

SURFACE TOLERANT COATINGS FOR OFFSHORE MAINTENANCE

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ABSTRACT

This study was set up to try and develop a testing schedule which could be used to differentiate between various systems used for the maintenance of hydroblasted areas on offshore installations. Systems used currently for new construction projects were evaluated against more traditional maintenance systems.

The work carried out has focused putting forward a system which would give optimum performance.

Key Words: Maintenance, Surface Tolerant, UHP.

BACKGROUND

Maintenance and repair of offshore structures has always been a concern, especially with regard to long term performance of anti-corrosive paint systems. Therefore, it has become critical that the performance testing for fitness for purpose is carried out with substrates that would be encountered in practice. The aim of this work was to identify suitable coating systems and an alternative approach to testing on a particular substrate which could represent the worst conditions likely to be encountered in offshore maintenance, i.e. structural steel which has been previously shot blasted to a poor profile, i.e. 25-30 microns, on which failure has occurred. Preparation of these failed areas was carried out by Ultra High Pressure water jetting. This paper details the preparation, application and testing of systems on this substrate.

COATING SYSTEMS

Coating systems to be used in this study were decided upon by recommendation from track record or previous anti-corrosive performance testing. The coating systems were:-

- (1) Moisture Cured Urethane
- (2) Zinc Rich Epoxy/HB Epoxy/Polysiloxane
- (3) Epoxy Zinc Phosphate/HB Epoxy/Polysiloxane
- (4) High Solids Modified Epoxy (1)/Polysiloxane
- (5) Ultra High Build Epoxy
- (6) Surface Tolerant Epoxy/Isocyanate Free
- (7) Surface Tolerant Epoxy Low Temperature Cure/Polysiloxane
- (8) High Solids Modified Epoxy (2)/Polysiloxane
- (9) Zinc Rich Epoxy/Surface Tolerant Epoxy/PU Fluoropolymer

In all cases each coat of each system was airless sprayed onto the specimens, with the exception of the moisture cured polyurethane which was brush applied.

TEST PROGRAM

The coated specimens were subjected to a varied and exhaustive testing regime, which included some standard testing and some internally designed tests which were thought to be a method of accelerating possible failure due to cracking (see Table 1 and Figures 3, 4 and 5).

SUBSTRATE

Due to the economics of blasting large amounts of steel for construction of offshore modules, there has been more and more temptation to utilize wheelabrator using 100% shot blasting. However, this type of surface preparation can lead to substrates which are unsuitable for today's high solids coatings due to poor anchor pattern and low surface area. (See Figures 1 and 2).

Steel surface can be clean but issues may arise with regard to long term adhesion and resistance to corrosion in areas of damage which can lead to large areas of corrosion and disbondment.

This also causes further problems when maintenance is carried out after failure, as in many parts of the world where dry blasting is becoming a problem because of contamination of equipment by dust, disposal of debris, and general health and safety and environmental issues.

Methods of surface preparation utilized are thus increasingly ultra high pressure water blasting (at >30,000 p.s.i., >2,100 bar) or traditional power tool cleaning, where hot permits can be obtained. From a long term performance viewpoint, ultra high pressure water blasting is clearly preferred but it must be realized the original profile is all that is obtained together with, by the time paint is applied, a light layer of corrosion product. In the case of this study this can mean slightly re-oxidized shot blasted steel or poor anchor pattern.

Initial surface preparation of test pieces with Rust Grade 'A' to 'B' is described by the following schedule:-

- Sharp edges/weld spatter removed.
- Degreased.
- Abrasive shot blasted:-
 - S280 Shot
 - Grade 'B' Sa2 (approx) ISO 8501-1:1988
 - Combination of poor surface cleanliness and low surface profile, 20-50µm (worst case)

This corroded substrate was simulated for this study using the previously mentioned test pieces which were artificially corroded at a coastal weathering site for 6 months and periodically sprayed with sodium chloride solution. When a suitable rusting standard was achieved, i.e. pitting evident, ultra high pressure water blasting was used to prepare the steel for painting. Salt levels were measured and results were 214 mg/m² (21.4 µg/cm²). This was considered to be surprisingly high but would suit our study as all of the maintenance and repair work would be carried out offshore where levels of high salt contamination could be a problem, even after ultra high pressure water blasting.

