRN EN ISO 2813:2004	80,9/93,4	63,2/81,5	32,4/77,1	77,5/87,1
Adhesion (Gt 2mm) HRN EN ISO 2409:2007	0	0	0	0

Key: ZPE – zinc phosphate epoxy, PU - polyurethane

Table 3 Results of testing the properties of samples after salt chamber testing
Tablica 3. Rezultati ispitivanja svojstava uzoraka nakon ispitivanja u slanoj komori

Properties STANDARD	Sample 1: ZPE base/PU cover coat	Sample 2: ZPE base/PU water cover coat	Sample 3: ZPE multi-layered base /PU multi- layered cover coat	Sample 4: ZPE dispersion/PU water cover coat
Dry film thickness HRN EN ISO 2808:2007	65-75 µm	84-117 µm	83-100 µm	91-103 µm
Gloss 20°/60° HRN EN ISO 2813:2004	77,3/88,6	59,8/78,6	30,5/76,8	72,9/86,4
Adhesion (Gt 2mm) HRN EN ISO 2409:2007	0	0	0	0
Surface blistering HRN EN ISO 4628-2:2003	d0/S0	d0/S0	d0/S0	d0/S0
Notch blistering HRN EN ISO 4628-2:2003	d3/S4	d4/S3	d5/S3	d3/S4
Surface corrosion HRN EN ISO 4628-3:2004	0 (Ri)	0 (Ri)	0 (Ri)	0 (Ri)
Notch flaking HRN EN ISO 4628-8:2005	3 mm	9 mm	4 mm	15 mm
Notch corrosion HRN EN ISO 4628-8:2005	0 mm	20 mm	0 mm	0 mm
Nuance by reference specimen	Matching	Matching	Matching	Matching

Key: ZPE – zinc phosphate epoxy, PU - polyurethane

corrosion around notch (HRN EN ISO 4628-8), and of nuances (by reference specimen) [7, 8]. Tab. 2 shows the results of testing the properties of 4 samples after 6 months in laboratory and Tab. 3 shows the results of testing the

properties of 4 samples after salt chamber testing.

Figures 2 to 5 compare the appearances of the 4 samples following the testing.



Figure 2 Comparison of sample 1 (zinc phosphate epoxy base coat/polyurethane cover coat) after 6 months in laboratory (1st plate) and 1008 h testing in salt chamber (2nd plate)

Slika 2. Usporedba uzorka 1 (cink fosfat epoksidni temeljni premaz/poliuretanski pokrivni premaz) nakon 6 mjeseci u laboratoriju (1. pločica) i 1008 h ispitivanja u slanoj komori (2. pločica)

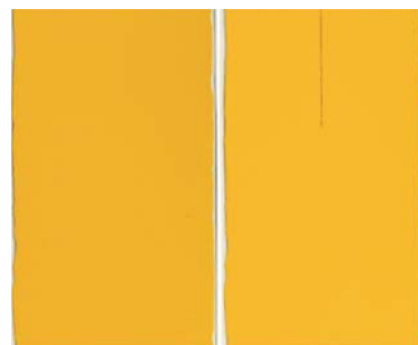


Figure 4 Comparison of sample 3 (zinc phosphate epoxy multi-layered base coat/polyurethane multi-layered cover coat) after 6 months in laboratory (1st plate) and 1008 h testing in salt chamber (2nd plate)

Slika 4. Usporedba uzorka 3 (cink fosfat epoksidni temeljni premaz debeloslojni/ poliuretanski pokrivni premaz debeloslojni) nakon 6 mjeseci u laboratoriju (1. pločica) i 1008 h ispitivanja u slanoj komori (2. pločica)



Figure 3 Comparison of sample 2 (zinc phosphate epoxy base coat/polyurethane water cover coat) after 6 months in laboratory (1st plate) and 1008 h testing in salt chamber (2nd plate)

Slika 3. Usporedba uzorka 2 (cink fosfat epoksidni temeljni premaz/poliuretanski pokrivni premaz vodeni) nakon 6 mjeseci u laboratoriju (1. pločica) i 1008 h ispitivanja u slanoj komori (2. pločica)



Figure 5 Comparison of sample 4 (zinc phosphate epoxy dispersion/ water polyurethane cover coat) after 6 months in laboratory (1st plate) and 1008 h testing in salt chamber (2nd plate)

Slika 5. Usporedba uzorka 4 (cink fosfat epoksidna disperzija/ poliuretanski pokrivni premaz vodeni) nakon 6 mjeseci u laboratoriju (1. pločica) i 1008 h ispitivanja u slanoj komori (2. pločica)

3

Discussion

Rasprava

During the experiment, corrosion testing of the P 265 GH structural steel plate samples protected by different coating systems, was performed in salt chamber in addition to the laboratory testing. The obtained values of roughness show that all samples have the same starting roughness which corresponds to the Sa 2,5 degree of surface preparation and is within the value limits according to ISO 8503-4:1988.

The testing also shows that all samples have the same adhesion (Tables 3 and 4) since the cross-cut test shows the value Gt 0 which denotes exceptionally good adhesion according to the HRN EN ISO 2409 standard 8. The system has a corresponding quality for all samples which is shown by good adhesion to the substrate of base coating so that a quality substrate is obtained for the other layers of the whole system of steel structure protection in aggressive atmosphere.

The samples in Figures 2, 3, 4 and 5, tested in salt chamber, showed good results in corrosion protection although the rate of corrosion is considerably higher on Fig. 3 sample with water polyurethane covering coating. The gloss of all samples was significantly changed after testing in aggressive environment.

4

Conclusion

Zaključak

The paper shows that the new generation coatings can be used for corrosion protection of steel structures. The testing shows that new technologies can be applied in corrosion protection improving the quality and reliability of steel structures.

The experimental work showed that both the high content of solid matter coatings and waterborne coatings can be used for steel structure protection. Equal corrosion stability of the coating systems was shown in all tests and the results are compatible with the most durable standard solvent based coatings.

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