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Heavy Corrosion Protection – Notes on design and preparation in accordance with coating requirements

QIB
Qualitätsgemeinschaft Industriebeschichtung

Content

1. Introduction

If a high level of corrosion protection is to be achieved by contract coating, important details must already be taken into account in the construction or preparation of the components to be coated.

In day-to-day coating practice, discrepancies frequently arise during the acceptance of goods with regard to coatability. In the often standardised pre-treatment processes, activities such as deburring the cutting edges or removing scale layers can represent an additional expense that is not taken into account in the quotation price.

This leaflet is intended to provide a clear and descriptive summary of the preparatory measures that are considered to be the state of the art.

2 Corrosivity Categories

Each environment and the associated corrosion load on metals is assigned to a corrosivity category according to ISO 9223. To determine the corrosivity category for atmospheric ambient conditions, an ageing of standardised samples is carried out and the layer thickness reduction and mass loss after the first year is determined. An estimate of the corrosion category for known ambient conditions is possible in principle.

Both the carrying out of the coating system and the surface preparation must be designed in accordance with the intended use of the component, its installation location and the associated corrosion load and must be known to the coating company.

Table 1: Corrosivity categories for atmospheric use
(source: DIN EN ISO 12944-2) [1]

	Examples for typical ambient conditions in a moderate climate	
Category - Load	**exterior**	**interior**
C1 – very low	-	heated buildings with neutral atmospheres, e.g. offices, hotels
C2 – low	atmosphere with low level of pollution; mostly rural areas	unheated buildings where condensation may occur, e.g. depots, sports halls.
C3 - medium	urban and industrial atmospheres, moderate sulphur dioxide pollution; coastal areas with low salinity	production rooms with high humidity and some air pollution, e.g. laundries, breweries, dairies
C4 – high	industrial areas and coastal areas with moderate salinity	chemical plants, swimming pools, boat shed above seawater
C5 – very high	industrial areas with extreme high humidity and aggressive atmosphere and costal areas with high salinity	buildings and areas with almost permanent condensation and with high pollution
CX – extreme high	offshore areas with high salinity, industrial areas with extreme high humidity and aggressive atmosphere, subtropical and tropical atmospheres	industrial areas with extreme high humidity and aggressive atmosphere

Moreover, there are separate categories for use in water or soil. [1]

Table 2: Corrosivity categories for use in water/soil
(source: DIN EN ISO 12944-2)

Category	Environment	Examples for environment and steel construction
Im1	fresh water	river engineering, hydropower plants
Im2	sea or brackish water	steel structures in water without cathodic corrosion protection (e.g. harbour areas with steel structures such as lock gates, barrage, piers; offshore installations)
Im3	soil	containers in the ground, steel sheet pile, steel pipes
Im4	sea or brackish water	steel structures in water with cathodic corrosion protection (e.g. harbour areas with steel structures such as lock gates, barrage, piers; offshore installations)

3 Degrees of preparation

In addition, according to DIN EN 1090-2, the expected live time, i.e. the expected period of time of the coating system until first repair [2], of the corrosion protection system of a component in an environment with a certain corrosivity category requires a certain degree of preparation of the surface according to DIN EN ISO 12944-4 and DIN EN ISO 8501. The simpler the degree of preparation, the higher the risk of defects and associated corrosion characteristics.

Table 3: Overview of required degrees of preparation to achieve required expected live time with given corrosivity category
(source: DIN EN 1090-2)

live time of corrosion protection	corrosivity category	degree of preparation
> 15 years	C1	P1
	C2 to C3	P2
	over C3	P2 or P3 as agreed on
5 to 15 years	C1 to C3	P1
	over C3	P2
< 5 years	C1 to C4	P1
	C5 – Im	P2

Table 4: specification of degree of preparation
(source: DIN EN ISO 8501-3)

