Composite Solutions for Returning Strength to Damaged Assets

By Peter Johnson
Belzona Polymeric
World Leader in Composite Repair Solution

developed by working closely with major Oil and Gas companies since the 1970s.

Belzona Materials:

Resist aggressive chemicals and corrosion, slow down erosion

Provide complete protection in high temperature and high pressure environments

Success demonstrated by prequalification testing and case studies
Global Presence - Local Service

More than 140 Distributors operating in over 120 countries

Hajjan Trading – Distributor in Saudi Arabia Since 1982
Composite Solutions for Returning Strength to Damaged Assets

1. Composite Cold Bonding
2. Composite Wrapping

Used for;
Tanks, Vessels, Pipes...

Suffering from;
corrosion, wall thinning, leaking...

without Hot welding
Composite Cold Bonding and Structural Repair

For Pipework, Vessels, Tanks, Decks, Towers, Supports, Internal parts, etc...
Composite Cold Bonding - Advantages

- No Hot Welding
- Save Shutdown Cost/Time
- Simple / Quick Repair Time
- Strength can be calculated based on Test Data and Material properties
- No Corrosion After Repair
- No Heat Distortion to the base metal
Cold Bonding

Paste Method

Think of it as a “Composite sandwich”

Example: bonding deck/ tank external fittings
Cold Bonding

Injection method

Demonstration with Perspex to show material distribution
The Science & The Proof

- Design
  - How does it work?

- Stress Concentration Nodes are avoided
- Stress Dissipation Element (Belzona Material)
- Top metallic plate used for further reinforcing
- Provides protection to Belzona Material
The Science & The Proof
Opus, Bonding Separator Internals

2003, Fittings bonded with no risk of metal distortion

Excellent adhesion and compressive strength
Opus, Bonding Separator Internals

2003, Fittings bonded with no risk of metal distortion

Inspection after 8 years in service, flawless
Refinery Sprinkler System Bonding

Mobil, Altona Refinery, Australia
Deck Bonding

Cable tray supports bonding for BP Greater Plutonio

Belzona was chosen due superior characteristics and vendor support
Pipe Support Bonding
Gas Separation Plant, Thailand - Jan 2013
Pipe Support Bonding
Gas Separation Plant, Thailand - Jan 2013

Condition of Corrosion Under Support – After Wet Blasting
Severe metal loss revealed
Pipe Support Bonding
Gas Separation Plant, Thailand - Jan 2013

Belzona 1111 Supermetal was used for bonding metal plates provided by customer. Plate size was 350 mm x 250 mm. Bonding thickness was 2 mm.

Apply Belzona 1111 on the metal plate
Belzona 1111 Supermetal was used for bonding metal plates provided by Customer
Plate size was 350 mm.x 250 mm. Bonding thickness was 2 mm.
Pipe section was lifted up, bonded with metal plate securing with strap.

Bond metal plate with corroded pipe
Pipe Support Bonding
Gas Separation Plant, Thailand - Jan 2013

Belzona 1111 Supermetal was used for bonding metal plates provided by Customer.
Plate size was 350 mm x 250 mm. Bonding thickness was 2 mm.
Pipe section was lifted up, bonded with metal plate securing with strap.
Independent Testing

Cranfield Impact Centre Limited

Tested Several Properties

- Bending Moment – 7418 Lb (3364 Kg) To Break
- Impact Loading – 500 Joules Impact (No Damage)
- Drag Loading – 1 Tonne Drag (No Damage)
- Lap Shear – 4945 Lb (2243 Kg) To Break

Plate Bonding on Buchan Alpha

Based on excellent results Belzona was chosen as the solution and is on-going throughout North sea
Deck Bonding
CNR, Ninian Central Platform at the North Sea

Application
Deck Bonding

CNR, Ninian Central Platform at the North Sea

Inspection one year later
Independent Testing

Lehigh Testing Laboratories, Inc.

