CONSTRUCTION FROM WEATHERING STEELS WITH PAINT SYSTEMS APPLIED

Tomáš LANÍK a, Jitka PODJUKLOVÁ b, Kateřina KREISLOVÁ c, Vratislav BÁRTEK d, Petr GRUBAŘ e, Kateřina SUCHÁNKOVÁ f, Sylvie KOPANÁKOVÁ a

a VŠB-TU Ostrava, 17. listopadu 15, 708 33 Ostrava-Poruba, Česká republika, tomas.lanik@vsb.cz
b VŠB-TU Ostrava, 17. listopadu 15, 708 33 Ostrava-Poruba, Česká republika, jitka.podjuklova@vsb.cz
c SVÚOM s. r. o. U Měšťanského pivovaru 934/4, 170 00 Praha 7, Česká republika, kreislova@svuom.cz
d VŠB-TU Ostrava, 17. listopadu 15, 708 33 Ostrava-Poruba, Česká republika, vratislav.bartek.st@vsb.cz
e VŠB-TU Ostrava, 17. listopadu 15, 708 33 Ostrava-Poruba, Česká republika, petr.srubar.st4@vsb.cz
f VŠB-TU Ostrava, 17. listopadu 15, 708 33 Ostrava-Poruba, Česká republika, katerina.suchankova.st2@vsb.cz
g VŠB-TU Ostrava, 17. listopadu 15, 708 33 Ostrava-Poruba, Česká republika, sylvie.kopanakova.st@vsb.cz

Abstract

Weathering steels are used in civil engineering for the building of bridge or pylon structures and in architecture. Due to chemical composition and suitable atmospheric conditions, an oxide layer called patina is formed on steel surfaces. Thanks to the weathering layer, these steels are subjected to the degradation effects of atmospheric corrosion more slowly than carbon steels. If these steels are exposed to the environment in which cyclical humidification and drying of the surface occur, they do not require any surface treatments. Thus financial expenditures on their anti-corrosive maintenance are reduced and, simultaneously, environmental load is lowered.

The weathering steels exposed to an environment adversely influencing the formation of the weathering layer, e.g. leakage of surface water into the construction, deposits of dust, leaves, gravel sand etc. which have not been removed, degrades similarly to carbon steel. A significant corrosion-aggressive agent is salting solutions which contact the material surface directly due to winter maintenance of road surfaces. If protective patina does not occur and large losses of material occur due to chloride leakage, it is recommended that surface protection, e.g. a paint system, is applied to the surface.

Experimental tests were focused on the application of paint systems to weathering steel. Before the application of the paint systems, the surface was blasted according to ISO 8501-1 to the surface-preparation grade Sa 2 ½. Samples with a formed stable oxide layer were brushed to the surface-preparation layer St 2. The result of the tests showed the necessity to remove patina before paint systems are applied.

Key words: oxide layer, weathering steels, paint system, bridge structures

1. WEATHERING STEELS

Weathering steels are in the group of low-alloyed steels with increased resistance to atmospheric corrosion. These steels are alloyed with Cr, Ni, Cu and the contents of alloying elements do not exceed 2%. In suitable atmospheric conditions, a stable oxide layer is formed on the surface. In the Czech Republic, these steels have been used, for instance, for construction of bridge structures on the D1 highway (D47) recently.

On long-exposed bridge structures there can be places where, due to neglected maintenance, protective patina has not been formed and huge material losses have occurred. These are places on the surface of constructions with layers of impurities, soil and biological fall retaining humidity for a long time. Further, they can be structures where there are leakages of surface water containing chlorides from chemical de-icing agents in winter months, see fig. 1a.
2. SUBSTRATE MATERIALS

Samples of Atmofix and COR-TEN weathering steel were used as experimental materials. A stable patina layer was formed on the Atmofix weathering steel samples. The samples were obtained from cladding of the department store in Liberec after 24-year-lasting exposure to an atmospheric environment with the corrosion aggression degree C3 and C4. Before application of paint systems, the surface was brushed to the surface-preparation grade St 2 according to ISO 8501-1.

The materials bearing the brand name Cor-ten (type A and B) were corundum-blasted to the surface purity Sa ½ according to ISO 8501-1. It can be supposed that paint systems for weathering steels will have shorter service life than the ones for the substrate materials which have been blasted to the surface-preparation grade Sa 2 ½.

3. PAINT SYSTEMS

Paint systems were applied on samples sized 100 x 150 x 3 mm on both sides by means of a brush, always in two layers. For the bottom (priming) layer as well as for top-coat, the same type of the paint system was used. Wet layer thickness of the paint systems were chosen according to the technical data sheet, which was supplied together with the paint systems.

