The Effect of Water Aging on Cured-In-Place Pipe (CIPP) Samples Using Non-Destructive Tests

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Nondestructive Testing
What is CIPP?

- Installation: Inversion or pull in
- Positioning: air pressure or water pressure
- Curing: hot water or steam or UV-curing
Abnormalities of CIPP
Inspect of CIPP

Now

reparation

transportation

to laboratory

Future
Electromagnetic spectrum

Microwaves (dm-, cm-, mm-waves)
## Nomenclature

<table>
<thead>
<tr>
<th>Name</th>
<th>Metric name</th>
<th>Wavelength</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microwaves</td>
<td>Decimeter waves</td>
<td>1 m to 10 cm</td>
<td>300 MHz to 3 GHz</td>
</tr>
<tr>
<td></td>
<td>Ultra High Frequency (UHF)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Centimeter waves</td>
<td>Centimeter waves</td>
<td>10 cm bis 1 cm</td>
<td>3 GHz to 30 GHz</td>
</tr>
<tr>
<td></td>
<td>Super High Frequency (SHF)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Millimeter waves</td>
<td>Millimeter waves</td>
<td>1 cm to 1 mm</td>
<td>30 GHz to 300 GHz</td>
</tr>
<tr>
<td></td>
<td>Extreme High Frequency (EHF)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terahertz waves</td>
<td>Decimillimeter waves</td>
<td>1 mm to 0.1 mm</td>
<td>300 GHz to 3 THz</td>
</tr>
</tbody>
</table>

ICT, Wikipedia, ITWissen
Scattering parameter S11 at each measurement position for 201 frequencies
Detection of defects in CIPP

Microwave-surface scan of a CIPP specimen with artificial defects (flat bottom hole) from the undamaged side
## Sample properties

<table>
<thead>
<tr>
<th>Profile</th>
<th>Material</th>
<th>Fibre</th>
<th>Leakage test</th>
<th>Elastic modulus [MPa]</th>
<th>Bending stress [MPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN1000</td>
<td>Needle felt</td>
<td>Not woven</td>
<td>yes</td>
<td>3247</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Unsaturated Polyester</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Experimental

Polishing → Optic microscop Leica DM6000M → Microwave test → 1 hour at 100°C

After 1 day, 1 week, 3 weeks and 5 weeks → Water aging at room temperature
Process of saturation

\[ \% \text{increase in weight} = \frac{\text{wet weight} - \text{conditioned weight}}{\text{conditioned weight}} \times 100 \]

Specimen 1: 0.52%
Specimen 2: 0.54%
Optic mikroscope analyze

Sample1
Optic mikroscope analyze

Sample2
Elongation of fibres

\[
\% \text{increase in length} = \frac{\text{length after aging} - \text{length before aging}}{\text{length before aging}} \times 100
\]

from 1.03% to 1.41%

green specimen 1 and blue specimen 2
Reflection measurement in time domain mode

![Graph showing reflection measurements before and after aging for specimens 1 and 2.](image)
# CIPP characterization before and after aging

<table>
<thead>
<tr>
<th></th>
<th>before aging Specimen 1</th>
<th>after aging Specimen 1</th>
<th>before aging Specimen 2</th>
<th>after aging Specimen 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weight (g)</strong></td>
<td>13.0382 (Conditioned weight)</td>
<td>13.1060</td>
<td>13.4925 (Conditioned weight)</td>
<td>13.5651</td>
</tr>
<tr>
<td><strong>Thickness (mm)</strong></td>
<td>16.02</td>
<td>16.20</td>
<td>16.14</td>
<td>16.33</td>
</tr>
<tr>
<td><strong>Time of flight (ps)</strong></td>
<td>180.0</td>
<td>202.5</td>
<td>180.0</td>
<td>202.5</td>
</tr>
<tr>
<td>(c \text{ (m/s)} \times 10^{8})</td>
<td>1.780</td>
<td>1.600</td>
<td>1.793</td>
<td>1.613</td>
</tr>
<tr>
<td>(\varepsilon'_r)</td>
<td>2.84</td>
<td>3.51</td>
<td>2.80</td>
<td>3.45</td>
</tr>
</tbody>
</table>
Conclusion

- Increase of the weight
- Increase thickness
- Water absorption could be observed by growth in size of the fibres
- The microwave attenuation and time shift measurements showed sensitivity of the complex permittivity with water absorption
- Increase in water content significantly increased both time of flight and attenuation.
Thank you for your attention

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