- Three different pipes pressure tested
- Pipe 1 – 3” DIA / SCH 80 / 12” Nipples
- Pipe 2 – 3” DIA / SCH 80 / Pipe Caps
- Pipe 3 – Welded construction pipe
- All pipes have: ½” hole and repaired with ¼” plate

Results

- Pipe 1 – 3050 psi (214 Kg/cm²) to failure
- Pipe 2 – 3100 psi (217 Kg/cm²) to failure
- Pipe 3 – 3400 psi (239 Kg/cm²) to failure
Prepare another 2 x pipe spools, specification as follows:

- **4-inch pipe, API 5L Gr. B, Sch. XS (8.56 mm)**
- Pressure-Temp Rating = **1,350 psig** at -20 to 100 F.
- Drill small hole (approx. **10 mm Dia.**) and grinding of metal wall to imitate the leak and corrosion.
Pipe Leak Bonding Repair
Offshore Oil&Gas Operator, Thailand - 2005

• Follow the same procedures for Abrasive Blasting and Cleaning Surface with Belzona 9111 (N.F. Cleaner/ Degreaser).

• Followed by application of Belzona 1111.
• Belzona 1111 was mixed and applied to the defect area
Pipe Leak Bonding Repair
Offshore Oil&Gas Operator, Thailand - 2005

- **Plate bonding spool:**
  - 6-inch pipe sleeve, same wall thickness at 1/4 of circumferential was blasted and cleaned prior to Belzona 1111 application.
  - Belzona 1111 was then spread over pipe surface and internal area of plate sleeve.
Pipe Leak Bonding Repair
Offshore Oil&Gas Operator, Thailand - 2005

- **Plate bonding spool:**
  - Edges chamfered to ensure Belzona 1111 spread with 45 degree at base of pipe.
Pipe Leak Bonding Repair
Offshore Oil&Gas Operator, Thailand - 2005

- Hydrostatic Test
- Adhesive failure between plate and product
- Pressure retention 200 bar
Composite Wrapping

Belzona SuperWrap

ISO24817 / ASME PCC2 Compliant Repair
For Pipeworks, Vessels
Composite Wrapping - Advantages
Belzona SuperWrap

- No Hot Welding
- Save Shutdown Cost/Time
- Simple / Quick Repair Time
- Reinstate the Pipe Strength compliant with ISO/ASME Standard
- No Corrosion After Repair
- No Heat Distortion to the base metal
Composite material repairs return strength to a weakened substrate by providing adhesion and hoop strength.

- Adhesion is affected by surface profile and area.
- Adhesion can be increased by
  - Selecting materials with high mechanical adhesion
  - Increasing surface area contact

- Hoop strength is affected by the composite cohesive strength

- How can hoop strength be increased?
  - No voids or creases
  - Proper wetting/consolidation
  - Stronger fiber
Compliant Solution

- Composite repair is pre-qualified against industry recognized standards
- Solution is mathematically engineered and applied by factory-trained personnel

Two critical variables to design for a composite repair are:

- Thickness
- Axial Extent
Governing documentation for nonmetallic composite solutions covering

- Required performance properties for the composite materials to be qualified
- Requirements for the design of the composite repair
- Training requirements for application, supervision, and designing of the composite repair system
- Requirements for successful execution including ASR, method statements, QA/QC documentation
Composite Materials & Standardisation
Belzona SuperWrap

ASME PCC 2

“Repair of Pressure Equipment and Piping: Nonmetallic Composite Repair Systems for Piping and Pipework”

ISO 24817

“Requirements and recommendations for the qualification and design, installation, testing and inspection of composite pipe repairs”
What is Compliance?

- Compliance is achieved when a standard is met
  - ISO/24817(2015),
  - ASME PCC-2 Section 4.1
  - Belzona’s compliant piping repair system is SuperWrap

- There are many non-compliant repair systems that can also be used for pipe repair
How Does a Wrap Comply?

- Prequalification testing carried out in accordance with ISO/24817 and ASME PCC-2
- Correct failure mode
- Validated training to ensure application standards
- Designs carried out in accordance with standards
Introducing a Compliant Solution

Surface Preparation

1. Surface preparation prior to installation of the repair must be the same as that used for pre-qualifying the repair system.
2. Belzona SW II has been pre-qualified onto carbon and stainless steel substrates.

