SIMULATION OF COATING BEHAVIOR IN BURIED SERVICE ENVIRONMENT

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ShawCor Research & Development
The Paper comprises:

- Description of the coating systems under evaluation
- Test apparatus used for their evaluation
- Results of the investigation
General Corrosion Prevention Methods

• Prevent Corrosive species to get to the metal by having the coating maintain its integrity when buried
• Use of Inhibitors
• Use of Cathodic Protection
• etc...
The Coating Integrity depends on:

- Type of soil
- Soil compaction
- Wet & Dry Cycles
- Burial depth
- Freeze & Thaw Cycles
- Operating temperature
- Pipe size
- etc..
Mechanically Induced Stresses are classified into four categories

- Static Stress (Load - Soil type & pipe wt)
- Axial Stress (Expansion / Contraction of pipelines)
- Circumferential stress (Lateral Movement of the Pipe at bends)
- Random Stress (soil swelling and shrinking)
Coating Systems Evaluated

- Extruded Polyethylene (2LPE)
- F.B.E.
- 3-Layer Polyethylene (3LPE)
- Cold Applied Tapes
- Heat Shrinkable Sleeves
Extruded Polyethylene (2LPE)

- In use since the 60’s
- Generally Soft Adhesive/Sealant
- High Density P.E.
- Very well suited for Small Diameter Pipes
FBE (Fusion Bonded Epoxy)

- In use since the 70’s
- Good properties at low and high temperatures
- Hard Coating
- Suitable for any pipe size – most commonly large diameter
3 Layer Polyethylene (3LPE)

- In use since the 80’s
- Extensive use in Europe / Asia & increasing in North America
- A combination of the previous two coatings
- Adhesive is a Hot Melt
- Can be used for any pipe size
Cold Applied Tapes

- An early method of protecting pipelines
- Rubber-based adhesives
- Most common for:
  - Low Operating Temps.
  - Small Size pipes
Heat Shrinkable Sleeves

- In use for >30 Years
- Uses a variety of adhesives and PE’s
- PE topcoat is cross-linked and stretched
- Shrinking develops continuous hoop stresses
Test Apparatus
Soil Box

- Box (1.5 x 1.0 m)
- Pump (circulates heated oil)
- Reversible Electric Drive with Limit Switch
- Main Panel
- Pressure plate
- Air Piston
Sample Preparation

- Coated pipes – 54” (1.37m) long
- Samples are applied at the mid-point of 54” pipe

Type of Soil
- Any type is possible
- For this testing, a mixture of dry soil and gravel was used
Procedure

• Place sample into the Soil Box
• Secure the Sample
• Fill the Soil Box
• Install Pressure Plate
• Set the key variables:
  - Number of cycles
  - Speed of movement
  - Distance of travel
  - Temperature of Circulating Oil
# Sample Evaluation

<table>
<thead>
<tr>
<th>Sleeves</th>
<th>Tapes</th>
<th>Coatings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration of sand under the sleeve</td>
<td>Penetration of sand under the seams</td>
<td>Abrasion Resistance</td>
</tr>
<tr>
<td>Displacement of sleeve</td>
<td>Integrity at Overlaps</td>
<td>Wrinkling</td>
</tr>
<tr>
<td>Wrinkling/Tearing</td>
<td>Wrinkling</td>
<td>Tearing</td>
</tr>
<tr>
<td>Closure Integrity</td>
<td>Tearing</td>
<td>Shifting</td>
</tr>
<tr>
<td>Disbondment</td>
<td>Disbondment</td>
<td>Disbondment</td>
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</table>
# Results at 23°C
*(X = No Changes observed)*

<table>
<thead>
<tr>
<th># of Cycles</th>
<th>2LPE</th>
<th>3LPE</th>
<th>FBE</th>
<th>Tapes</th>
<th>Heat-Shrinkable Mastic Sleeves</th>
<th>Heat-Shrinkable Hot Melt Sleeves</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>40</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Minor Lifting</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>100</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Major Wrinkling</td>
<td>Some soil penetration</td>
<td>X</td>
</tr>
<tr>
<td>150</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Wrinkling and Shifting</td>
<td>Closure Lift-up</td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>X</td>
<td>X</td>
<td>Minor Scratches</td>
<td></td>
<td>Minor soil Penetration</td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>Minor Scratches</td>
<td>Minor Scratches</td>
<td>Minor Scratches</td>
<td></td>
<td>Major soil Penetration</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>A few major scratches</td>
<td>Minor Scratches</td>
<td>A few major scratches</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Results at 60°C