Kind of irregularity	degree of preparation		
	P1 – slight preparation	P2 – thorough preparation	P3 – highly thorough preparation
Welding seams			
welding splashes	The surface must be free of all loose welding splashes.	The surface must be free of all loose and slightly adhering welding splashes. Highly adhesive welding spatters with a low contact angle may remain.	The surface must be free of all welding splashes.
corrugated / profiled weld seam	no preparation	The surface must be prepared to remove irregular and sharp profiling.	The complete surface must be prepared, i.e. be smooth.
weld slag	The surface must be free of weld slag.	The surface must be free of weld slag.	The surface must be free of weld slag.
marginal notch	no preparation	surface as obtained	The surface must be free of marginal notches.
welding porosity	no preparation	Surface pores must be sufficiently open to allow penetration of the coating material	The surface must be free of visible pores.
crater at the end of the welding seam	no preparation	End craters must be free of sharp edges.	The surface must be free of visible end craters.
Edges			
rolled edges	no preparation	no preparation	The edges must be rounded with a minimum radius of 2 mm (see DIN EN ISO 12944-3)
edges produced by punching, cutting, sawing	No part of the edges may be sharp; the edges must be free of burrs.	The edges must be reasonably smooth.	The edges must be rounded with a minimum radius of 2 mm (see DIN EN ISO 12944-3)
thermically cut edges	The surface must be free of slag and loose tinder.	No part of the edge must have an irregular profile.	The cut surface must be reworked, and the edges must be rounded with a minimum radius of 2 mm (see DIN EN ISO 12944-3)
Surfaces in general			
holes, craters	Holes and craters must be sufficiently open to allow penetration of the coating material.	Holes and craters must be sufficiently open to allow penetration of the coating material.	The surface must be free of holes and craters.
scurf	The surface must be free of detached material.	The surface must be free of visible scurf.	The surface must be free of visible scurf.
overrolling, separation	The surface must be free of detached material.	The surface must be free of visible overrollings/ separations	The surface must be free of visible overrollings/ separations
rolled-in extraneous substances	The surface must be free of extraneous substances.	The surface must be free of extraneous substances.	The surface must be free of extraneous substances.
corrugations, furrows	no preparation	The radius of the corrugations and furrows must be at least 2 mm.	The surface must be free of corrugations and the radius of furrows must be at least 4 mm.
impressions and markings from rollers	no preparation	Impressions and markings of rollers must be smooth.	The surface must be free of impressions and markings from rollers.

4 Requirements for the Construction

4.1 Gaps / Joints / Overlaps

These are preferred places for corrosion attacks and should therefore be avoided at all costs. The critical gap width is 0.01 - 0.5 mm [3]. There is a risk of crevice corrosion. This must be prevented by completely continuous weld seams or by sealing with permanently elastic compounds that can be coated over.

A lifted material such as separations, overrolling and scurf also form crevices and must therefore be mechanically removed [4].

The construction can also take into account welding feet. It is important here to plan a so-called window in the planned spacing of the weld seams, which has at least a 15 mm gap that can be easily coated.

Figure 1: special test specimens of the QIB-project C5-2016 after 1440 h neutral salt spray testing DIN EN ISO 9227, note the corrosion appearance on the non-solid weld due to crevice corrosion.

4.2 Troughs / sinkers / sackholes / pockets

In general, anything that makes it difficult for liquids to drain off must be avoided. Experience has shown that holes with a diameter of ≤ 5 mm must be rinsed more thoroughly in order to sufficiently remove residual chemicals from the chemical pre-treatment. Ensure, if possible, that the components are oriented appropriately so that process solutions can run off unhindered.

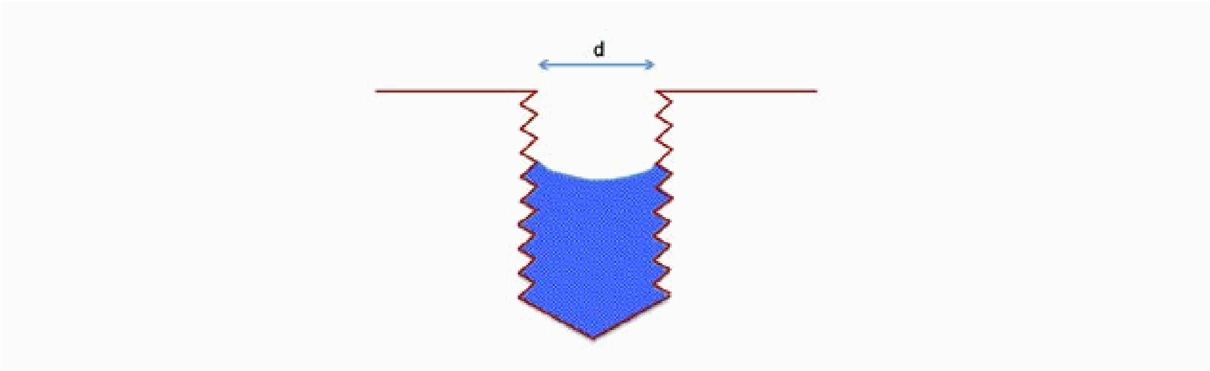

Figure 2: Schematic drawing of a blind hole with thread. Diameters d ≤ 5 mm are problematic

4.3 Combination of Materials

If different materials are to be used due to the construction, unfavourable material combinations, e.g., unalloyed steel on stainless steel, must be avoided, as otherwise contact corrosion can occur on local elements. The prerequisite for this is the presence of two materials that have a potential difference and are in contact via an electrolyte.

If different materials are necessary for technical reasons, they should be separated from each other by insulating layers [4]. Insulating layers may also be coatings that prevent direct contact of the material combination.

Figure 3: Example for contact corrosion: stainless steel handrail, galvanized screwing

The risk of contact corrosion is influenced by parameters such as conductivity of electrolyte and above all by the surface ratio of anode to cathode. In this respect it is important to realise, if possible, a high surface ratio of anode to cathode, especially for connecting elements such as screws to reduce the probability of contact corrosion. Therefore, galvanized screws are not readily suitable for fastening stainless steel elements, whereas the reverse is usually possible without any problems.

