PERFORMANCE OF COATINGS OVER WATERJETTED SURFACES

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LEARNING OBJECTIVES

• THIS WEBINAR WILL EXPLORE ISSUES ASSOCIATED WITH WATERJETTING SURFACE PREPARATION PRIOR TO APPLICATION OF INDUSTRIAL COATINGS
  • REVIEW THE LATEST SSPC WATERJETTING STANDARDS (WJ-1, WJ-2, WJ-3 AND WJ-4)
  • REVIEW THE TECHNICAL LITERATURE RELATING TO THE PERFORMANCE OF COATING APPLIED OVER WATERJETTED STEEL SURFACES
WATERJET CLEANING OF METALS

• REMOVES MATERIAL FROM THE SURFACE THAT CAN CAUSE EARLY FAILURE OF THE COATING SYSTEM

• ENHANCES THE ADHESION OF THE NEW COATING SYSTEM

• EXPOSES THE SURFACE PROFILE OF THE SUBSTRATE THAT IS UNDERNEATH THE EXISTING COATING OR RUST AND OTHER CORROSION PRODUCTS

• REDUCES OR REMOVES NONVISIBLE CONTAMINATION

• VARIOUS PRESSURES FROM 10,000 PSI TO 40,000 PSI
  • LESS THAN 10,000 PSI IS “WATER CLEANING”
SURFACE PREPARATION OF CONCRETE

- SURFACE PREPARATION REQUIREMENT FOR CONCRETE BY MECHANICAL, CHEMICAL OR THERMAL METHODS PRIOR TO THE APPLICATION OF A PROTECTIVE COATING
  - HIGH PRESSURE WATER CLEANING OR WATERJETTING PER ASTM D 4259
- CONCRETE SHOULD BE INSPECTED FOR DEFECTS, DAMAGE AND CONTAMINATION.
  - CONCRETE SHOULD BE IN ACCORDANCE WITH ACI 308
ULTRA HIGH PRESSURE WATERJETTING

- METHOD OF SURFACE PREPARATION USING WATER AT PRESSURES ABOVE 30,000 PSIG
  - MAY LEAVE WET SURFACE WHICH CAN DEVELOP FLASH RUST
- TWO TYPES OF EQUIPMENT
  - ROBOTIC METHOD
    - CLOSED LOOP
    - OPEN LOOP
  - HAND LANCE METHOD
HAND LANCE EQUIPMENT

- Used to clean areas with complex shapes
- Do not incorporate water removal devices
- Surface tend to remain wet longer and develop flash rust
  - Can blow down with air to minimize flash rust
- Flash rust may require remediation prior to painting
ROBOTIC EQUIPMENT

- INCORPORATE WATER REMOVAL DEVICES
- LITTLE TO NO FLASH RUST
USE OF RUST INHIBITORS

- CONCERN THAT THEY INCREASE PROPENSITY FOR BLISTERINGING
  - NOT COMMONLY USED
  - RELATED TO TOTAL DISSOLVED SOLIDS EXTRACTED FROM SURFACE
  - NON-IONIC INHIBITORS BETTER (LEAVE LESS SOLUBLE MATERIALS)
# Abrasive Cleaning and Waterjet Cleaning Are Different

<table>
<thead>
<tr>
<th>Dry or Wet Abrasive</th>
<th>WaterJet</th>
</tr>
</thead>
<tbody>
<tr>
<td>New and Repair</td>
<td>Repair</td>
</tr>
<tr>
<td>Makes new profile</td>
<td>Exposes profile under paint or corrosion</td>
</tr>
<tr>
<td>Erodes from the top surface</td>
<td>Shears at interface</td>
</tr>
<tr>
<td>Looks uniform</td>
<td>Exposes problems</td>
</tr>
<tr>
<td>Cleans top, leaves material in crevices (stain)</td>
<td>Gets into crevices, Could leave top material</td>
</tr>
<tr>
<td><strong>NO Rust Back</strong> Allowed (Dry)</td>
<td>Flash Rust allowed</td>
</tr>
<tr>
<td><strong>Flash Rust</strong> Allowed (Wet)</td>
<td></td>
</tr>
</tbody>
</table>
WATERJET BLAST DOESN’T LOOK LIKE DRY BLAST
Complete Coating Removal

