Use of Underwater Dry Welding for In-Situ Repair to Offshore Structures

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In-Situ Welding

- Steel Structures

- Suitability of Repair Methods

- Mobile Offshore Units
  - Dry Docking Schedule (Inspection and Repair)
  - Underwater Inspection In-Lieu of Dry Dock (UWILD)

- Fixed Offshore Units
Difficulties in Welding

- Welding Challenges
- Diver and Operational Challenges
Welding Challenges

- Water
  - Rapid Cooling Rates
  - Hydrogen
  - Cracking

- Ambient Pressure
  - Porosity

- Material
  - Higher carbon content (Older)
  - Alloyed Steels

Operational Challenges

- **Welder Challenges**
  - Environment
    - Sea state and current
    - Visibility
  - Weld Location
    - Access to Weld Area
    - Fatigue
  - Technique

- **Repair Time Challenges**
  - Diving weather window
  - Depth limited dive time
Welding Codes

- Welding Procedure Specification

- Classification Body Codes
  - DNV GL
  - ABS
  - Lloyd’s Register
  - Bureau Veritas

  - Weld Classification
    - Class A – suitable for comparable applications to surface welding
    - Class B – suitable for less critical applications and fitness for purpose
    - Class O – meet additional code or standard requirements
Welding Procedure Specification

A document which outlines the steps to be followed to produce a weld with the required properties.

Some Essential Variables:
- Depth
  - Ambient Pressure
- Steel chemical composition (Carbon and Carbon Equivalent)
  - Hardenability (350HV10)
- Welding consumables
- Pre- and Post- Heating
# Weld Classes

<table>
<thead>
<tr>
<th></th>
<th>Class A</th>
<th>Class B</th>
</tr>
</thead>
<tbody>
<tr>
<td>**Visual Inspection /</td>
<td>No visible cracks, porosity, or inclusions</td>
<td>No visible cracks</td>
</tr>
<tr>
<td>Surface Inspection**</td>
<td>Maximum undercut 1.5mm</td>
<td>Maximum undercut 3mm</td>
</tr>
<tr>
<td><strong>Material Properties</strong></td>
<td>Weld metal yield and tensile strength to meet or exceed base material</td>
<td>Weld metal tensile strength to meet or exceed base material specification</td>
</tr>
<tr>
<td></td>
<td>specification</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hardness below 325HV10</td>
<td>Hardness below 375HV10</td>
</tr>
<tr>
<td></td>
<td>For specified tensile strength below 485MPa, average impact of 27J</td>
<td>For specified tensile strength below 485MPa, average impact of 20J</td>
</tr>
<tr>
<td></td>
<td>(minimum 14J)</td>
<td>(minimum 14J)</td>
</tr>
<tr>
<td><strong>Non-Destructive Testing</strong></td>
<td>Radiographic Testing</td>
<td>Radiographic Testing</td>
</tr>
<tr>
<td></td>
<td>Ultrasonic Testing</td>
<td></td>
</tr>
</tbody>
</table>
Methods of Underwater Welding

**Wet Welding**
- Welding arc and weld is not separated from the water

**Dry Spot Welding – NEPSYS**
- Weld is separated from the water
- Diver is separated from the water

**Hyperbaric Welding**
- Weld is separated from the water
- Diver is not separated from the weld
## Welding Method Comparison

<table>
<thead>
<tr>
<th></th>
<th>Wet</th>
<th>Dry Spot (NEPSYS)</th>
<th>Hyperbaric</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Typical Quality</strong></td>
<td>Class B</td>
<td>Class A</td>
<td>Class A</td>
</tr>
<tr>
<td><strong>Repair Depth</strong></td>
<td>Achieved up to 100m</td>
<td>Achieved up to 60m</td>
<td>Achieved up to 400m</td>
</tr>
<tr>
<td><strong>Repair Materials</strong></td>
<td>Carbon Content &lt;0.1%, and</td>
<td>Restrictions comparable to</td>
<td>Restrictions comparable to</td>
</tr>
<tr>
<td></td>
<td>Carbon Equivalent &lt;0.37%</td>
<td>surface welding</td>
<td>surface welding</td>
</tr>
<tr>
<td></td>
<td>Limited wet welding</td>
<td>Variety of electrodes</td>
<td>Variety of electrodes</td>
</tr>
<tr>
<td></td>
<td>specific electrodes</td>
<td>may be used</td>
<td>may be used</td>
</tr>
<tr>
<td><strong>Application</strong></td>
<td>Almost nil restrictions</td>
<td>Some restrictions due to</td>
<td>Restrictions due to</td>
</tr>
<tr>
<td></td>
<td>to weld area geometry</td>
<td>habitat size and weld</td>
<td>chamber size and weld</td>
</tr>
<tr>
<td><strong>Safety</strong></td>
<td>Welder mobility</td>
<td>Welder mobility</td>
<td>Separation of Welder and</td>
</tr>
<tr>
<td></td>
<td>Separation of Welder and</td>
<td></td>
<td>water</td>
</tr>
<tr>
<td></td>
<td>weld</td>
<td></td>
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</table>
### Typical Commercial Comparison

