Compliant Repair Solutions for Pipework and Equipment in Petroleum, Petrochemical and Natural Gas Industries

ISO / ASME COMPLIANT COMPOSITE REPAIR SYSTEM

Designed to restore strength to weakened or holed metallic substrates, compliant to ISO 24817 and ASME PCC2.
NACE Jubail Technical Workshop

Corrosion Under Insulation
10th December, 2015

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QA / QC Manager
Hajjan Trading and Industrial Services Co. Ltd. (HATCON)
Topics

- Introduction
  - Need for Composite Repairs
  - Compliant V/s Non-Compliant Repairs
  - Governing Standards

- Technical Considerations
  - Process Parameters
  - Product Parameters

- Case Histories

- HATCON Capabilities
  - Design, Installation, Supervision, Testing and Inspection

- Conclusion
Introduction

- Need for Composite Repairs
  - Various types of composite repair systems have been in place across the years and are still being used to restore strength to weakened metallic substrates damaged by corrosion, abrasion, impact etc.
Introduction

- Compliant V/s Non-Compliant Repairs
  - Repairs can normally be divided into two broad categories based on the methodology adopted
  - Both are being used worldwide to address the various problems faced by plants when it comes to the damaging effects of wear and chemical attack on pipes and equipment

- Our desired scenario
  - A safe, reliable system that can last for an intended lifetime
  - What must the applied system go through?
    - Various internal and external loads, effects of chemicals (water to hydrocarbons and many more), corrosive external environment and multiple wear modes

- Both compliant and non-compliant repairs basically appear the same; so where’s the difference?
Introduction

- Compliant V/s Non-Compliant Repairs

  - Compliant Repairs
    - Designed using scientific methods and engineering formulae
    - Each design in unique
    - Applied only by validated and certified installers
    - Fully traceable
    - Confidence to the end user
      - Product quality
      - Process control

  - Non - Compliant Repairs
    - Designed on the need of the hour and often based on empirical design calculations – not scientific methods
    - Traceability is not guaranteed
    - Liabilities?
Introduction

- Governing Standards:

**ISO 24817:2015**
Petroleum, petrochemical and natural gas industries – Composite repairs for pipework – Qualification and design, installation, testing and inspection

**ASME PCC – 2 – 2015**
Repair of Pressure Equipment and Piping

[The above standards are available for purchase through the websites of ISO and ASME]
Technical Considerations – Process Parameters

- System Life Cycle
  - Qualification of the repair system
  - Design
  - Installation, testing and inspection
  - Validation process and control
  - On-going integrity management through repair design life
  - Decommissioning of engineered composite repair
Technical Considerations – Process Parameters

- Qualification of the repair system
  - Even before a product (system) can be recommended for a particular application or situation, it must be pre-qualified for that scenario; else the final repair is considered to be non-compliant

- Pre-qualification tests (adapted from ISO 24817:2015; for information / educational purposes only):
  - Mechanical properties
    - Young’s modulus
    - Poisson’s ratio
    - Shear modulus
    - Thermal expansion coefficient
    - Tg (Glass transition temperature) or HDT (Heat Distortion Temperature) of the resin when cured at relevant temperatures
    - Barcol or Shore Hardness
  - Adhesion strength
    - Lap shear
  - Performance data
    - Energy release rate
    - Short-term pipe spool survival test (ISO 24817, Annex C)
    - Impact survival test (ISO 24817, Annex F)

Tests to be carried out in line with relevant ISO, ASTM standards or Annexures of ISO 24817:2015 as defined in ISO 24817:2015
Technical Considerations – Process Parameters

- Qualification of the repair system
  - Belzona® SuperWrap II - Published Performance Data

