Development of a North America Drinking Water Pipelines’ Defect Coding and Condition Rating Standard

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Outline

- Project Background
- Project Scope and Framework
- Watermain Defect Coding and Condition Rating
- Q&A
Project Background

- Civil Infrastructure Condition Assessment
  - Distress/Defect Codes
  - Condition Rating (defect scores and weights)
  - Example
    - Water Research Centre’s (WRc) Manual of Sewer Condition Classification
    - WRc’s Sewerage Rehabilitation Manual
Project Background (cont’d)

• Example – WRc Defect Coding and Condition Rating
  Structural and Operational Defects - Examples
# Structural Defect Scores

*(based on WRc Sewerage Rehabilitation Manual 4th ed.)*

<table>
<thead>
<tr>
<th>Defect</th>
<th>MSCC Code</th>
<th>Description</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collapsed</td>
<td>X</td>
<td></td>
<td>165</td>
</tr>
<tr>
<td>Spalling</td>
<td>SSS</td>
<td>Slight</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>SSM</td>
<td>Medium</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>SSL</td>
<td>Large</td>
<td>120</td>
</tr>
<tr>
<td>Wear</td>
<td>SWS</td>
<td>Slight</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>SWM</td>
<td>Medium</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>SWL</td>
<td>Large</td>
<td>120</td>
</tr>
<tr>
<td>Deformation</td>
<td>D</td>
<td>• 0 – 5 %</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 6 – 10 %</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• &gt; 10%</td>
<td>165</td>
</tr>
</tbody>
</table>
Structural Condition Grades

- Structural Condition Grading Example

<table>
<thead>
<tr>
<th>Internal Condition Grade (ICG)</th>
<th>Peak Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (acceptable)</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>2</td>
<td>10 – 39</td>
</tr>
<tr>
<td>3</td>
<td>40 – 79</td>
</tr>
<tr>
<td>4</td>
<td>80 – 164</td>
</tr>
<tr>
<td>5 (worst, collapsed or collapse imminent)</td>
<td>≥ 165</td>
</tr>
</tbody>
</table>
Project Background (cont’d)

- No Standard *Defect Coding and Condition Grading System for Watermains*
- Water Research Foundation RFP 4498: Potable Water Pipeline Defect Condition Rating
  - Project Duration: Jan. 2014 to Apr. 2017
  - Objective: Create a framework and contents of a standard defect coding and condition rating system for watermains
Project Background (cont’d)
Participating Utilities and Organizations

1. Ontario Clean Water Agency, Canada
2. Greater Cincinnati Water Works, USA
3. City of Calgary, Canada
4. City of London, Canada
5. City of Waterloo, Canada
6. City of Los Angeles, USA
7. Louisville Waterloo Company, USA
8. Miami Dade County, USA
9. Monroe County Water Authority, USA
10. Portland Water Bureau, USA
11. Washington Suburban Sanitary Commission, USA
12. Halifax Water, Canada
Project Background (cont’d)
Technology Providers

• Pure Technologies

• Echologics

• Russell NDE Systems Inc.
Project Background (cont’d)
Technical Resource Team

1. Philip Wildbore, DEFRA, UK
2. Cliff Jones, Vice President, Ontario Clean Water Agency
3. Dr. Balvant Rajani, Rajani Consultants Inc.
4. Dan Ellison, HDR
5. Chris Macey, AECOM
6. Dr. Declan Downey, Trenchless Opportunities Ltd.
7. Dr. Samuel Ariaratnam, Arizona State University
Project Scope and Framework

Requirements and Guidelines

1. Flexible Framework – incorporate variety of information
   • Failure modes and mechanisms
   • Visual understanding and classification of pipe failures
   • Consider criticality of pipelines
   • Defect codes and condition rating system
   • Decision criteria to categorize pipes for various rehabilitation and replacement techniques

2. Cater for Reactive Approach

3. Also consider Selective Inspection
Project Scope and Framework

Major Tasks

1. Pipe criticality and priority ranking for evaluation (Dr. Kleiner)

2. Development of defect coding and condition rating system (Drs. Younis and Knight)

3. Rehabilitation or replacement decision making (Dr. Matthews)
Overall Framework

Pipe criticality and priority ranking for evaluation

Task 1
Estimate Pipe Criticality

State-of-the-Practice Review and Coordination with WaterRF, AWWA, and ASCE Initiatives
Collect and store pipe data into an inventory database

