How Surface Preparation Methods Affect Delamination in Ballast Tanks

By A.W. Momber, Muehlhan AG, Hamburg, Germany; and S. Koller, Germanischer Lloyd AG, Hamburg, Germany

Delamination is an infamous phenomenon frequently observed on coated steel substrates. Delamination at an artificial scribe is usually used as a corrosion-resistance evaluation parameter in conjunction with a salt spray test per ISO 7253. Major reasons for the delamination of organic coatings include the following:\(^1\)

- Penetration of a liquid between substrate and coating, caused by mechanical damage
- Osmotic processes
- Contamination of substrate surfaces
- Insufficient adhesion between substrate and coating
- Too much swelling of the binder
- Large temperature differences between substrate and environment
- Solvent retention

Some of these processes, namely contamination and adhesion, depend solely on the method used to prepare the substrate before coating application, if all other parameters of the coating system and environment are kept constant. There are a number of studies that evaluate the effects of surface preparation methods—basically dry abrasive blast cleaning (AB) and waterjetting (UHP)—on coating performance. These studies also include investigations of the long-term behavior of the coating systems.\(^2,^3\) These authors, however, were concerned with adhesion assessment procedures (falling ball impact, pull-off testing, pen knife disbondment) only, and they did not consider delamination on an artificial scribe after salt spray exposure as a parameter characterizing the corrosion protection performance of coatings.

The laboratory research described in the present article focuses on delamination at the scribe for coatings primarily suitable for ballast tanks.

**Objective of the Investigation**

The combination of AB and UHP is an innovative approach in the surface protection industry. Although this method—denoted UHPAB throughout this study—is already introduced into ship repair practice, there is limited information available to evaluate quality aspects associated with UHPAB.
Previous studies have shown that UHPAB removes soluble salts and ground abrasive debris from steel substrates, and that the method can guarantee an excellent adhesion between organic coatings and steel substrates. It is the objective of this study to investigate the delamination of various coating systems applied to substrates prepared with three surface preparation methods—AB, UHP, and UHPAB. The investigation focuses on ship repair and steel structure repair applications. The selected coating systems are mainly suitable for ballast tank applications. However, one additional coating, originally designed for steel-water constructions, was also included to check the ability of the investigated methods to prepare surfaces of steel-water construction, such as weirs and flood barrages.

The environment for evaluating coating performance was selected according to the classifications listed in ISO 12944-2. In detail, the following categories were considered.

- Atmospheric-corrosivity: C5-M (marine)—This category covers coastal and offshore environments with high salinity as well as areas with almost permanent condensation
- Categories for water and soil: Im2—This category covers sea or brackish water; structures considered include sluice gates, locks, and offshore structures

These two categories determined the type and intensity of the laboratory tests to be performed according to ISO 12944-6. These tests are listed in Table 1. The results of the neutral salt spray tests are of particular concern because they were evaluated in terms of delamination.

### Surface Preparation and Coating Procedures

The following three methods were used for surface preparation in our study.

- AB (dry abrasive blast cleaning)
- UHP (waterjetting)
- UHPAB (ultra-high-pressure abrasive blasting; μjet)

The performance parameters of these methods are listed in Table 2. The abrasive material applied for dry abrasive cleaning and UHPAB was a commercial copper slag (NAstra®), according to ISO 11126-3, with the following properties: hardness: > 7 (Mohs); density: 3600 kg/m³; particle size range: 0.4-1.2 mm; particle shape: irregular. For the UHP and UHPAB applications, tap water was used with a specific electrical conductivity of 650 µS/cm.

Test panel size was 3 m in length and 0.5 m in width. The area of each panel was separated into three parts: one for AB, one for UHP, and one for UHPAB. All test panels were originally coated with an organic coating system with an average DFT between 400 and 800 µm. After coating removal, the surfaces were allowed to dry. Thereafter, the new coatings were applied to the entire panel surface. Thus, any individual coating application was performed identically to the three types of prepared surfaces.

Five commercial organic coating systems were used for coating; their major properties are listed in Table 3. The coatings were applied with an airless spray device in a spraying booth with a controlled climate. The hardening period was 50 days. After that period, specimens for the laboratory tests were manufactured. Their size was 15 x 10 cm, per the requirements of ISO 12944-6. The specimens were cut with plate shears. Edge protection was manually applied to each sample with a commercial protective coating system. Debonding was evaluated on the samples after the salt spray test per ISO 7253. The coating was then artificially injured with a knife before the salt spray testing. The length of the artificial cut was 130 mm, and the cut

### Table 1: Test Procedures for Paint Systems Applied to Steel (ISO 12944-6)

<table>
<thead>
<tr>
<th>Corrosivity Category</th>
<th>Durability Range</th>
<th>Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5-M medium</td>
<td>-</td>
<td>480 h</td>
</tr>
<tr>
<td>Im2 medium</td>
<td>2000 h</td>
<td>-</td>
</tr>
</tbody>
</table>