TEST RESULTS

Norsok Cyclic Test

Norsok Cyclic Test is based upon the principle of cyclic conditions of temperature, UV exposure and degree of wet and dry out during the test, rather than a static set of conditions as in the salt fog test. A description of the cycle can be found below.

| | |
|---------------|------------------|
| Salt Spray | 72 Hours |
| Drying in Air | 16 Hours |
| QUV-A (340nm) | 80 Hours |
| Total | 168 Hours |

25 Cycles are carried out at a total of 4200 hours.

The best overall performance from the Norsok cyclic tests was exhibited by the zinc phosphate epoxy/high build epoxy/polysiloxane system which was used in the study due to its heavy usage in the Offshore market, and these results tend to justify its inclusion. Results for the Norsok cyclic tests carried out in this study are detailed in Table 2. It should also be noted that this system on hydroblasted steel has been approved to Norsok System 1. (See Table 3).

It is interesting to note that all of the zinc rich epoxy systems performed well on this test, actually out-performing both surface tolerant epoxy and modified epoxy systems.

See Figures 7 to 10 for best/worst test panels.

Thermal Cycling

This test can be best described by the schematic shown in Figure 11.

The test was developed in the laboratory with a view to inducing cracking failure of the systems tested on complex test pieces, including sharp edges and welds. Coating systems were applied at x3 or x4 film thickness to simulate the occurrences observed offshore when coating complex structures.

The thermal cycling tests have shown that the best systems are not the zinc rich systems in this case, and that more traditional MAINTENANCE AND REPAIR systems perform better.

The best system was the moisture cured urethane, which helps justify their wide use for maintenance and repair due to flexibility gained from their polyurethane chemistry. The zinc rich epoxy system may be failing due to the fact that compared to the other systems they are relatively weak cohesively and the cracking is caused initially within the zinc film and the HS epoxy.

Results detailed in Table 4.

See Figures 12 to 14 for best/worst test panels.

Coastal Exposure (Blyth, North East England)

Test pieces, i.e. pipes and girder sections, were prepared and exposed at our marine coastal site for long term testing. The exposure site is actually situated less than 5 meters from the sea wall.

See Figures 15, 16 and 17 for photographs of Blyth Coastal site.

Performance after 24 months exposure has shown some very interesting results.

- The overall best performance with regard to blistering and rusting resistance is System 4 (High Solids Modified Epoxy (1)/Polysiloxane), at both single and double dry film thickness on both girder sections and pipe sections.
- The next best was System 2 (zinc rich epoxy/HB epoxy/polysiloxane), which did show some slight blistering on the pipe section.
- All other systems showed signs of blistering and rusting to various degrees.
- The worst performance was observed by System 6, which showed rusting through on the girder section and crack formation, as well as rusting, on the pipe section.

CONCLUSIONS

The best overall performing system evaluated in this study was the High Solids Modified Epoxy/Polysiloxane (1). This system gave acceptable anti-corrosive performance in the cyclic corrosion tests and was good on the thermal cyclic tests, together with easily the best performance on external exposure after 24 months at the Blyth Coastal site. It is important to note that the second best performing system on this corroded hydroblasted substrate is a standard new construction system, i.e. System 2. Although there is some slight blistering, there is no evidence of the underfilm corrosion observed on some of the other systems. Due to the nature of the testing and panel preparation, this correlation between laboratory testing and external exposure is a major development in the method development/testing of maintenance systems for offshore. These results have also been corroborated as this system has been used offshore for maintenance and repair on hydroblasted surfaces.

It can be seen from the laboratory testing that if the substrate can be sufficiently cleaned to a good standard of preparation then products which previously have not been put forward as maintenance and repair systems have actually performed very well. Results from the cyclic tests have shown excellent scribe creep resistance. However, it must be noted that the good performance of these products may only come from the fact that the steel was allowed to corrode to a heavily pitted condition before hydroblasting was employed. This actually meant that the resulting steel profile was actually better than the original shot blasted substrate.

This has been further corroborated by the latest test results which show that much worse performance is obtained from repair areas where removal of original coating has left the original shot blasted profile which has been allowed to re-oxidize after hydroblasting. An equivalent set of anti-corrosive tests have shown very poor performance for all the systems previously described. Blister failure and very poor system adhesion have resulted in the tests being suspended. In these areas it does not seem that hydroblasting is a safe option for preparation of the substrate, and it may be better to use some sort of mechanical preparation such as discing or grinding.

The tests that were carried out in this study have given results which will not be correlated to external exposure until late 2003, when the specimens from the Blyth Coastal Exposure site start to yield results. However, the thermal cyclic tests have shown some correlation to performance actually observed offshore. Thermal cycles Tests have also been included in the latest draft of NACE TG260.