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Qualification and Set Up</td>
<td>Weld and Welder qualification</td>
<td>Small habitat design / fabrication</td>
<td>Large chamber design / fabrication</td>
</tr>
<tr>
<td>Project Mobilisation</td>
<td>Personnel</td>
<td>Diving spread</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Welding equipment and consumables</td>
<td>Welding / habitat equipment and consumables</td>
<td>Welding / chamber equipment and consumables</td>
</tr>
<tr>
<td>Operations</td>
<td>Vessel / personnel</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Welding speed comparable to surface welding</td>
<td>Habitat set up / removal by divers</td>
<td>Chamber set up / removal by vessel crane</td>
</tr>
<tr>
<td></td>
<td>Reduced Welding Speed</td>
<td>Welding speed comparable to surface welding</td>
<td></td>
</tr>
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<tbody>
<tr>
<td><strong>Qualification and Set Up</strong></td>
<td>Days to Weeks</td>
<td>Weeks to Months</td>
<td>Months</td>
</tr>
<tr>
<td></td>
<td>Low Cost</td>
<td>Medium Cost</td>
<td>High Cost</td>
</tr>
<tr>
<td><strong>Project Mobilisation</strong></td>
<td>Days to Weeks</td>
<td>Days to Weeks</td>
<td>Weeks</td>
</tr>
<tr>
<td></td>
<td>Low Cost</td>
<td>Low to Medium Cost</td>
<td>High Cost</td>
</tr>
<tr>
<td><strong>Operations</strong></td>
<td>Small Vessel</td>
<td>Small Vessel</td>
<td>Larger Vessel including crane</td>
</tr>
<tr>
<td></td>
<td>Low number of dives</td>
<td>Medium number of dives</td>
<td>Low number of dives</td>
</tr>
</tbody>
</table>
Case Study - NEPSYS System

- Habitat which isolates the weld area is designed.
  - Accommodates the geometry of the area surrounding the weld
  - Incorporates windows for visibility and access to the weld
- Heated gas displaces the water, creating a dry, protected environment for welding
- Welding Rods are coated and hermetically sealed to protect from the environment before being used in welding
Case Study

- 1.5m diameter raked pile
- Approximately 25% of the circumference was damaged at -17m LAT
- Damage to the underside of the pile
- Contacted by client in August
- Grouting of piles in October

- Options for repair:
  - Removal and Re-piling
  - Clamp
  - Repair Patch via wet weld
  - Reinstatement of Material via dry welding
Welding Qualification

- Base Steel had high Carbon Content 0.18% (CE 0.44%)
- Initial Hardness Testing – Maximum 276HV10

- Weld preparation designed to minimise welding time
- Procedure qualification in the Vertical and Overhead positions over three weeks
- Qualification in Perth witnessed by third party
- Multiple welder qualification
Insert Plate and Habitat Design

- Insert plate design adapted for damage profile, welding procedure
- Habitat design adapted for insert plate profile
- Habitat fabrication (one week)

- Removal of damaged area via water jetting which left edges suitable for welding
- Insert plate installation allowed progression of grouting works
Mobilisation from Perth to Queensland of NEPSYS equipment and personnel
Operations conducted with local dive spread
Diving from the back of a 15m work boat
Nitrox mixture used to ensure longer dive times at the repair depth
Four qualified welders
Approximately 45 hours of welding
2800mm of weld in 16mm plate
**Results**

- Weld ground flush to the pile
- No surface defects found via Magnetic Particle Inspection or Creep Wave Ultrasonic Testing
- No subsurface defects found via Shear Wave Ultrasonic Testing or Time of Flight Diffraction
- Damaged area fully removed from the pile and reinstated
- Design strength of the pile restored
Conclusion

- In-situ repair options
- Suitability of Welding Methods
- Questions?