Partial Coating Removal

Light Clean Pressure Wash

PRODUCTION RATE AREA/Hour
Coating destruction   Rapid coating erosion   Minimal coating erosion

40 Kpsi  
270 MPa  
(5 tips)  
0.28 mm  
1.96 L/min

20 Kpsi  
140 MPa  
(2 tips)  
0.686 mm  
8.33 L/min

10 Kpsi  
68 MPa  
(2 tips)  
1.02  
12.9 L/min/tip

Cross Sec   mm²   0.0613   0.369   0.811
Jet Velocity   m/sec   738   522   363
Impact force/tip kg   2.4   7.3   8.1
Jet Energy   kJ   89   189   142
Energy Intensity kJ/mm²   1,450   512   175
Assumption: $P'' \alpha \frac{1}{R''^2}$

$V_1 = $ Jet Velocity
$P_1 = $ Jet Pressure

$P'' = $ Pore Pressure - a proxy for a “pull test”
$R'' = $ Radius at Point of Stress
INTERESTING OBSERVATION

• ULTRA HIGH PRESSURE WATERJET APPEARS TO CHANGE SURFACE ENERGY

Solvent wiped, cold rolled steel test panel
STANDARDS

• SSPC-SP WJ-1/NACE WJ-1 THROUGH SSPC-SP WJ-4/NACE WJ-4 – WATERJET CLEANING OF METALS
  • REPLACES NACE NO. 5, SSPC SP-12

• SSPC-VIS NO. 4 NACE VIS 7 – GUIDE AND REFERENCE PHOTOGRAPHS FOR STEEL SURFACES PREPARED BY WATERJETTING

• ISO 8501-4 – INITIAL SURFACE CONDITIONS, PREPARATION GRADES AND FLASH RUST GRADES IN CONNECTION WITH HIGH-PRESSURE WATER JETTING
SURFACE PREPARATION AND CLEANING OF METALS BY WATERJETTING PRIOR TO RECOATING

Visible Contaminants

Non-Visible Contaminants

Flash Rust
# WATERJET CLEANING OF METALS

<table>
<thead>
<tr>
<th>Degree of Surface Cleanliness</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WJ-1 Clean to Bare Substrate</td>
<td>Free of all visible rust and other corrosion products, dirt, previous coatings, mill scale, and foreign matter</td>
</tr>
<tr>
<td>WJ-2 Very Thorough Cleaning</td>
<td>Allows staining or tightly adherent matter to a maximum of 5 percent of each unit area of the surface</td>
</tr>
<tr>
<td>WJ-3 Thorough Cleaning</td>
<td>Allows staining or tightly adherent matter to a maximum of 33 percent of each unit area of the surface</td>
</tr>
<tr>
<td>WJ-4 Light Cleaning</td>
<td>Allows as much of the tightly adherent matter to remain as possible</td>
</tr>
</tbody>
</table>
PHOTOGRAPH GUIDES - FLASH RUST

• SSPC-VIS NO. 4 NACE VIS 7 “GUIDE AND REFERENCE PHOTOGRAPHS FOR STEEL SURFACES PREPARED BY WATERJETTING”

• SSPC-VIS 5 NACE VIS 9 “GUIDE FOR STEEL SURFACES PREPARED BY WET ABRASIVE BLAST CLEANING”

• VARIOUS PROPRIETARY GUIDES
SSPC-VIS NO. 4 NACE VIS 7 – GUIDE AND REFERENCE PHOTOGRAPHS FOR STEEL SURFACES PREPARED BY WATERJETTING

- PROVIDES REFERENCE PHOTOGRAPHS
  - VISUAL CLEANLINESS
    - SIX INITIAL CONDITIONS
    - FOUR DEGREES OF CLEANLINESS
      (WJ-1 THROUGH WJ-4)
  - FLASH RUST
    - TWO INITIAL CONDITIONS
    - TWO DEGREES OF CLEANLINESS
      (WJ-2 AND WJ-3)
- PROCEDURES FOR THEIR PROPER USE
INITIAL CONDITIONS
WJ-4, LIGHT CLEANING