### Table 2: Surface Preparation Method Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Method</th>
<th>AB</th>
<th>UHP</th>
<th>UHPAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating pressure in MPa</td>
<td></td>
<td>0.85 (air)</td>
<td>200 (water)</td>
<td>150 (water)</td>
</tr>
<tr>
<td>Nozzle diameter in mm</td>
<td></td>
<td>10</td>
<td>6 x 0.3</td>
<td>19</td>
</tr>
<tr>
<td>Water consumption in l/min</td>
<td></td>
<td>0</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Abrasive consumption in kg/min</td>
<td></td>
<td>12</td>
<td>0</td>
<td>12</td>
</tr>
</tbody>
</table>

### Table 3: Properties of Applied Coating Systems

<table>
<thead>
<tr>
<th>Property</th>
<th>1a</th>
<th>1b</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primer</td>
<td>Zn</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Density in kg/l</td>
<td></td>
<td>2.8</td>
<td>1.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Solid content in vol.-%</td>
<td></td>
<td>67</td>
<td>100</td>
<td>96</td>
<td>83</td>
<td>60</td>
</tr>
<tr>
<td>DFT in µm</td>
<td></td>
<td>70</td>
<td>490</td>
<td>346</td>
<td>253</td>
<td>273</td>
</tr>
<tr>
<td>VOC in g/l</td>
<td></td>
<td>-</td>
<td>free</td>
<td>-</td>
<td>385</td>
<td>170</td>
</tr>
</tbody>
</table>

1) two-pack; 2) two-pack epoxy-mastic; 3) two-pack modified; 4) two-pack, polyamide-hardened; 5) high-build polyamide epoxy

Continued
PPG Protective and Marine Coatings (PMC) protect customer assets in some of the world’s most demanding conditions and environments. Our research and development teams, in partnership with industry experts, work tirelessly to develop new and innovative systems that prevent corrosion and provide protection from the elements.

PPG PMC provides coatings systems that target the growing market and needs of chemical processors. Protecting critical steel assets, including storage tanks, exterior coatings and interior tank linings, piping, pipe racks and exposed steel structures, is a primary focus of ours. Our coatings are uniquely positioned to guard facilities against corrosion and enhance their appearance while meeting and exceeding customer specifications.

Your facility deserves nothing but the best.
For more information, contact a PMC Specialist or visit www.ppgPMC.com.
Personnel at the Atlanta Braves Spring Training Facility at Wide World of Sports Disney in Orlando, Florida realized that a membrane between the 125,000 square-foot stadium’s structural concrete slab and the topping slab had failed in spots. As a result, water had seeped through cracks in the concrete and started to damage the superstructure. They needed an expert team to develop a winning game plan.

Our vision for a waterproof topcoat built on polyaspartic resin technology from Bayer MaterialScience was a home run. The polyaspartic color topcoat was applied to a new external membrane installed above the concrete topping. Once applied, it provided a high film build to develop the waterproof coat needed to protect the stadium’s structural concrete from further water damage. It’s exceptionally durable, protecting the external membrane from wear or damage due to heavy cart and foot traffic from thousands of fans.

Initial performance tests conducted during the first four-and-a-half years of service have indicated that the polyaspartic color coat will outperform traditional polyurethane coats. It will retain its sheen much longer and will be easier to clean.

Plus despite a late start, the coating was applied quickly and dried fast . . . just in time for the year’s 400 professional and little league baseball games.

That’s the power of polyurethane coatings built on Bayer technology.

At Bayer MaterialScience, vision works. All it takes is the know-how to transform that vision into products you can use.

of the widths of the delaminated areas at both sides of the artificial scribes.

Results of Delamination Tests
The results of the tests are summarized in Table 4 and in Figs. 1 to 5. There were notable differences in the degree of

Continued
delamination. First, Coating System 1 showed excellent performance compared to the other coating systems. This result agrees with results of delamination and underrusting tests performed by other authors.6–8 Pietsch and Kaiser9,10 found that, at dry blast cleaned substrates (Sa 2½), replacing a zinc phosphate primer with a zinc dust-based primer reduced delamination. However, if the substrates were prepared with hand-held tools (St 2, surfaces partly rusty) or needle guns (surfaces partly rusty), the primer type did not notably affect undercreeping. Thus, corrosion and delamination at defects depended on the condition of the substrate before coating and on the pigmentation of the coating systems. Coating systems with inert pigments tended to exhibit cathodic delamination on dry blast cleaned substrates, and this process occurred at comparatively high rates.9

With respect to the surface preparation method, a notable trend can be seen in Fig. 1. UHPAB always showed the lowest delamination values for any of the coating systems being tested. However, the beneficial effect of UHPAB depended on the coating system. It was highest for Coating System 3 and lowest for Coating System 4. AB generated high delamination values in most cases. The only exception was Coating System 5, where UHP had higher values than AB. These results confirmed results obtained by Pietsch and Kaiser,9 who found that delamination was more intense on dry blast cleaned surfaces than on surfaces prepared with hand-held tools.