In general, the testing schedule in this study has been shown to be possibly on the right track but will probably need to be modified after results from the external exposure tests are available.

CURRENT FURTHER WORK

The disappointing results for the re-oxidized shot blasted steel have highlighted areas for further testing, as it seems that the pitted rusty steel areas are the least of our worries with regard to repair. Areas around the failure which have not corroded pose a more demanding substrate for Surface Tolerant Coatings. A full set of tests need to be carried out to include mechanical preparation to give a better anchor for the maintenance and repair coating. A repeat test of the re-oxidized shot blast needs to be carried out to confirm the results of previous tests.

TABLE 1

| Test Type | Test Piece/System | Test Piece Size |
|--|------------------------------------|--|
| Natural Coastal Exposure (Blyth, North East England) | 1 Pipe Section 1 Girder Section | ~0.17m ² ~0.54m ² |
| Norsok Cycling (M-501, Rev 4) (including Adhesion Test) | 4 x Panels | 150 x 75 x 4mm |
| Thermal Cycling Immersion Test | 1 Angle Bar with Weld | 10 x 10 x 4mm |
| Deflection Bend Tests (selected systems) | 2 x Panels | 200 x 60 x 4.5mm |

TABLE 2
NORSOK CYCLIC TEST RESULTS

| System | Corrosion Creep* | Other Defects* |
|---|---------------------------|---|
| Moisture Cured Urethane | 1.3 – 1.5mm | No blistering. Good adhesion. |
| Zinc Rich Epoxy/HB Epoxy/Polysiloxane | 1.5 – 3.9mm | No blistering. Acceptable – good adhesion. |
| Epoxy Zinc Phosphate/HB Epoxy/ Polysiloxane | 0.5 – 1.0mm | No blistering. Good adhesion. |
| High Solids Modified Epoxy/ Polysiloxane (1) | 3.3 – 7.1mm | No blistering. Poor – excellent adhesion. |
| Ultra High Build Epoxy | 4.0mm Complete failure | Poor – good adhesion. |
| Surface Tolerant Epoxy/NCO Free | 2.8 – 5.8mm | Blistering M8 (ASTM D714). Poor – acceptable adhesion. |
| Surface Tolerant Epoxy/Polysiloxane | 2.3 – 4.2mm | Blistering F8 (ASTM D714). Acceptable adhesion. |
| High Solids Modified Epoxy/ Polysiloxane (2) | 3.7 – 7.6mm | No blistering. Acceptable adhesion. |
| Zinc Rich Epoxy/Surface Tolerant Epoxy/ PU Fluoropolymer | 1.7 – 2.7mm | No blistering. Acceptable – good adhesion. |

*Summary of 3 test panels.

TABLE 3
PREVIOUS EXTERNAL APPROVALS FOR
NORSOK M-501 ON HYDROBLASTED STEEL

| Surface Treatment | Specification | D.F.T. (µm) | Corrosion Creep Value |
|---------------------------------------|---|-----------------|-----------------------|
| UHPWJ to HB 2½ M – H Flash Rusting | HS Zinc Epoxy Polysiloxane | 75 125 | <3mm |
| UHPWJ to HB 2½ M – H Flash Rusting | Zinc Phosphate Primer Polysiloxane | 75 125 | <3mm |
| UHPWJ to HB 2½ M – H Flash Rusting | Modified Epoxy Polysiloxane | 200 125 | <3mm |
| UHPWJ to HB 2½ M – H Flash Rusting | Zinc Phosphate Primer Modified Epoxy | 75 350 | <3mm |
| UHPWJ to HB 2½ M – H Flash Rusting | Zinc Phosphate Primer HS Rothsmediate Epoxy NCO Free Finish | 75 200 60 | <1mm |

TABLE 4
THERMAL CYCLING TEST RESULTS (4 WEEKS DURATION)

| System | Weld Defects at x2 D.F.T. | Rating |
|---|---------------------------|------------|
| Moisture Cured Urethane | No cracking | Very good |
| Zinc Rich Epoxy/HB Epoxy/Polysiloxane | Moderate cracking | Borderline |
| Epoxy Zinc Phosphate/HB Epoxy/Polysiloxane | Three cracks | Acceptable |
| High Solids Modified Epoxy/Polysiloxane (1) | Two very small cracks | Good |
| Ultra High Build Epoxy | Not tested | - |
| Surface Tolerant Epoxy/NCO Free | Not tested | - |
| Surface Tolerant Epoxy/Polysiloxane | One crack | Good |
| High Solids Modified Epoxy/Polysiloxane (2) | Severe cracking | Poor |
| Zinc Rich Epoxy/Surface Tolerant Epoxy/PU Fluoropolymer | Micro-cracks | Borderline |