• USED WHEN THE OBJECTIVE IS TO ALLOW AS MUCH OF THE TIGHTLY ADHERENT RUST AND OTHER CORROSION PRODUCTS, COATING, AND MILL SCALE TO REMAIN AS POSSIBLE

• DISCOLORATION OF THE METAL SUBSTRATE MAY BE PRESENT

• REDUCES AND MAY COMPLETELY REMOVE WATER-SOLUBLE SURFACE CONTAMINANTS
  • INCLUDES CONTAMINANTS FOUND AT THE BOTTOM OF PITS ON THE SURFACE OF CORRODED METALLIC SUBSTRATES
INITIAL
WJ-4, LIGHT CLEANING
WJ-3, THOROUGH CLEANING

• USED WHEN THE OBJECTIVE IS TO REMOVE MUCH OF THE RUST AND OTHER CORROSION PRODUCTS, COATING, AND MILL SCALE, AND LEAVE TIGHTLY ADHERENT THIN FILMS, BUT WHEN THE EXTRA EFFORT REQUIRED TO REMOVE ALMOST ALL OF THESE MATERIALS IS DETERMINED TO BE UNWARRANTED

• DISCOLORATION OF THE METAL SUBSTRATE MAY BE PRESENT

• REDUCES AND MAY COMPLETELY REMOVE WATER-SOLUBLE SURFACE CONTAMINANTS
  • INCLUDES CONTAMINANTS FOUND AT THE BOTTOM OF PITS ON THE SURFACE OF CORRODED METALLIC SUBSTRATES
INITIAL
WJ-3, THOROUGH CLEANING
WJ-2, VERY THOROUGH CLEANING

• Used when the objective is to remove every trace of the coating, mill scale, and rust and other corrosion products but when the extra effort required to remove all of these materials is determined to be unwarranted.

• Discoloration of the metal substrate may be present.

• Reduces and may completely remove water-soluble surface contaminants.

  • Includes contaminants found at the bottom of pits on the surface of corroded metallic substrates.
INITIAL
WJ-2, VERY THOROUGH CLEANING
WJ-1, CLEAN TO BARE SUBSTRATE

• Used when the objective is to remove every trace of the coating, mill scale, and rust and other corrosion products, and when the extra effort required to remove all of these materials is determined to be warranted.

• Discoloration of the metal substrate may be present.

• Reduces and may completely remove water-soluble surface contaminants.
  • Includes contaminants found at the bottom of pits on the surface of corroded metallic substrates.
INITIAL
WJ-1, CLEAN TO BARE SUBSTRATE
SURFACE PREPARATION AND CLEANING OF METALS BY WATERJETTING PRIOR TO RECOATING

Visible Contaminants

Non-Visible Contaminants

Flash Rust
NON-VISIBLE CONTAMINANTS

• ORGANIC MATTER
  • THIN FILMS OF OIL AND GREASE, SILICONE, WAX, ETC
  • MAY IMPACT COATING ADHESION OR OTHER PROPERTIES

• INORGANIC AND/OR SOLUBLE IONIC MATERIALS
  • CHLORIDES, FERROUS SALTS, NITRATES, AND SULFATES
  • MAY DEVELOP FLASH RUST
  • REFERENCE SSPC GUIDE 15

• NV-XX LEVELS NO LONGER EXIST
EFFECTS OF SURFACE SALTS

• PROMOTE OSMOTIC BLISTERING
• CREATE CORROSION CELLS UNDER FILMS
• INTERFERE WITH PROPER ADHESION
EFFECT OF CHLORIDES ON COATING PERFORMANCE

- CHLORIDES, EVEN AT VERY LOW LEVELS CAN CAUSE BLISTERING RESULTING IN CORROSION
  - TOP, <2 UG/SQ CM CL
  - CENTER, 10 UG/SQ CM CL
  - BOTTOM, 25 UG/SQ CM CL
SURFACE PREPARATION AND CLEANING OF METALS BY WATERJETTING PRIOR TO RECOATING
RECOMMENDED GUIDELINES FOR EVALUATING FLASH RUST