For the tests, four types of paint systems were chosen. They were paints used in industrial applications and they showed good results from the tests that had been carried out before. There are even other types of paint systems with similar properties on the market.
Paint Systems Used

a) Amercoat 450 S - Aliphatic polyurethane (total thickness of two dry layers of the paint system $100 \mu m$)

b) Amershield - Aliphatic polyurethane (total thickness of two dry layers of the paint system $250 \mu m$)

c) Amerlock 400 Al - Epoxy coating compound with high contents of solid matters (total thickness of two dry layers of the paint system $200 \mu m$)

d) Amerlock 400 Color - Epoxy coating compound with high contents of solid matters (total thickness of two dry layers of the paint system $200 \mu m$)

4. EXPERIMENTAL TESTS

4.1 Corrosion Test According to ČSN EN ISO 9227

The corrosion test in the artificial atmosphere was carried out according to the standard ČSN EN ISO 9227. The neutral salt fog test mode means the exposure of samples at a temperature of $35 ^\circ C$, 100 % relative humidity and spraying with 5 % solution of NaCl. During the corrosion tests, photographic documentation of the sample was taken. The assessment and photographic documentation intervals were set for 0 hr, 24 hrs, 48 hrs, 96 hrs, 168 hrs, 240 hrs, 480 hrs, and 720 hrs.

The samples with the applied paint systems were subjected to assessment of a blistering grade, rusting through grade, delaminating assessment and corrosion in the surroundings of the section as well as a blistering assessment in the surroundings of the sections. The assessment for the final cycle of 720 hrs is shown in tab. 1.

<table>
<thead>
<tr>
<th>Substrate material</th>
<th>Paint system</th>
<th>Blistering grade</th>
<th>Rusting through grade</th>
<th>Delaminating / Corrosion along the section</th>
<th>Blistering in the section surroundings</th>
</tr>
</thead>
<tbody>
<tr>
<td>COR-TEN A</td>
<td>Amerlock 400 Al</td>
<td>0 (S0)</td>
<td>R10 (S0)</td>
<td>0/1</td>
<td>3 (S4)</td>
</tr>
<tr>
<td></td>
<td>Amerlock 400 Color</td>
<td>0 (S0)</td>
<td>R10 (S0)</td>
<td>0/1</td>
<td>0 (S0)</td>
</tr>
<tr>
<td></td>
<td>Amercoat 450 S</td>
<td>2 (S4)</td>
<td>R11 (S1)</td>
<td>3/3</td>
<td>2 (S5)</td>
</tr>
<tr>
<td></td>
<td>Amershield</td>
<td>0 (S0)</td>
<td>R10 (S0)</td>
<td>0/1</td>
<td>0 (S0)</td>
</tr>
<tr>
<td>COR-TEN B</td>
<td>Amerlock 400 Al</td>
<td>0 (S0)</td>
<td>R10 (S0)</td>
<td>1/1</td>
<td>2 (S4)</td>
</tr>
<tr>
<td></td>
<td>Amerlock 400 Color</td>
<td>0 (S0)</td>
<td>R10 (S0)</td>
<td>0/1</td>
<td>0 (S0)</td>
</tr>
<tr>
<td></td>
<td>Amercoat 450 S</td>
<td>2 (S4)</td>
<td>R11 (S1)</td>
<td>2/2</td>
<td>2 (S5)</td>
</tr>
<tr>
<td></td>
<td>Amershield</td>
<td>0 (S0)</td>
<td>R10 (S0)</td>
<td>0/1</td>
<td>0 (S0)</td>
</tr>
<tr>
<td>Atmofix 24 years of exp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Amerlock 400 Al</td>
<td>3 (S2)</td>
<td>R10 (S0)</td>
<td>1/0</td>
<td>2 (S4)</td>
</tr>
<tr>
<td></td>
<td>Amerlock 400 Color</td>
<td>3 (S2)</td>
<td>R10 (S0)</td>
<td>1/0</td>
<td>0 (S0)</td>
</tr>
<tr>
<td></td>
<td>Amercoat 450 S</td>
<td>4 (S2)</td>
<td>R11 (S2)</td>
<td>2/1</td>
<td>5 (S5)</td>
</tr>
<tr>
<td></td>
<td>Amershield</td>
<td>5 (S2)</td>
<td>R10 (S0)</td>
<td>1/0</td>
<td>4 (S3)</td>
</tr>
</tbody>
</table>

Tab. 1 Assessment of the paint systems after 720 hrs in the corrosion chamber

Assessed parameters:

a) Blistering of the paint systems $i$ numeric assessment characterising blisters in the paint as to their number (density) and size.

b) Rusting through the paint systems $i$ assessment characterizing the grade of formed rusting-through (rust penetrating onto the surface and visible underrusting) on the paint.
c) Delaminating and corrosion in the surroundings of the section - delaminating is the loss of coating adhesion, and corrosion is the surface of visible corrosive products.

All the paint systems applied onto the substrate material Atmofix exposed for 24 years showed visibly distinctive changes. Blistering, delaminating and blistering around the section occurred. The best results were reached after 720 hrs of exposure in the corrosion chamber with the paint system Amerlock 400 Al. On the surfaces of the samples, a low number of defects visible by the eye occurred. In the surroundings of the section, a low number of defects sized 0.5 and 5 mm occurred.