The differences in delamination for the surfaces prepared by various methods depended upon the coating systems. If Coating System 1 was applied, the surface preparation methods investigated...
in this study did not seem to affect the
delamination process. No delamination
occurred in that case at all. (Therefore,
Coating System 1 is not displayed in Fig.
1.) The high resistance to delamination
of Coating System 1 could be explained
partly by the protective action of dis-
solved zinc particles that penetrated the
artificial scribe. The hydrogen ions gen-
erated during zinc dissolution neutral-
ized hydroxyl ions from oxygen reduc-
tion. Thus, highly alkaline pH-values,
responsible for delamination, were pre-
vented.8 If, however, Coating System 3
was applied, delamination was a very
strong function of the surface treatment.
Concerning surface profile and roughness, the areas cleaned with UHP exhibited a lower profile. The steel plates had already been prepared before the application of the original coating. Because this coating was then removed by UHP water jetting to prepare the surface for applying the new paint, the original profile was deteriorated. The rather insufficient performance of the AB-samples could be due to the presence of abrasive debris that were detected and described in a previous study. Thus, fine cleaning after AB may be an additional parameter that influences the delamination process. However, other effects, namely the ability of UHP and UHPAB to remove dissolved salts, may also contribute to the superior performance of the coatings applied to the substrates prepared with UHP and UHPAB. The effects of the coating types on delamination can not easily be explained. All coatings, except System 1, were based on epoxy with inert pigments. This particular problem will be addressed in a subsequent study.

### Summary

In our study, delamination of organic coatings applied to metal substrates depended upon the surface preparation method and coating properties. In most cases, substrates prepared with AB showed the highest delamination values, whereas substrates prepared with UHPAB exhibited the lowest delamination values. Zinc dust containing primers prevented delamination during the testing period.

### References

1. STG-Richtlinie Nr. 2221: Korrosionsschutz für Schiffe und Seebauwerke, Teil III: Instand-
haltung von Korrosionsschutz-
systemen, Schiffbautechnische
waterjetting for ballast tank coating
3. Morris, M, 2000, “Update: evaluat-
ing UHP waterjetting as preparation
for ballast tank coating,” PCE, Vol. 5,
No. 9, 54-59.
salt concentration of prepared steel
substrates,” JPCL, Vol. 23, No. 2, M2-
M8.
5. Momber, A.W., Koller, J, Dittmers,
H.-J., 2004, “Effects of surface prepa-
ration methods on adhesion of
organic coatings to steel substrates,”
Beschichtungsschäden an Stahl-
wwaterbauten. 2. Tagung Korrosions-
schutz in der maritimen Technik,
Hamburg, 124-142.
an Kaimanlagen, Schiffahrtswegen
und Seebauwerken. 1. Tagung
Korrosionsschutz in der maritimen
Technik, Hamburg, 84-102.
8. Binder, G., 2003, “Examination of
accelerated laboratory tests for cor-
rrosion protection,” PCE, Vol. 8, No.
11, 8-16.
Defect-induced undermining of anti-
corrosive paints – influence of zinc
dust and rust. Proc. Eurocorr ’97,
Trondheim, Norway, Vol. II, 367-
371.
Unterrostung am Defekt –
Korrosion von beschichtetem Stahl
an mechanischen Verletzungen.
Farbe & Lack, Vol. 107, 141-145

Sven Koller has
worked for German-
ische Lloyd AG,
Department MCM,
Hamburg, since 1996.
His areas of expertise
include materials technique, non-fer-
rrous metals, corrosion, and corrosion
protection. He was given the 2007
JPCL Editors’ Award for a paper he co-
wrote with A.W. Momber.

Dr. Andreas Momber
is head of research &
development at
Muehlhan Surface
Protection International
GmbH and a lecturer at
Aachen University, Germany, in the
Development of Mining, Metallurgy and
Earth Sciences. He was given the 2007
JPCL Editors’ Award for a paper he co-
wrote with Sven Koller.

Novatek provides a full range of surface preparation equipment
to tackle your toughest removal challenges. Our scalers,
grinders, air hammers, air powered scrapers, walk behind
machines, and dust collection / portable air filtration equipment
are what you need to get the job done FAST and Clean!

Call us Toll Free to learn more about
how Novatek can make your job easier
and Save You Money.
Have You Marked Your Calendar for PACE 2009?

Make plans to exhibit at one of the most talked about shows in the industry.

PACE is a powerful tool that provides you with competitive intelligence.

“PACE is definitely the place where industry and buyers get together! I’ve already booked our PACE 2009 exhibit space and invite all of you to do the same. New Orleans is back bigger and better and PACE 2009, the fifth anniversary of the show, will be a grand celebration.”
— Phil Calvo, Eagle Industries

Increase your visibility and build your brand.

“This year’s PACE event was by far the best yet for us – we were constantly busy. The main strength of the show, however, is the quality of the visitors. They are a very high-quality, well-targeted audience, which is very important to the success of an exhibitor.”
— Jack Ford, Zinsser

Contact PACE Today!

Marsha Bass
Exhibit Sales
bass@pace2009.com
Tel: 314-514-7322 | Fax: 314-514-9417

Lorena Walker
Exhibit and Sponsorship Sales
walker@pace2009.com
Tel: 412-288-6034 | Fax: 412-281-9993

Click our Reader e-Card at paintsquare.com/ric