Table 5: Critical or non-critical combinations of material under atmospheric stress

		component with small surface area				
		C-steel / cast	zinc / galv. steel	aluminium	copper	stainless steel
component with large surface area	C-steel / cast	good*	bad	bad	good*	good*
	zinc / galv. steel	good*	good	good	unsafe	good
	aluminium	unsafe to bad	unsafe	good	unsafe to bad	good
	copper	bad	bad	bad	good	good
	stainless steel	bad	bad	unsafe to bad	good	good

* combination influences corrosion little, not recommended due to strong self-corrosion of the less noble material

4.4 Hollow Components

Open hollow components must be provided with air circulation and drainage holes, closed hollow components must be absolutely tight [5, 6]

Figure 4: Examples for closed hollow components
left: Metal post; middle and right: Detail shots of weld seams on a street lamp

4.5 Accessibility of the surface during coating work

Minimum distances must be observed in the construction so that, in case of coating, the surface can be completely covered by the coating (avoid shadow gaps). The minimum distances are based on the coating technology. For large, open hollow components, which are usually coated with liquid coating, openings must be provided so that they can be reviewed and reached with tools. Rectangular openings must be provided with a minimum size of 500 x 700 mm and round openings with a diameter of 600 mm. For this, see DIN EN ISO 12944-3 annexes B and C.

Inaccessible areas of components must be made of corrosion-resistant material or protected in such a way that they achieve the same life time as the rest of the component [5]

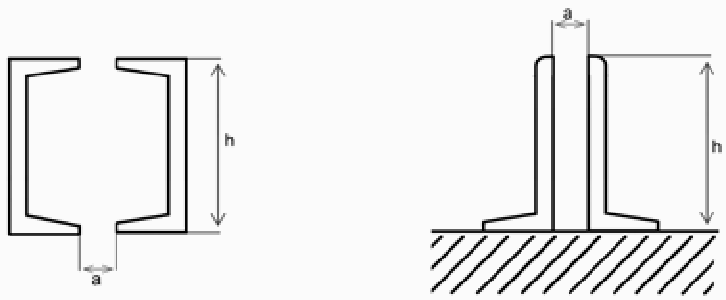

Figure 5: Minimum dimensions at tight distances between surfaces (see DIN EN ISO 12944-3)

4.6 Transport / Handling / Assembly / Storage

Precautions must be taken to avoid transport damage or damage during handling and assembly but also during assembly or construction site work such as welding, cutting or grinding [5, 7]. To avoid damage, care must be taken to ensure appropriate storage. For example, temperature changes in packaged components can cause temperature to fall below the dew point and ultimately lead to moisture damage. This leads to colour changes as shown in Figure 6. Normally, these can be removed again by a temperature treatment of > 120° C. This expels stored moisture again.

Figure 6: Moisture damage on powder-coated aluminium panels: Visible colour changes occur due to the storage of moisture.

5 Requirements to surface preparation

All inherent (tinder, laser tinder, rust and rolling skin) and non-inherent (markings, old coatings, oils, greases, residual chemicals, etc.) contaminations must be removed. [4, 8]

5.1 Mechanical preparation

The mechanical preparation of the surface should be carried out according to the degrees of preparation of DIN EN ISO 8501-3 and must be adapted to the conditions.

For a long protection period with high corrosivity categories, DIN EN ISO 12944-3 prescribes the degree of preparation P3 (no holes, no scurf, no overrolling, no rolled-in foreign substances, etc.). See also Chapter 3. [5]

5.1.1 Blasting

Surfaces to be blasted must be blasted to preparation degree Sa 2½ (very thorough) or better. Sa 2½ means that all impurities such as rolling skin, tinder, rust, undesired coating and non-inherent contamination have been removed. Deviations from the pure metallic lustre of merely optical nature are allowed. [9]

Table 6: Nominal roughness values of the individual segments of a comparator

segment	set point R_{y5} - grit	set point R_{y5} – shot	roughness
1	25 µm	25 µm	fine
2	60 µm	40 µm	medium
3	100 µm	70 µm	coarse
4	150 µm	100 µm	