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Property</th>
<th>Belzona 1981</th>
<th>Belzona 1982</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_1$</td>
<td>0º Tensile Modulus</td>
<td>38800</td>
<td>38600</td>
<td>MPa</td>
</tr>
<tr>
<td>$E_2$</td>
<td>90º Tensile Modulus</td>
<td>16300</td>
<td>15500</td>
<td>MPa</td>
</tr>
<tr>
<td>$E_3$</td>
<td>0º Tensile Strength</td>
<td>524</td>
<td>505</td>
<td>MPa</td>
</tr>
<tr>
<td>$E_{90}$</td>
<td>90º Tensile Strength</td>
<td>126</td>
<td>121</td>
<td>MPa</td>
</tr>
<tr>
<td>$v_1$</td>
<td>0º Poisson's Ratio</td>
<td>0.26</td>
<td>0.26</td>
<td></td>
</tr>
<tr>
<td>$v_2$</td>
<td>90º Poisson's Ratio</td>
<td>0.27</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>$\epsilon_{short 1}$</td>
<td>0º Strain to Failure</td>
<td>1.37</td>
<td>1.34</td>
<td>%</td>
</tr>
<tr>
<td>$\epsilon_{short 2}$</td>
<td>90º Strain to Failure</td>
<td>0.81</td>
<td>1.24</td>
<td>%</td>
</tr>
<tr>
<td>$G$</td>
<td>Shear Modulus</td>
<td>7830</td>
<td>7630</td>
<td>MPa</td>
</tr>
<tr>
<td>$E$</td>
<td>0º Bending Modulus</td>
<td>37977</td>
<td>37462</td>
<td>MPa</td>
</tr>
<tr>
<td>$E_2$</td>
<td>90º Bending Modulus</td>
<td>14247</td>
<td>14031</td>
<td>MPa</td>
</tr>
<tr>
<td>$\alpha_1$</td>
<td>0º Thermal Expansion Coefficient</td>
<td>0.00000944</td>
<td>0.00001126</td>
<td>mm/mm°C</td>
</tr>
<tr>
<td>$\alpha_2$</td>
<td>90º Thermal Expansion Coefficient</td>
<td>0.00001296</td>
<td>0.00002076</td>
<td>mm/mm°C</td>
</tr>
<tr>
<td>$T_g$</td>
<td>Resin Glass Transition Temperature</td>
<td>90 / 194</td>
<td>115 / 239</td>
<td>°C / °F</td>
</tr>
<tr>
<td>$Shore D Hardness$</td>
<td></td>
<td>90</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>$Lap Shear Adhesion$</td>
<td></td>
<td>15.5</td>
<td>12.3</td>
<td>MPa</td>
</tr>
<tr>
<td>$Lap Shear Adhesion (1000 hour immersion)$</td>
<td></td>
<td>15.5</td>
<td>19.0</td>
<td>MPa</td>
</tr>
<tr>
<td>$\gamma_{LCL}$</td>
<td>Energy Release Rate</td>
<td>66.87</td>
<td>66.82</td>
<td>W/m²</td>
</tr>
<tr>
<td>$\epsilon_\text{LCL}$</td>
<td>Lower Confidence long term strain</td>
<td>Passed</td>
<td>Passed</td>
<td>min/mm</td>
</tr>
<tr>
<td>$S_\text{LCL}$</td>
<td>Performance Data (1000 hour)</td>
<td>ASME 129770</td>
<td>ASME 139250</td>
<td>N/m²</td>
</tr>
</tbody>
</table>

$0^\circ =$ hoop direction, $90^\circ =$ axial direction
Technical Considerations – Process Parameters

■ Design

- Each repair is unique and designed only by certified designers using the methodology defined in the standard
- Designers must pass rigorous validation exams and meet minimum levels of competence
- Two design scenarios: Type A (Thin-wall defects) and Type B (Through-wall defects)
Technical Considerations – Process Parameters

Design

- Every design problem is only as good as the quality of the input
- The input is provided by the client through ASR forms as shown below:
Technical Considerations – Process Parameters

- **Design**
  
  - There are two outputs to every design problem which then becomes the basis for estimating the quantity of materials required, costs, planning of operational activities etc.
    
    - Thickness of the repair (minimum required in axial / circumferential direction, whichever is larger and within the constraint imposed by the standard)
      
      \[
      t_{\text{design}} < \frac{D}{12}, \text{ where } D \text{ is the outer diameter of the pipe}
      \]

    - Total axial extent (total length of the repair and consists of the defect size, axial length of the repair and the taper length which is set to approximately 5 times the thickness of the system in either direction)
Technical Considerations – Process Parameters

- Installation, testing and inspection
  - Just as every design problem is only as good as the input received, every application is only as good as the quality of the installers responsible for installing the system in line with the design specifications, while ensuring that all Application Reports and necessary QA/QC documentation are duly filled through the course of the application.