*(X = No Changes observed)*

<table>
<thead>
<tr>
<th># of Cycles</th>
<th>2LPE</th>
<th>3LPE</th>
<th>FBE</th>
<th>Tapes</th>
<th>Heat-Shrinkable Mastic Sleeves</th>
<th>Heat-Shrinkable Hot Melt Sleeves</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>40</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Major Wrinkling</td>
<td>Some soil penetration</td>
</tr>
<tr>
<td>100</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Wrinkling and Shifting</td>
<td>X</td>
</tr>
<tr>
<td>150</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>250</td>
<td>Minor Scratches</td>
<td>Minor Scratches</td>
<td>Minor Scratches</td>
<td>Minor soil Penetration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>Minor Scratches</td>
<td>Minor Scratches</td>
<td>Minor Scratches</td>
<td></td>
<td>Major soil Penetration</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>A few major scratches</td>
<td>Minor Scratches</td>
<td>A few major scratches</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Observations

• Most samples passed higher # of Cycles than expected

• “Continuous Coatings” (FBE, 2LPE, 3LPE):
  – Minimal effects of temperature (23/60°C)
  – Minimal effects on # of cycles
  – PE and FBE damage was abrasion-related with PE slightly better than FBE
Observations ... continued

• Sleeves:
  - Hot Melts performed better than Mastics, particularly at higher temperatures
  - Residual Hoop Stresses help the performance

• Tapes:
  - Wrinkling & sand penetration occurred at 23 & 60°C
  - Failure occurred at lowest # of cycles

• Profiles/Overlaps are the weak points
Failures Due To Soil Ingress Between Adhesive & Pipe

Probable Causes:

- Poor bond of adhesive to the pipe coating
- Poor coating application
- Poor surface preparation
Failure between Adhesive & Top Coat

- Adhesive did not bond well to PE Backing
- Clay Soils tend to bond tenaciously to the PE and cause the pipe to slide inside
Failure at Overlaps

- Too many overlaps
- Relatively low hoop stresses
Abrasion Failures

- Scratches
- PE slightly better than FBE
Failure of Low Cohesive Strength Adhesives

• Hot Melt vs. Mastic adhesive technologies
• Lower shear strength adhesive
**Swedish DH Specification:**
- Sand / Gravel mixture
- Simulated 3 or 6 ft. depth
- Travel 1 cm/minute
- Longitudinal 10 cm distance
- Pass = 20 cycles

<table>
<thead>
<tr>
<th>Pipe Diameter (Inches)</th>
<th>HSS/Hot Melt at 23°C</th>
<th>HSS/Hot Melt at 50°C</th>
<th>HSS/Mastic at 23°C</th>
<th>HSS/Mastic at 50°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>6”</td>
<td>&gt; 500</td>
<td>&gt; 250</td>
<td>&gt; 50</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>12”</td>
<td>&gt; 250</td>
<td></td>
<td>&gt; 25</td>
<td>&lt; 5</td>
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<tr>
<td>24”</td>
<td></td>
<td></td>
<td>&lt; 25</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>36”</td>
<td></td>
<td></td>
<td>&lt; 25</td>
<td>&lt; 5</td>
</tr>
</tbody>
</table>
Excellent coatings and girth welds protection systems are available but “always” a compromise

- Cost
- Surface Preparation
- Installation Time
- Pre-Heat
- Type of Backfill
- Equipment availability
- Crew size
- Inspectability
- Sensitivity to application conditions
Conclusions

- Coatings with smooth continuous outer sheath (2LPE, 3LPE and FBE) performed very well.
- The greater the number of exposed edges, the more the coating is prone to soil penetration.
- Mastic adhesives are more sensitive to temperature (Adhesive shear resistance at operating temperature is important).
- Given the same adhesive, coatings with X-linked Top-coats and High Hoop Stresses perform better than the coatings without X-Linking or Hoop Stresses.