The corrosion test results of the paint systems applied onto the substrate materials COR-TEN (A, B) were very good. All the paint systems, except for the paint system Amercoat 450 S, did not show large damage. There were no visible blisters on the surfaces of the samples after 720 hrs. Rusting-through did not occur, either.

Amerlock 400 Al paint systems appeared to be the best ones for the samples with a created section. No blisters or corrosion occurred around the section after exposure to the corrosion chamber. The corrosion was very small, with no sign of delaminating.

4.1.1 Adhesion Cross-cut Test According to ČSN EN ISO 16276-2

Graph 1 Average classification values of the cross-cut test a) on the substrate material COR-TEN A, b) on the substrate material COR-TEN B, c) on the substrate material Atmofix exposed for 24 years

The cross-cut test was carried out with reference samples and the samples inserted into the corrosion chamber. The interval of the tests was set to 0 hr, 120 hrs, 480 hrs, and 720 hrs.

It arises from the graph 1 that the adhesion of the paint systems applied and substrate material Atmofix exposed for 24 years is low. The damage to the grid after 720 hrs of exposure in the corrosion chamber ranged within 35 % to 65 % or more. This fact corresponds to the classification grades of 4 and 5 of the cross-cut test according to ČSN EN ISO 16276-2.
The best result were reached with the paint system Amershield which was applied onto the substrate material COR-TEN B, see graph 1 b. The paint system chipped on average in the places of section crossings and the damaged surfaces was lower than 5%.

4.1.2 Adhesion Pull-Off Test According to ČSN EN ISO 16276-1

![Graph 2](image)

**Graph 2** Average values of pull-off strength a) on the substrate material COR-TEN A, b) on the substrate material COR-TEN B, c) on the substrate material Atmofix exposed for 24 hrs.

The pull-off test was carried out with reference samples and samples inserted into the corrosion chamber. The intervals of executed tests were set to 0 hr, 120 hrs, 480 hrs, and 720 hrs.

It arises from the graph 2 c that after the 720 hr exposure of the paint systems in the corrosion chamber, the average pull-off strength was low under the value of 3 MPa. This is the limit value for assessing whether the paint system has good adhesion as to pull-off strength. Cohesion damage in weathering layer occurred averagely.

The pull-off strength of the paint systems applied onto the substrate materials COR-TEN (A, B) ranged between 4 and 6 MPa. This result points to good adhesion. For the greater part, damage to the second layer of the paint system happened. Only with the paint system Amershield, mainly adhesive damage between the substrate material and the first applied layer occurred.

4.2 X-cut testion

A X-cut test was carried out after 1 year of exposure of the paint systems exposed in atmospheric testing stations. These atmospheric stations are located in the area of VGB-TU Ostrava (corrosive environment C2) and in Svoboda Coking Plant Ostrava (corrosion environment C4).

Amerlock 400 Color paint system applied onto the substrate material Armofix exposed for 24 years showed significant damage. Not falling-off, but peeling-off from the substrate occurred. The paint systems Amershield and Amercoat 450 S showed blistering around sections. Further exposure may cause an increase in
blistering and subsequently possible rusting-through. The blisters are problematic due to possible pulling-off and exposure of the surface. However, generally speaking, the paint systems applied onto the substrate materials Atmofix with the layer of protective patina did not have very good adhesion.

The paint system Amershield showed the best results; it is also true for Amerlock 400 Al and Amerlock 400 Color applied onto substrate materials COR-TEN (A, B).

5. CONCLUSION

The results of the performed tests clearly showed that it is necessary to pay attention to quality surface preparation. If it to be the contrary, it is evident that anti-corrosive protection will be affected adversely. The paint system applied onto the substrate material Atmofix 24 exposed for 24 years had average adhesion to the surface. Being exposed to the corrosive environment, decrease in the adhesion of the patina layer occurs and a cohesive fracture in patina emerges. The disadvantage of the weathering layer is its low adhesion and impurities can be accumulated in the layers. The impurities may have an adverse effect on the anti-corrosion protection quality.

The surface must be blasted to the surface preparation grade of Sa 2 ½ according to ČSN EN ISO 8501-1 before application. The results of experimental tests with the weathering steel samples which had been blasted before application of the paint systems were satisfactory, contrasted to the non-blasted samples.

Repairs to the corrosion-critical places or the place significantly damaged by corrosion by means of the paint systems are not generally suitable and effective for enough time. The repairs by means of the paint systems are, therefore, recommended only with those parts of the construction, where its further function cannot be otherwise ensured. The paint system service life in corrosion-critical places will be significantly limited compared to its stated service life, even providing that the painting is applied onto the suitably prepared surface of the structure. The first condition for gaining at least short-term effectiveness of the applied paints is to remove the cause of the increased corrosion stress of the construction (fig. 3).

The recommendations for repairs to the weathering-steel structures are mentioned in the Directive for Usage of the Steel with Increased Resistance to Atmospheric Corrosion. [3]

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LITERATURE