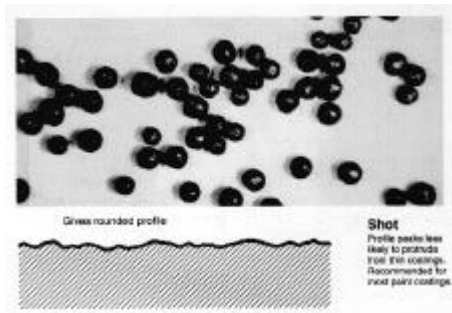


FIGURE 1

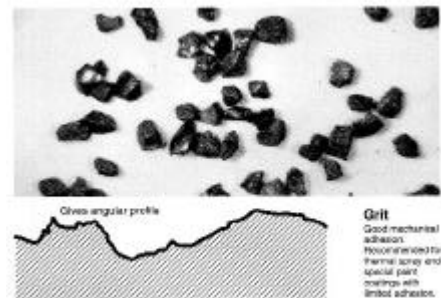


FIGURE 2



FIGURE 3
Pipe Section



FIGURE 4
Angle Bar and Weld



FIGURE 5
Girder Section



FIGURE 7
Surface Tolerant/
Epoxy Polysiloxane

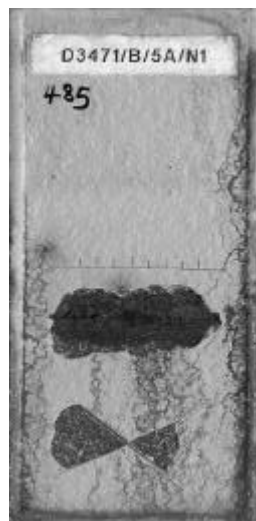


FIGURE 8
Ultra High Build
Epoxy



FIGURE 9
Zinc Epoxy/High Build
Epoxy/Polysiloxane

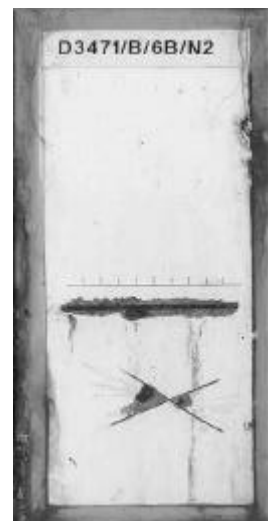


FIGURE 10
Epoxy Zinc
Phosphate/High Build
Epoxy/Polysiloxane

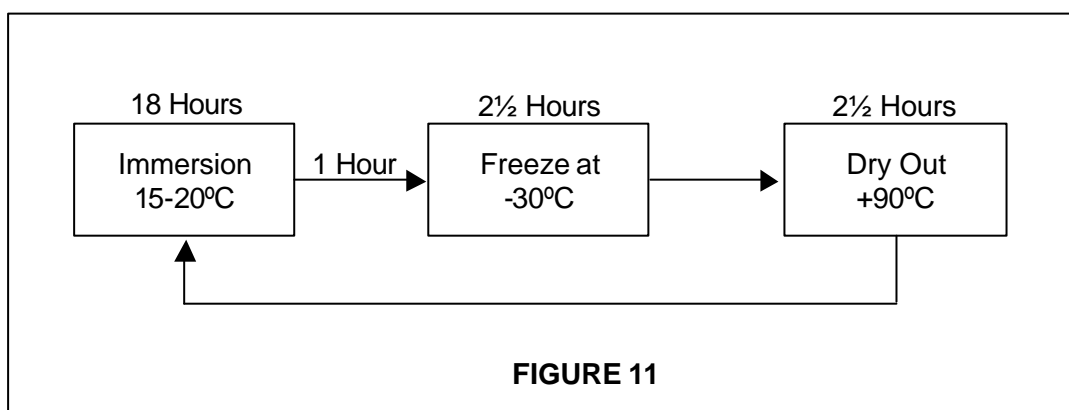


FIGURE 12
Moisture Cured
Urethane



FIGURE 13
Epoxy Zinc Phosphate
HB Epoxy Polysiloxane



FIGURE 14
High Solids Modified Epoxy
Polysiloxane (2)



FIGURES 15



FIGURES 16



FIGURES 17