PROTECTING SEVERE WASTEWATER STRUCTURES

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The Problem:

Deterioration of wastewater infrastructure. Traditional protective coatings not offering necessary protection.
VAPOR PHASE ATTACK
Collection: manholes

biogenic sulfide corrosion
VAPOR PHASE ATTACK

Collection: lift stations

biogenic sulfide corrosion
VAPOR PHASE ATTACK

Collection: lift stations

biogenic sulfide corrosion
VAPOR PHASE ATTACK

Collection: interceptors

biogenic sulfide corrosion
VAPOR PHASE ATTACK

Treatment: influent channels

biogenic sulfide corrosion
VAPOR PHASE ATTACK

Treatment: junction boxes

biogenic sulfide corrosion
LIQUID PHASE ATTACK

Treatment: primary

aluminum sulfate exposure
LIQUID PHASE ATTACK

Treatment: primary

ferric chloride exposure
LIQUID PHASE ATTACK

Treatment: primary

chloride induced corrosion
LIQUID PHASE ATTACK

Example: Brewery process wastewater
LIQUID PHASE ATTACK

Example: Secondary Containment (acid) Exposure
LIQUID PHASE ATTACK

Example: Secondary Containment (acid) Exposure
Technical Reasons for Attack:

- Concrete is a mixture of portland or blend of cement, fine and coarse aggregates, water, and one or more admixtures.
- Freshly cast concrete has pH > 12
  - High pH = result of formation of calcium hydroxide by-product of hydration
  - Surface will not allow growth of any bacteria
- Exposure to acids with pH below 6.5 will attack most cementitious materials and below pH 4 all types will be attacked.
- Acid solutions can be naturally occurring or manmade
  - Decayed organic matter (biogenic sulfide corrosion)
  - Treatment chemicals or manufactured inorganic acids
SEVERE WASTEWATER ENVIRONMENTS

Sewer Gas Mixture
- Hydrogen sulfide (H₂S)
- Carbon dioxide (CO₂)
- Methane (CH₄)

Sewer Gas Mixture, typical
- H₂S: 60%
- CO₂: 37%
- CH₄: 3%

CONCRETE ATTACK

• Biogenic Sulfide Corrosion:
  – Biological oxidation of $\text{H}_2\text{S}$ to $\text{H}_2\text{SO}_4$ within headspace areas of enclosed wastewater structures

  $$\text{H}_2\text{S} + 2\text{O}_2 \xrightarrow{\text{Thiobacillus SOB}} \text{H}_2\text{SO}_4$$

  – $\text{H}_2\text{SO}_4$ attacks the matrix of the concrete above the waterline (i.e., pipe crowns, walls, soffits)
biogenic sulfide corrosion process illustration
SEVERE WASTEWATER ENVIRONMENTS

Contributing Factors

• Removal of heavy metals from waste stream
• Longer detention times
• Higher strength wastewater (in terms of elevated biochemical oxygen demand, e.g. BOD)
• More turbulence in collection system
• Utilization of odor control covers
• Over-designed wet wells for future capacities
METAL CORROSION
Vapor Phase Corrosion

Metallic appurtenances in lift station
METAL CORROSION

Vapor Phase Corrosion

metallic surfaces in covered primary clarifier
METAL CORROSION

Vapor Phase Corrosion

Vapor Phase

H₂S

CO₂

CH₄
METAL CORROSION

Vapor Phase Corrosion

ductile iron pipe
METAL CORROSION

Vapor Phase Corrosion
METAL CORROSION

Liquid Phase Corrosion
Not All Protective Coatings Perform:

Many high-performance protective coatings (linings) insufficiently perform in wastewater vapor phase environments.
COATING FAILURES

clean tar epoxy
COATING FAILURES

Coal tar epoxy
COATING FAILURES

Polyamide epoxy
COATING FAILURES

*Ceramic novolac epoxy on ductile iron pipe*
COATING FAILURES

polyurea elastomer
SEVERE WASTEWATER ANALYSIS TEST

• Developed by a coalition of industry experts to create an accelerated laboratory testing program to measure a coating’s resistance to severe wastewater headspace conditions.

• Simulates & accelerates conditions characteristic of severe wastewater headspace environments
  – Eliminates the long periods of time during normal wastewater exposure
  – Introduced at WEFTEC 2003 (Water Environment Federation Technical Exhibition & Conference)
  – Presented at PACE 2008 (Paint And Coatings Exposition)
  – Presented at UCT 2010 Conference (Underground Construction Technology)
  – Received NACE International’s MP Reader’s Choice Corrosion Innovation Award 2012.
SEVERE WASTEWATER ANALYSIS TEST, cont’d

• Measures the permeation and physical alterations of a protective lining in a period of 28-days
• Allows for quantitative evaluation of protective systems
• Commercially offered:
  1. RAE Engineering & Inspection, LTD
     www.RAEEngineering.ca
  2. Corrosion Testing Laboratories, Inc.
     www.CorrosionLab.com
  3. KTA-Tator, Inc.
     www.KTA.com
• The vapor phase is novel compared to “acid contact” laboratory testing regimens oftentimes used or referenced by the wastewater industry.