- DEVELOPED BY THE U.S. NATIONAL SHIPBUILDING RESEARCH PROGRAM
  - CONTAINS A TABLE WHICH BREAKS DOWN THE FLASH RUST DEFINITIONS
  - DISCUSSES IMPACT OF INSPECTION CONDITIONS
    - TIME, ILLUMINATION, DISTANCE
  - PROVIDES A MORE DETAILED METHOD FOR PERFORMING BRUSH-WIPE TEST
  - DISCUSSES PRESSURE WASHING FOR REMEDIATION
SUGGESTED “BRUSH-CLOTH” WIPING TEST

• RECOMMENDED TO IMPROVE CONSISTENCY OF EVALUATION
SUGGESTED "BRUSH-CLOTH" WIPING TEST
“TEN TAPE” TEST

Moderate

Heavy
REMOVAL OF FLASH RUST

Other methods of removing flash rust include:

- Solvent Wipe
- Sweep Blast
- Dry Ice Blast
- Power Tool Clean

Not Pressure Washed

After Pressure Washing
CONCERNS REGARDING COATING OVER FLASH RUST

- FLASH RUST MAY CONTAIN CONTAMINANTS
  - COULD LEAD TO UNDERCUTTING, OSMOTIC BLISTERING OR LOSS OF ADHESION
  - SURFACE SHOULD BE TESTED FOR NON-VISIBLE CONTAMINANTS
  - SURFACE SHOULD HAVE BEEN THOROUGHLY CLEANED BEFORE FLASH RUSTING BEGINS

- FLASH RUST MAY INTERFERE WITH ADHESION
  - DOES THE COATING ADEQUATELY WET THE FLASH RUST?
  - DEPENDS ON COATING CHEMISTRY AS WELL AS FLASH RUST
BENEFIT OF ALLOWING COATING OVER FLASH RUST

- REDUCE SURFACE PREPARATION COST AS MORE FLASH RUST IS ALLOWED
  - ALLOWS OPERATIONS TO BE SEQUENCED MORE EFFICIENTLY
  - ONE SOURCE ESTIMATED SAVINGS OF 20% OF TYPICAL WATERJETTING SURFACE PREPARATION COST
    - DEPENDS ON EXTENT OF REMEDIATION REQUIRED (E.G., COMPLEXITY OF STRUCTURE, CLEANLINESS REQUIREMENT)
SUITABILITY OF FLASH RUST FOR COATING

• SEVERAL STUDIES HAVE SHOWN THAT ULTRAHIGH PRESSURE WATERJETTING PROVIDES AN EXCELLENT SURFACE FOR COATINGS
  • MOST AGREE THAT SOME LEVEL OF FLASH RUST IS ACCEPTABLE FOR COMMON MARINE QUALITY EPOXY BASED COATING SYSTEMS
  • TYPICALLY EITHER “LIGHT” OR “MODERATE” IS THE ALLOWABLE FLASH RUST LEVEL
    • PREDOMINATE CONCERN IS ACCURATELY CHARACTERIZATION
    • MUST BE CLEANED FIRST (I.E., NO “OLD RUST”)
ADHESION DATA FROM SHIPS IN SERVICE

- Negligible Flash Rust (Closed Loop)
- Moderate Flash Rust (Hand Lance)
- Light Flash Rust (Remediated Hand Lance)

Tensile adhesion above 800 psi is considered "good" performance.

Dominate Failure Location:
- primer/substrate
- within coating
- glue
KEY CONCEPTS

• THREE IMPORTANT CRITERIA MUST BE CONSIDERED FOR A WATERJET CLEANED SURFACE
  • VISIBLE CONTAMINANTS
  • FLASH RUST
  • NON-VISIBLE CONTAMINANTS
ACKNOWLEDGEMENTS

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• SSPC: THE SOCIETY FOR PROTECTIVE COATINGS
• NACE INTERNATIONAL
• NATIONAL SHIPBUILDING RESEARCH PROGRAM
QUESTIONS?

THANK YOU FOR ATTENDING!