**SSPC-SP 10 – ISO 8501-1 Sa 2 ½ - NACE No. 2**
NEAR WHITE METAL

Minimum average substrate profile of 75 micron (3 mil)

**SSPC-SP 11**
POWER TOOL CLEANING TO BARE METAL

Minimum average substrate profile of 25 micron (1 mil)
# Introducing a Compliant Solution

## Belzona SuperWrap Resin

#### Resin Selection - 100% solids epoxy based

- Outstanding mechanical adhesion
- Low tendency to creep
- No shrinkage when curing
- High HDT values
- High heat resistance
- Extremely durable

<table>
<thead>
<tr>
<th>Resin Type</th>
<th>Application Temperature Level (°C)</th>
<th>Maximum Service Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cool Climates</td>
<td>Above 5</td>
<td>80</td>
</tr>
<tr>
<td>Tropical Climates</td>
<td>Above 20</td>
<td>85</td>
</tr>
<tr>
<td>High Operating Temps</td>
<td>5 - 40</td>
<td>150</td>
</tr>
</tbody>
</table>
SuperWrap II Resins

SuperWrap II Resin Options

Belzona 1981
- Fast curing resin designed for application in cold environments
- Application temperature 5 – 20 °C

Belzona 1982
- Long working life resin designed for application in warmer environments
- Application temperature 20 – 40 °C

Belzona 1983
- Resin designed for application at service temperature levels up to 150°C (302°F)
- Application temperature 5 – 40 °C
Introducing a Compliant Solution

Belzona SuperWrap Reinforcement Sheet
Introducing a Complaint Solution

Belzona SuperWrap Release Film
Application Procedure for Superwrap II
Belzona SuperWrap Application

- Treat the defect Area
  - Plate Bond
  - Live Leak
- Prepared beyond repair area
  - Sa 2.5 or SP11
  - 75 microns or 25 microns
- Degrease
Application Procedure for Superwrap II
Belzona SuperWrap Application

Mix and apply resin to wet out the surface profile
Application Procedure for Superwrap II
Belzona SuperWrap Application

Wet out Belzona 9381 Reinforcement sheet with same resin
Application Procedure for Superwrap II
Belzona SuperWrap Application

Wrap wetted out reinforcement sheet around pipe
Repeat this Process to build up the required number of wraps / layers
Application Procedure for Superwrap II
Belzona SuperWrap Application

Tightly wrap Belzona 9382 around the repair
Application Procedure for Superwrap II
Belzona SuperWrap Application

Secure ends in place with masking tape
Once cured, remove 9382 and masking tape.
## Composite Materials & Standardisation

### Belzona SuperWrap Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Details</th>
<th>Test Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tensile Properties</strong></td>
<td>Tensile Strength, Tensile Modulus, Poisson’s Ratio, Strain to Failure</td>
<td>ASTM D3039 – Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials</td>
</tr>
<tr>
<td><strong>Thermal Expansion</strong></td>
<td>Coefficient of Thermal Expansion</td>
<td>ISO 11359 – Plastics – Thermomechanical Analysis</td>
</tr>
<tr>
<td><strong>Lap Shear Adhesion Strength</strong></td>
<td>Shear strength of composite bonded to substrate</td>
<td>EN 1465 – Lap Shear Strength, Adhesives, Rigid to Rigid Bonded Assemblies</td>
</tr>
<tr>
<td><strong>Structural Integrity</strong></td>
<td>Wrapped pipe with defect to survive short-term pressure test</td>
<td>ISO 24817 – Annex C Short-term Pipe Spool Survival Test</td>
</tr>
</tbody>
</table>
# Composite Materials & Standardisation