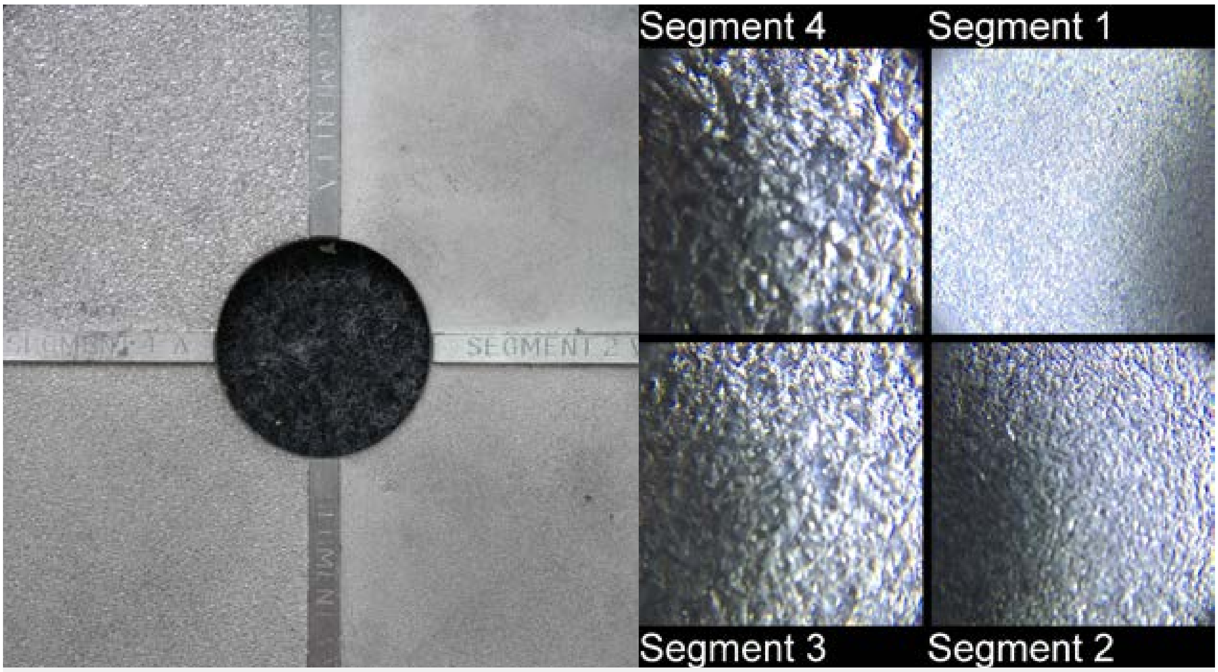

Figure 7 left: Roughness comparison pattern for grit blasting acc. to DIN EN ISO 8503-1 – Determination of the degree of roughness (grit) on blasted surface with angular abrasive (grit blasting) right: enlargement of said pattern

The surface must be freed of abrasive and dust after blasting.

Special care must be taken to remove it from angles and crevices.

Medium roughness values (powder coating Rz ≈ 20-30 µm, DIN ISO ISO 8503 segment 1 ≈ grit fine or liquid coating Rz ≈ 60 µm, DIN EN ISO 8503 segment 2 ≈ grit medium) with angular abrasives (grit see figure 8) are best suited for coating systems. [10]

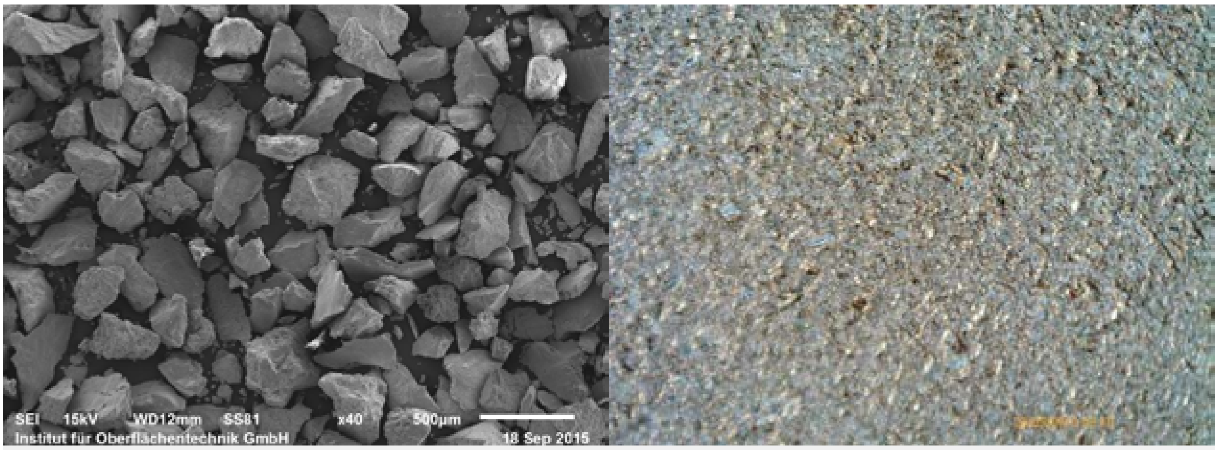

Figure 8: angular steel abrasive (grit), blasted surface, distance 0.3 m, 6 bar, angle 60-90°, Rz = 38 µm

5.1.2 Mechanical preparation / manual preparation

Mechanical / manual preparation must be carried out to a preparation level of St 3 (very thorough). After St 3 the surface must be free of oil, dirt, grease, loose rust, loose tinder, loose coatings, and loose non-inherent contaminations and must also have a pure metallic lustre. [9]

If only partially prepared, this is to be carried out to preparation degree P 3.