• Topic of numerous technical articles and presentations.
SEVERE WASTEWATER ANALYSIS TEST, cont’d

- NACE Corrosion Innovation of the Year 2012 Award
- ASTM G210-13
TESTING PARAMETERS

Laboratory Chamber Comprising:

1. Liquid Phase
2. Vapor Phase

S.W.A.T. Chamber
SEVERE WASTEWATER ANALYSIS TEST

TESTING PROCEDURE, *cont.*

A. Permeability
   – Coatings act as a barrier separating the substrate from the corrosive service environment
   – Low permeability to salts, water, gases, acids and other corrosive species are desired

• Measured via:
  1. Electrochemical Impedance Spectroscopy (EIS) Analysis
  2. Optical Microscopy Measurements
Electrochemical Impedance Spectroscopy Analysis
SEVERE WASTEWATER ANALYSIS TEST, cont’d

Increasing Protection

Poor

Protection Begins

Good

Excellent

Coating Impedance, Log Z (\(Z_{0.1\ Hz}\ \Omega \cdot \text{cm}^2\))

4 6 8 10

SEVERE WASTEATER ANALYSIS TEST (S.W.A.T):

EIS Analysis

Coating Impedance, Log Z

<table>
<thead>
<tr>
<th>Product</th>
<th>Initial</th>
<th>28 day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product A</td>
<td>10.7%</td>
<td>9.1%</td>
</tr>
<tr>
<td>Product B</td>
<td>11.3%</td>
<td>8.0%</td>
</tr>
<tr>
<td>Product C</td>
<td>11.4%</td>
<td>7.2%</td>
</tr>
<tr>
<td>Product D</td>
<td>10.1%</td>
<td>5.8%</td>
</tr>
</tbody>
</table>

Initial

28 day

High-Build Epoxy Mortars
SEVERE WASTEATER ANALYSIS TEST (S.W.A.T):

EIS Analysis

![Graph showing Coating Impedance, Log Z](chart)

- Product A: Initial - 11.3, 28 day - 11.1
- Product B: Initial - 11.9, 28 day - 10.7
- Product C: Initial - 11.5, 28 day - 9.8
- Product D: Initial - 10.1, 28 day - 0

High-Build Epoxy Liners

- Initial
- 28 day
SEVERE WASTEATER ANALYSIS TEST (S.W.A.T):

EIS Analysis

Coating Impedance, Log Z

Product A

Product B

Fiber-reinforced Epoxy Liners

Initial

28 day
OPTICAL MICROSCOPY ANALYSIS

Typical concrete cylinder coated with candidate systems

Concrete cylinder cross section

N.T.S.
OPTICAL MICROSCOPIC ANALYSIS, cont.

100% Solids Epoxy Mortar

Observation:
Total DFT 183 dft mils (avg.)
Permeation: 71 mils (avg.)

Permeation: 39%
Observation:
Total DFT: 59 dft mils (avg.)
Permeation: 5.5 mils (avg.)

Permeation: 9%
OPTICAL MICROSCOPY ANALYSIS, cont.

100% Solids Epoxy Liner

Observation:  
-Not attempted

Permeation: 100%
SEVERE WASTEWATER ANALYSIS TEST

TESTING PROCEDURE, cont.

B. Physical Testing
   – Any physical effects on the lining system are useful in detecting any
     significant changes a polymer may undergo as a result of exposure
   • Commonly used laboratory tests to measure physical properties:
     – Tensile Strength Testing
     – Flexural Strength Testing
     – Adhesion Testing
FIELD TESTING

• Typical testing sites

Field Racks & Permeation Samples, typical
FIELD TESTING, cont.

- Candidate coating systems
  - Concrete panels
  - Steel panels
- Concrete control panels
The Solution:
Perma-Shield®
An advanced generation, 100% solids epoxy coating with low permeation to sewer gases.
Employing a hydraulic pump to spray transfer material onto surface
Why Use High-Performance Protective Systems?
PROTECTING CONCRETE

High-Performance Protective Coatings are commonly employed to protect concrete:

- Provide a surface that is resistant to immersion, splashes, spills, and vapors from corrosive solutions
  - Acid attack
  - Alkali attack
  - Sulfates
- Protect structural rebar from corrosion
  - Chlorides
- Protect and enhance concrete integrity
  - Mechanical damage and wear
Epoxy Modified Mortar

- 100% volume solids, modified amine epoxy mortar for severe wastewater environments
- Concrete: 1/8 inch (125 mils) minimum
- Trowel applied (or spray transferred)
- Conducive for “tight” areas
- Optional: Series 435 Perma-Glaze for added protection
  - 15-20 mils
Applying Mortar onto surface using hydraulic transfer equipment.
Back-troweling Mortar

Backrolling using to level trowel licks
Example of finished Series
218/434/435 Perma-Shield system
Fiber Reinforced Epoxy

- 100% volume solids, fiber-reinforced, high-build, spray-applied epoxy lining for severe wastewater environments
- Concrete: 50-125 mils
- Conducive for large areas
  - Wet wells, primary clarifiers, etc.
- Optional: Epoxy Glaze Finish for added protection
  - 15-20 mils
Fiber Reinforced Epoxy Liner

FR high-build liner applications
Epoxy Mortar followed by Fiber-reinforced epoxy
Fiber Reinforced Epoxy
KEYS To Coatings Success

• Permeation resistance to sewer gases
• Adequate physical properties
• Chemical resistance

1. Trowel-applied epoxy mortar
2. Spray-applied epoxy liner
   • Resinous epoxy
   • Fiber-reinforced epoxy
High Performance Lining

Collection Systems

manholes
High Performance Lining
Collection Systems

lift stations
High Performance Lining
Wastewater Treatment

Influent Channels
HIGH-PERFORMANCE LININGS
Wastewater Treatment

Screening (“headworks”) Structures
High Performance Lining
Wastewater Treatment

Equalization Basins
HIGH-PERFORMANCE LININGS
Wastewater Treatment

(before/after)

Primary clarifier effluent channels
PERMA-SHIELD
Wastewater Treatment

Covered Primary Clarifiers