Use priority ranking to assign pipe to one of the four evaluation tiers

Tier 1
Desktop assessment of remaining life based on inferential indicators

Tier 2
Statistical analysis of operational data to forecast remaining life

Tier 3
Low-cost inspection surveys, e.g., leak detection, acoustics

Tier 4
Full length inspection

Task 2
Priority Ranking
Overall Framework
Pipe Criticality and Priority Ranking

Example: Kleiner at el.
Overall Framework

Defect Coding and Condition Grading

Task 2
Priority Ranking

Task 3
Develop Defect Coding and Condition Rating System and Interpret Evaluation Results

3.1 Investigate pipe failure modes and mechanisms
3.2 Defect Description Procedure
3.3 Quantification of Defects (weighting and scoring models and algorithms)

3.4 Trial the Water Pipeline Defect Coding and Condition Rating System
Assign codes to defects discovered from Tiers 3 and 4 inspections
Compute Condition Grades
Check the reliability and validity of the proposed system

Task 4
Rehabilitate or Replace?
Overall Framework

Defect Coding and Condition Grading (cont’d)

Defect Coding

Pipe Materials
- Cast Iron
- Ductile Iron
- PVC
- Asbestos Cement

Investigate mechanisms and causes of failures
- Identify defects

Input Data
- Asset/Inventory
- Operational/Performance
- Life Cycle Events

Defect Description Procedure
- Defect Observation
- Defect Names, Attributes, and Codes
- Defect Recording and Reporting

Output/ Deliverables
- Manual of Water Condition Classification including Data Model
Overall Framework
*Defect Coding and Condition Grading* (cont’d)

- Pipe Failure Modes and Mechanisms

Internal and External Factors Contributing to Water Pipe Failures (Uddin, Hudson, and Haas, 2013)

Select Failure Modes for Water Pipes (WSAA, 2012)
Overall Framework

Defect Coding and Condition Grading (cont’d)

- Defect Identification
  - Example: Metal Loss

<table>
<thead>
<tr>
<th>Internal Inspection</th>
<th>Material 1</th>
<th>Technology 1</th>
<th>Technology 2</th>
<th>Technology 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>External Inspection</td>
<td>Material 1</td>
<td>Technology 2a</td>
<td>Technology 3a</td>
<td>Technology 1b</td>
</tr>
<tr>
<td></td>
<td>Material 2</td>
<td>Technology 2b</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Material 3</td>
<td>Technology 3b</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: [http://www.ge-energy.com/content/multimedia/_files/downloads/MagneScan_Threat_Matrix.pdf](http://www.ge-energy.com/content/multimedia/_files/downloads/MagneScan_Threat_Matrix.pdf)
Overall Framework

Defect Coding and Condition Grading (cont’d)

• Defect Coding – Defect Description Procedure

<table>
<thead>
<tr>
<th>Defect Name or Distress Indicator: Corrosion</th>
<th>Perspective: Physical Integrity; Hydraulic Integrity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Related Measurements</td>
<td></td>
</tr>
<tr>
<td>1. % Pit Depth</td>
<td></td>
</tr>
<tr>
<td>2. Longitudinal extent of corrosion (mm or in), $L_m$</td>
<td></td>
</tr>
</tbody>
</table>

**Description and Explanation**

% Pit Depth: This parameter measures the depth of corrosion pit as a percent of nominal wall thickness of pipe.

$$\% \text{ pit depth} = 100 \frac{d}{t},$$

where $d =$ measured maximum depth (mm or inch) of corroded area, and $t =$ nominal wall thickness of pipe (mm or inch).

Longitudinal extent of corrosion (mm or In), $L_m$

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Overall Framework
Defect Coding and Condition Grading (cont’d)

• Defect Coding – Defect Description Procedure

Example of Location and Dimension for Metal Loss Defect (POF, 2009)
Overall Framework
Quantification of Defects

• Defect Scores and Weights
  • Develop measurement scale
    • Appropriateness of defects and corresponding scores and weights
    • Expert Judgement and Empirical and/or other Computational Tools
    • Validation: Face and Content Validity; Reliability (consistency; stability)
Overall Framework

Decision Making

• No renewal or re-assign pipe to one of the four inspection tiers (*i.e.*, *Tiers 1 to 4 mentioned in Task 1*)

• Rehabilitation

• Replacement
Overall Framework

Decision Making

• Rehabilitation or Replacement Decisions Guidelines
  • Open cut replacement
  • Online replacement without upsizing
  • Structural or semi-structural spot repair
  • Structural or semi-structural lining system
Questions?