Possible tools to be used for manual preparation are e.g. rust removing impact hammers and rotating descalers, needle guns, grinding machines, e.g. with belts, discs or flap wheels, brushing machines, e.g. wire or fibre brushes, plastic fleece with embedded abrasive. [12]

5.2 Chemical pre-treatment

The pre-treatment must be adapted to the material and corrosion stress group, see QIB leaflet 1-1. [13]

Surfaces to be pickled with acid must be cleaned to the degree of preparation Be, which means that all coating residues, tinder and rust must be removed. Coatings, on the other hand, must be adequately removed beforehand. [14]

It should be noted, however, that heavy surface contamination can now and then only be removed by a combination of mechanical and chemical pre-treatment.

6 Handling of special component features

6.1 Edge covering

Sharp, right-angled edges are inherently bad, “broken” edges are better, rounded edges are ideal. Burrs and cut edges are also problematic. [7]

Components with an expected lifetime longer than 5 years with a corrosivity category C3 or higher must have rounded edges acc. to DIN EN ISO 12944-3 or have additional edge protection. [12]

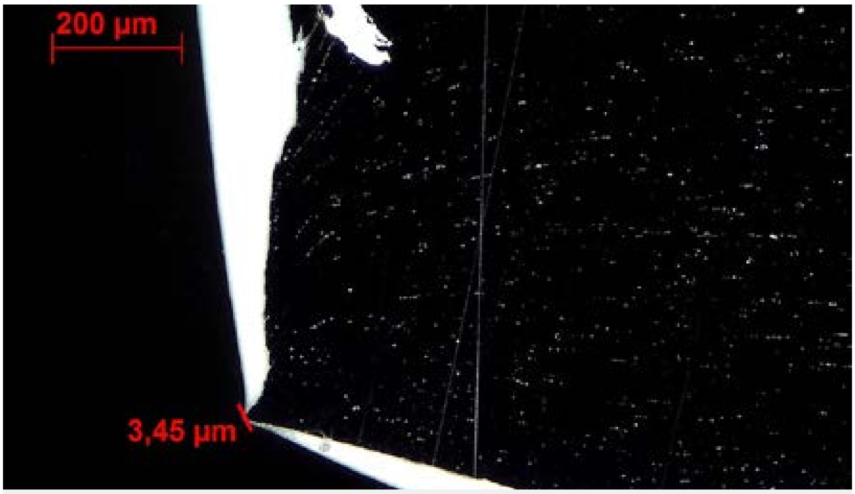

Figure 9: Sharp edge leads to lack of coverage of the base material. This defect usually leads to first signs of corrosion.

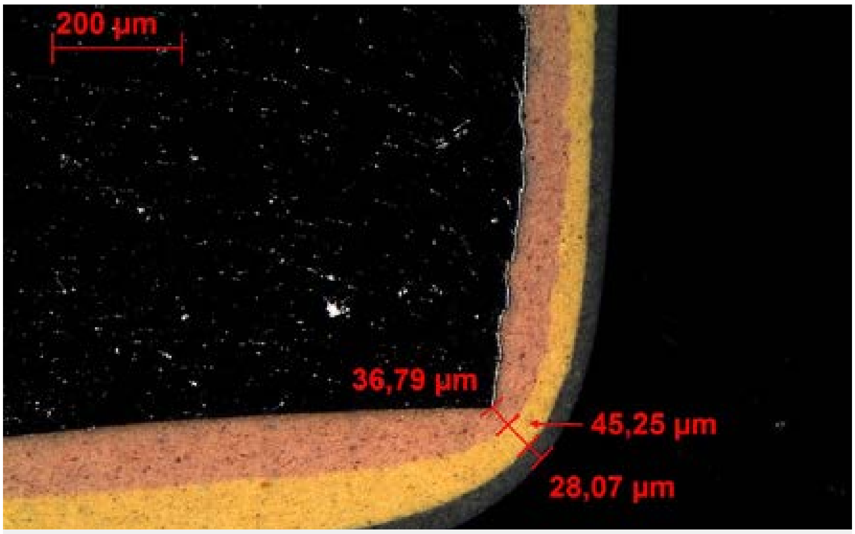

Figure 10: Reliable edge coverage on sharp edges can only be achieved by a multi-layer system.

Edges created by drilling must be deburred.

Figure 11: Special part of QIB project C5 with different prepared drilling holes, 90° lowered, 120° lowered

From edge radii smaller than 1.0 mm, edge alignment occurs, which makes the coating thinner and thus the edge more susceptible to corrosion. [8] Edges can be prepared with angle grinders and edge breakers.

The edges of drill holes can be rounded with a conical countersink. The angle of the countersink (60°, 90° or 120°) must be agreed with the coater and is, if necessary, freely selectable, as long as the edges are sufficiently broken and thus a good edge coverage can be guaranteed.