## Belzona SuperWrap Properties

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<tr>
<td><strong>In-Plane Shear Modulus</strong></td>
<td>Shear Modulus by V-Notched Beam Method</td>
<td>ASTM D 5379 Standard Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method</td>
</tr>
<tr>
<td><strong>Energy Release Rate</strong></td>
<td>Toughness parameter for the repair/substrate interface</td>
<td>ISO 24817 – Annex D -Measurement of $\gamma_{LCL}$ for through-wall defect calculation</td>
</tr>
<tr>
<td><strong>Long-Term Strength</strong></td>
<td>Long-term (creep rupture) strength of the composite repair</td>
<td>ISO 14692 – Annex E – Measurement of performance test data</td>
</tr>
<tr>
<td><strong>Long-Term Lap Shear Performance</strong></td>
<td>Measurement of lap shear adhesion strength after 1000 hours of heat exposure (at 40$^\circ$C)</td>
<td>EN 1465 – Lap Shear Strength, Adhesives, Rigid to Rigid Bonded Assemblies</td>
</tr>
</tbody>
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## Composite Materials & Standardisation

### Belzona SuperWrap Properties

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<tr>
<th>Properties</th>
<th>Reinforced Belzona 1981</th>
<th>Reinforced Belzona 1982</th>
<th>Carbon Steel (For comparison reasons)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tensile Strength</strong></td>
<td>(H) 524 MPa</td>
<td>(H) 505 MPa</td>
<td>400-550 MPa*</td>
</tr>
<tr>
<td></td>
<td>(A) 126 MPa</td>
<td>(A) 121 MPa</td>
<td></td>
</tr>
<tr>
<td><strong>Young’s Modulus</strong></td>
<td>(H) 38,800 MPa</td>
<td>(H) 38,600 MPa</td>
<td>200 GPa*</td>
</tr>
<tr>
<td></td>
<td>(A) 18,300 MPa</td>
<td>(A) 15,475 MPa</td>
<td></td>
</tr>
<tr>
<td><strong>Poisson’s ratio</strong></td>
<td>(H) 0.26</td>
<td>(H) 0.26</td>
<td>0.27 – 0.3*</td>
</tr>
<tr>
<td></td>
<td>(A) 0.27</td>
<td>(A) 0.13</td>
<td></td>
</tr>
<tr>
<td><strong>Thermal Exp. (mm/mm°C)</strong></td>
<td>(H) 9.44 E-06</td>
<td>(H) 11 E-06</td>
<td>8-12 E -06*</td>
</tr>
<tr>
<td></td>
<td>(A) 13 E-06</td>
<td>(A) 21 E-06</td>
<td></td>
</tr>
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## Composite Materials & Standardisation

### Belzona SuperWrap Properties

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<tr>
<td><strong>Tensile Shear Adhesion</strong></td>
<td>15.5 MPa</td>
<td>12.3 MPa</td>
</tr>
<tr>
<td><strong>Energy Release Rate</strong></td>
<td>68.57 J/m²</td>
<td>76.53 J/m²</td>
</tr>
<tr>
<td><strong>Short-Term Survival Test</strong></td>
<td>Passed when tested up calculated testing pressure level of 39.2 MPa</td>
<td></td>
</tr>
<tr>
<td><strong>Long-Term Survival Test</strong></td>
<td>60 MPa sustained for 1,000 h</td>
<td>60 MPa sustained for 1,000 h</td>
</tr>
</tbody>
</table>
Approvals and Specs
Belzona SuperWrap Testing

- ABS Approved
- KOC Specified
- EMEPI Specified
- OHE Tested
Delivering success
Belzona SuperWrap Process
Composite Wrap Overview
Belzona SuperWrap Compliance

- Hybrid reinforcement sheet infused with resin and compressed with release film
- Tested in accordance with ISO 24817 and ASME PCC-2
- Designed in accordance with equations from standards
- Installers/Supervisors trained in accordance with standards
- Engineered Design Life
Composite Wrapping
Belzona SuperWrap
Composite Wrapping
Belzona SuperWrap

Riser Pipe, Gulf of Thailand
Composite Wrapping
Belzona SuperWrap

Riser Pipe, Gulf of Thailand
Composite Wrapping
Belzona SuperWrap Bend and Tee

Gas Flowline, Gulf of Thailand
Different Geometry
Belzona SuperWrap on different Shapes
Composite Solutions for Returning Strength to Damaged Assets
Thank you for your time

Any questions?