



2nd IWA Leading-Edge Conference & Exhibition on **Strategic Asset Management**

Degradation of lining systems for drinking water networks

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Corrosion is a major reason for bursts and leaks of metallic pipes as well as reduced water quality

Those pipes need to be protected

.....Corrosion may occur even through protection systems



Impact on Asset Management

- Are the corrosion protection systems really protective?
- Have they any consequence for drinking water quality?
- What will be the actual service life?
- What will be the consequence for material selection?
- What will be the consequence for rehab method selection?

....This was the background why Norwegian cities jointly carried out research in several steps



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Linings that have been in practical used were adressed

- Cement mortar linings provided by pipe manufacturer
- Cement mortar linings performed in-situ
- Epoxy linings
- Cured-in-place pipes

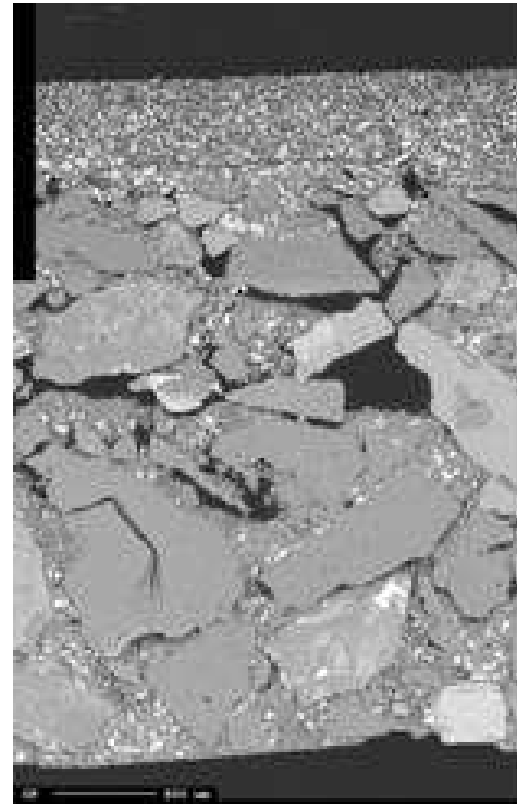
Polyuretan linings have recently been introduced and are not included in these studies



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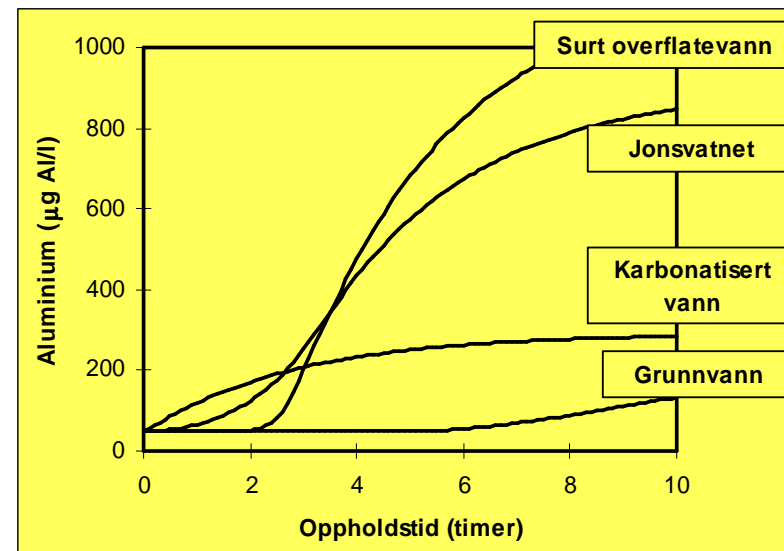
How were the concrete lining systems made?

- **Cement type**
 - Standard Portland
 - Alumina
 - Modified cements (fly ash, blast furnace slag cement)
- **Lining method**
 - Rotating spray unit (homogenous protection layer)
 - Rotating pipe (dense protection layer towards water)



Some results valid for soft/acidic water qualities

- "Rotating pipe" + modified cement with fly ash or slag appears the most stable
- "Rotating spray" + Portland cement linings (1. generation) are not resistant to degradation
- Alumina cement linings appear not stable, aluminium released to water body (problem even after 25 years)