6.2 Weld seams

The weld seam must be even and regular at best preparation degree P3 (acc. to DIN EN ISO 8501-3). If the weld seam is not ground even, pores and disturbances in the corrosion protection system can result, leading to premature corrosion.

Figure 12: Weld seams in descending degree of cleaning

Figure 13: Coating damage on a weld seam that has not been properly cleaned.

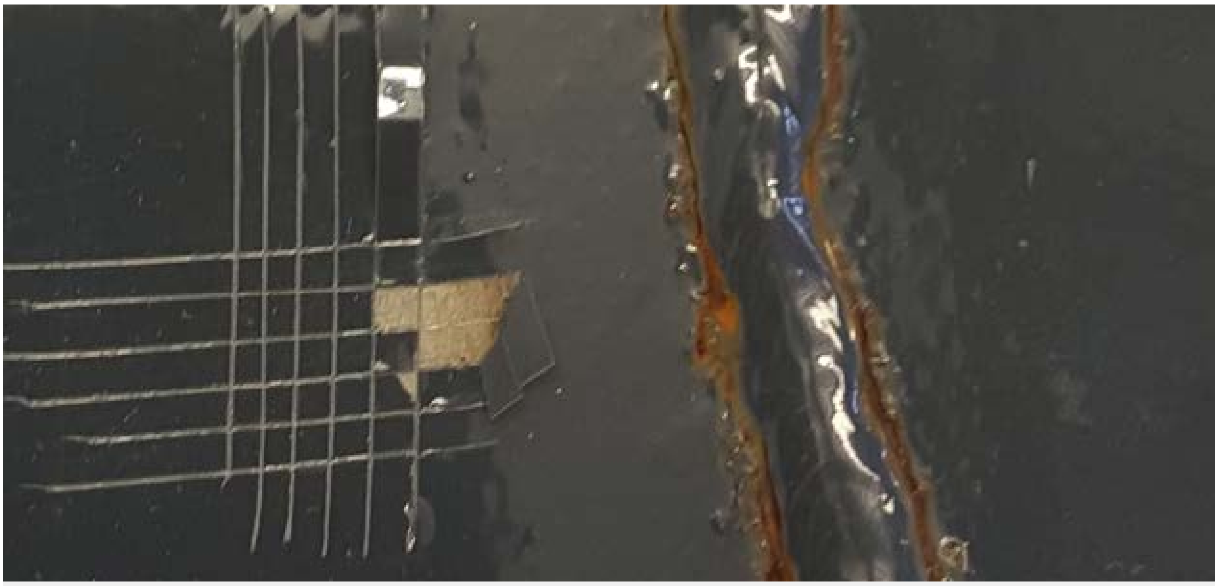

Figure 14: Project C5 test panel with unprepared weld seam only after 168 h neutral salt spray test

Weld seams must be prepared in such a way that superficial and enclosed slag is completely removed. For improved drainage of liquids triangular or concave fillet welds should be welded. Silicone-containing welding sprays are difficult or impossible to remove by chemical pre-treatment. Their use must be avoided. Instead – and only if absolutely necessary – grease and silicone-free sprays must be used. [15]

Before welding the component must be free of greases and oils, which can be cracked during welding. The resulting products cause surface defects. [15]

6.3 Heat-affected zones of spot welds

In heat-affected zones (HAZ), the microstructure is segregated. The heating leads to the formation of e.g. oxide layers which can have a negative influence on adhesion. HAZ should therefore either be kept small or subsequently removed.

Figure 15: Component with a large number of HAZ shown during the presentation of the QIB project C5 (source: Bader Pulverbeschichtung GmbH)

6.4 Screw connections

Screws, nuts and washers must have at least the same expected lifetime as the rest of the component in relation to the corrosion protection system. [5, 7]

6.5 Laser cutting edges

When metal components are cut with lasers, high temperatures occur locally, which lead to structural changes and hardening as well as the formation of oxide layers. Since the mixed oxides that form on the surface can only be removed by certain acid mixtures, standard pickling bathes are not sufficient for an adequate removal. This leads to adhesion problems of the subsequently applied coating system. Another negative effect is the very sharp edge that results from laser cutting. See also the earlier chapter on edge covering.

Figure 16: Unprocessed laser cutting edges with defects in corrosion and adhesion. The laser cuts are clearly visible. Oxide layers that form are sometimes difficult to remove by chemical pre-treatment. Laser systems working with inert gas can improve the situation.

Figure 17: Corrosion problems at the edge area due to unprepared edges.

7 Coating systems

With regard to the selection of suitable coating systems it is advisable that the requirements of the applicable standards such as DIN EN ISO 12944-6, DIN 13438 or DIN 55634 are verified in the form of the laboratory tests defined therein.

System structures as approved by the quality association QUALISTEELCOAT (www.qualisteelcoat.net) are considered as reliable and tested.