- In order for the repair to be compliant, the level of training of the Installer (or Supervisor) and the class of repair is important as mandated by the standard. Belzona® uses a slightly stricter approach here:

<table>
<thead>
<tr>
<th>Repair Class</th>
<th>Typical Service</th>
<th>Pressure</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>Low specification duties, e.g. static head, drains, cooling medium, sea (service) water, non-leaking utility hydrocarbons</td>
<td>&lt; 1 MPa (145 psi)</td>
<td>&lt; 40°F (104°C)</td>
</tr>
<tr>
<td>Class 2</td>
<td>Fire water/deluge systems</td>
<td>&lt; 2 MPa (290 psi)</td>
<td>&lt; 100°F (212°C)</td>
</tr>
<tr>
<td>Class 3</td>
<td>Produced water and hydrocarbons, flammable fluids, gas systems. Class 3 also covers operating conditions more labor demanding than described.</td>
<td>Qualified upper limit</td>
<td>Qualified upper limit</td>
</tr>
</tbody>
</table>

Class 1 repairs can be carried out by Validated Installers.

Class 2 and Class 3 repairs can be carried out by Validated Installers only when the application is Supervised by Validated Supervisors.
Technical Considerations – Process Parameters

- Installation, testing and inspection

  It is critical that various checks are carried out at “Hold Points” as defined in the table below:

<table>
<thead>
<tr>
<th>Hold Points</th>
<th>Class of repair</th>
<th>Checked by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method Statement - Belizona® SuperWrap Design Document</td>
<td>All Classes</td>
<td>Installer</td>
</tr>
<tr>
<td>Materials Preparation</td>
<td>All Classes</td>
<td>Installer</td>
</tr>
<tr>
<td>- Reinforcement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Resins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface Preparation</td>
<td>All Classes</td>
<td>Installer (Class 1) Supervisor (Class 2 and 3)</td>
</tr>
<tr>
<td>- Visual inspection (Cleanliness)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Surface profile test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Mechanical test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage Check on Reinforcement</td>
<td>All Classes</td>
<td>Installer</td>
</tr>
<tr>
<td>Tests on Repair Laminate</td>
<td>All Classes</td>
<td>Installer (Class 1) Supervisor (Class 2 and 3)</td>
</tr>
<tr>
<td>- Thickness</td>
<td>All Classes</td>
<td></td>
</tr>
<tr>
<td>- Dimensions</td>
<td>All Classes</td>
<td></td>
</tr>
<tr>
<td>- External inspection</td>
<td>All Classes</td>
<td></td>
</tr>
<tr>
<td>Pressure Test</td>
<td>Class 3</td>
<td>Inspection Authority</td>
</tr>
</tbody>
</table>
Technical Considerations – Process Parameters

- Validation process and control

  - The validation process is strictly controlled through a series of intensive courses, rigorous theoretical examinations and practical validation in accordance with the requirements of the appropriate sections of ISO 24817:2015 standard

  - All personnel need to undergo and pass the validated Installers course, have adequate years of experience and a current certification as mandated by the standard, prior to be eligible to attend the validated Supervisor’s course

  - All validated Installers and Supervisors are issued

  - Point to remember: Class 2 and Class 3 repairs need to have at least one validated Supervisor on site to oversee the works at all times!
Technical Considerations – Process Parameters

- Validation process and control

GLOBAL PRESENCE - LOCAL SUPPORT

Belzona have over 140 Distributors in more than 120 countries ensuring not only the availability of Belzona materials, but also specification support, project management, application and supervision services. Distributorships and their teams are supported by Belzona Corporate offices in Europe, North America and Asia.

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End Users,
EPC Contractors
Other Interested Parties
Technical Considerations – Process Parameters

- On-going integrity management through repair design life

  - An important stage in the whole process and is the responsibility of the end user to adopt a Risk Based Approach (RBI) type of inspection technique

  - Due consideration must be given to the reason for which the engineered compliant composite repair system was required in the first place

  - For external corrosion mechanisms and externally applied loads (such as in case of buried or submerged pipes), the integrity of the composite wrap may be examined visually and by using other non-destructive techniques as applicable

  - For internal corrosion modes, the client may use any technique as may be convenient to them and appropriate to the situation at hand.
    - Belzona® has carried out X-Ray detection tests and results have proven to be excellent as shown on the next slide
Technical Considerations – Process Parameters

- On-going integrity management through repair design life
Decommissioning of engineered composite repair

- A decision that is typically taken as the engineered composite repair approaches its design life.

- Adequate systems of work and documentation must be maintained – minutes of meetings shall be recorded; points raised and observations shall be noted.

- The final (timely and informed) decision would basically be to proceed with a further repair or to seek a replacement of the composite repair system as appropriate.
Technical Considerations – Product Parameters

- Belzona® Sue