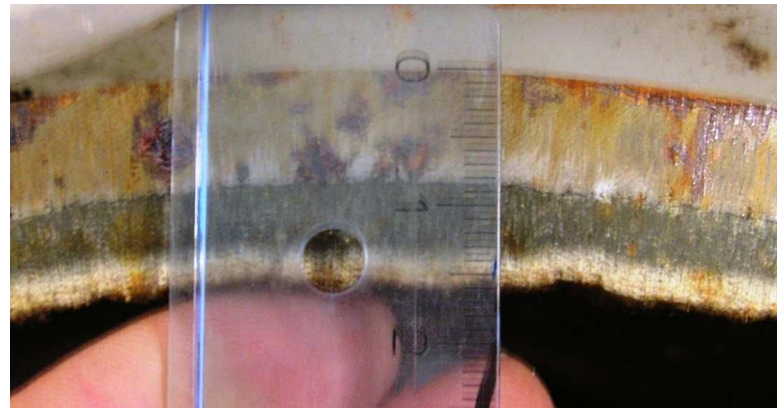
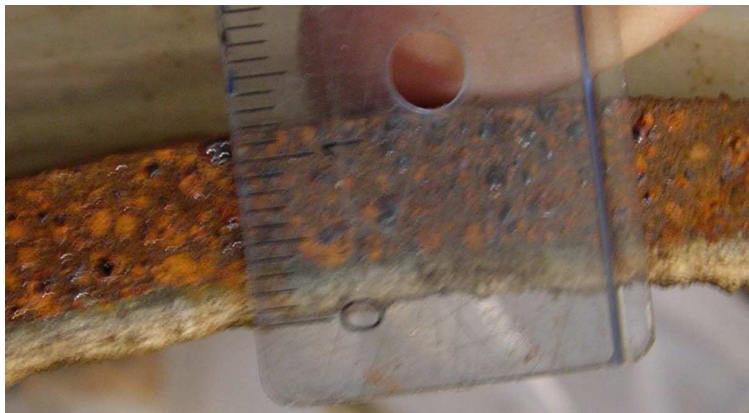


New investigation - concrete linings

- Nine samples arrived at laboratory in 2006
 - Renovated, 1970+1998/2000
 - Original, 1966-1977
- Visual test to observe surface degradation
- Laboratory processing
 - Thickness of lining
 - pH indicator (phenolftalein)
 - Adhesion to pipe surface
 - SEM (Scanning Electron Microscope)



Visual test of in-situ lining: Uneven wall thickness



Results from lab investigations

- Lined at the producer (slag cement used)
 - 1974 "some signs of corrosion"
 - 1970 "some corrosion"
 - 1970 "no corrosion"
 - xxxx "significant corrosion"
 - 1977 "no corrosion"
 - 1975 "several corrosion spots"
- Lined on site (Portland cement used)
 - 1970 "significant corrosion"
 - 1998 "no signs of corrosion"
 - 1998 "no signs of corrosion"
 - 1997 "indices of corrosion"



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Assessment concrete linings

■ Properties

- Pipe samples were either Portland cement (in-situ lined) or blast furnace slag cement (lined at manufacturer)
- The original linings were aged from 1966-1977, and the in-situ performed linings from 1998-2000

■ Findings

- The in-situ lined samples had uneven thicknesses
- All samples were degraded until depths from 2.1 to 5.0 mm (degraded zone represents a $\text{pH} < 9.5$)
- The majority of samples indicated corrosion attack and two of them were strongly affected



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Epoxy and CIPP based linings

- Six test samples received at laboratory in 2006.
- Pipes originally built in 1966-70, renovated in 1998-2000
- Visual test to observe surface degradation
- Laboratory processes
 - Longitudinally cut, cleaned and inspected
 - Lining thickness
 - Adhesion to pipe surface



Assessment epoxy and CIPP based linings

■ Epoxy linings

- General good corrosion protection, no blistering/corrosion under lining were observed
- Limited adhesion to pipe wall and partly delamination, but lining performance seem not affected by this
- Epoxy linings thinner than recommended today

■ CIPP linings

- No degradation of CIPP linings were observed
- Stretch test indicated adequate adhesion to pipe wall



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Conclusion: Impact on Asset Management

- Are the corrosion protection systems really protective?
 - Prior corrosion of pipes has been stabilised by the in-situ lining. The plastic lining and cement mortar lining has completely covered the corrosion pits
 - Cement mortar linings are exposing some degradation, as well in-situ cement mortar lined pipes as original linings aged from 1970's
- Have they any consequence for drinking water quality?
 - Alumina cement mortar linings should not be used for drinking water systems
- What will be the actual service life?
 - Plastic linings (CIPP and epoxy) seems to maintain the structure without any sign of degradation, service life > 50 years



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Thank you for listening!

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