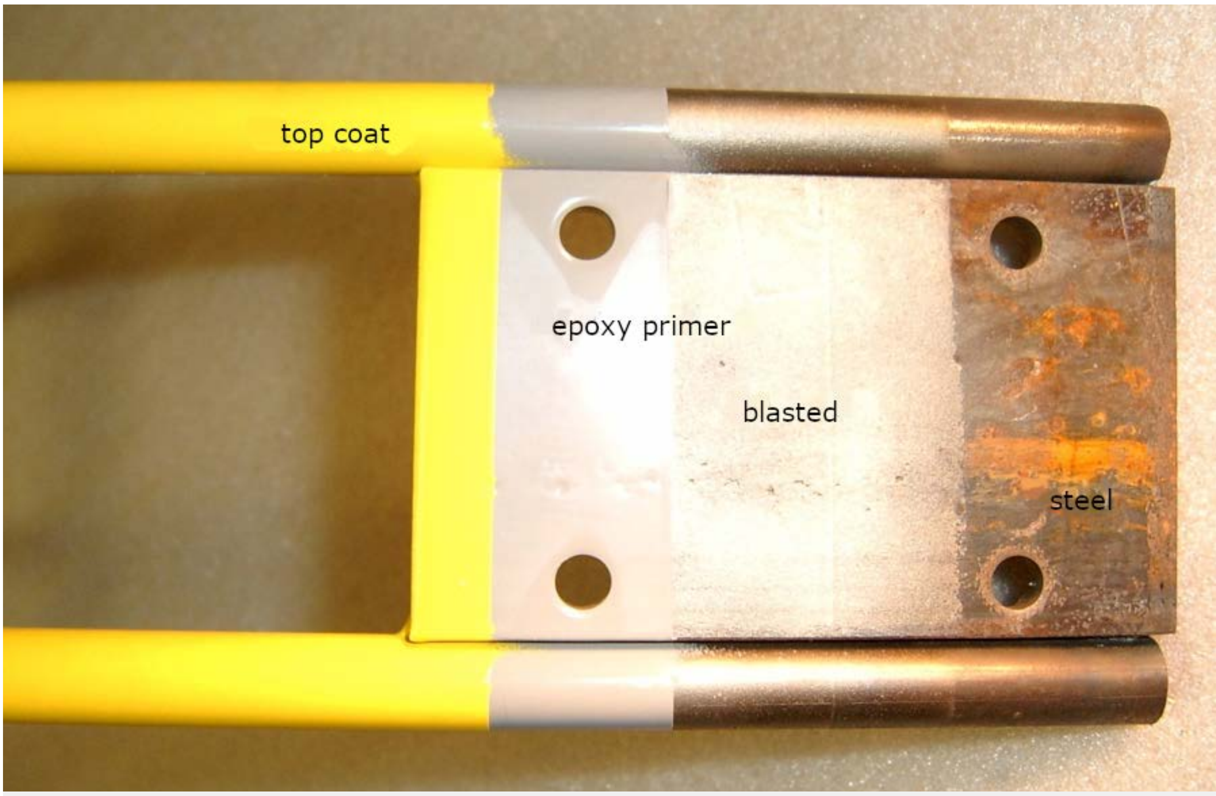

Figure 18 Exemplary layer structure with the process steps from unprocessed to top coat (source: Bader Pulverbeschichtung GmbH)

8 Final assessment

Corrosion prevention and protection does not start with the coater, but with the construction. An adequate coating contributes significantly to the prevention of corrosion damage and this can also be ensured with the help of this information sheet. Corrosion damage is more expensive for the customer than a construction that is suitable for coating - and thus also for corrosion protection - by a factor of 1000 [3].

High corrosion protection classes of C4 and C5 as well as long protection periods can only be achieved if the preparation and the construction fulfil the above-mentioned requirements, as shown in the following illustrations.

Figure 19: Overview of results of the QIB project C5 - test specimen after 1440 h neutral salt spray test from different coating companies

Figure 20: Detailed view of a sample that meets the currently valid standard requirements of a C5 corrosivity category. Corrosion visible in the gap could still be avoided by additional sealing.

9 Indexes

9.1 List of references

[1] Paints and varnishes - Corrosion protection of steel structures by protective paint systems – Part 8: Development of specifications for new work and maintenance (ISO 12944-8); German version EN ISO 12944-8

[2] Paints and varnishes - Corrosion protection of steel structures by protective paint systems – Part 1: General introduction (ISO 12944-1); German version (EN ISO 12944-1)

[3] K.-H. Tostmann; Korrosion – Ursachen und Vermeidung, Wiley-VCH, 2001, ISBN 3-527-30203-4

[4] Preparation of steel substrates before application of paints and related products - Visual assessment of surface cleanliness - Part 3: Preparation grades of welds, edges and other areas with surface imperfections (ISO 8501-3); German version EN ISO 8501-3)

[5] Paints and varnishes - Corrosion protection of steel structures by protective paint systems - Part 3: Design considerations (ISO 12944-3); German and Englisch version

[6] Prof. Dr.-Ing habil. U. Nürnberger; Korrosion und Korrosionsschutz im Bauwesen (Corrosion and Corrosion Protection in Building industry) Band 2; Bauverlag, 1995, ISBN 3-7625-3199-4

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[8] J.E. Pietschmann, H. Pfeifer, Ch. J. Raub, Schwäbisch Gmünd; Einfluß der Zusammensetzung des Pulverlackes auf die Kantendeckung (Influence oft he composition oft he powder coating on the edge covering), Metalloberfläche 44 (1990), Carl Hanser Verlag 1990, S. 515

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[12] Preparation of steel substrates before application of paints and related products - Surface preparation methods – Part 3: Hand- and power-tool cleaning (ISO 8504-3)

[13] Qualitätsgemeinschaft Industriebeschichtung (editor.); QIB information sheet 1-1, 2020

[14] Paints and varnishes - Corrosion protection of steel structures by protective paint systems - Part 4: Types of surface and surface preparation (ISO 12944-4); German version EN ISO 12944-4

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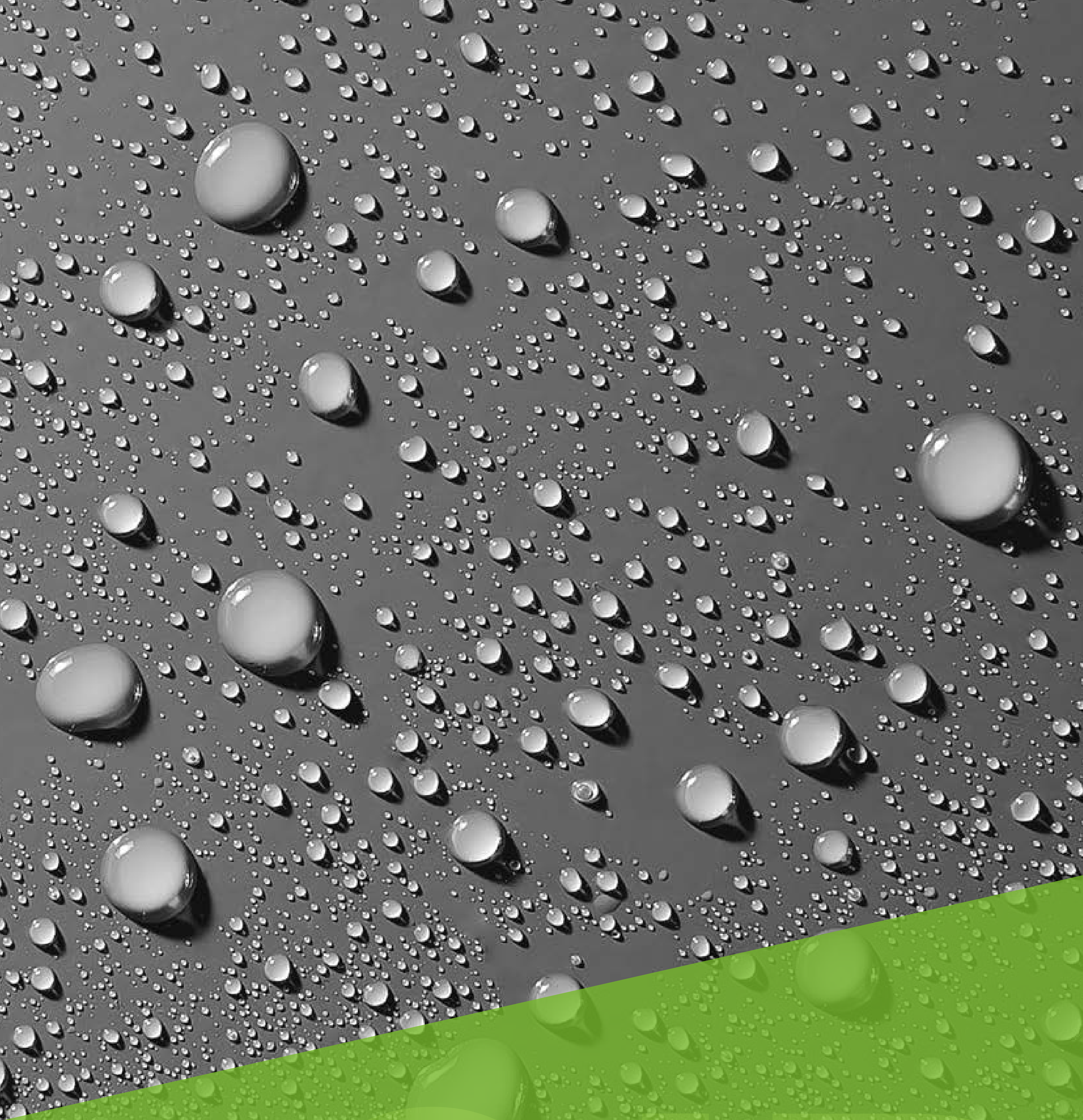
9.2 List of figures

9.3 List of tables



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