SP2 Report

On

Survey and Review of Current Rehabilitation and Coating Technologies for Many Entry Sewer Pipes and Manholes with Protective Coatings

Part 1: DECISION TOOLS

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SUMMARY OF FINDINGS AND RECOMMENDATIONS

SP2 (sub-project 2) on *General assessment of repair and coating materials for sewers and review of the emerging designs of pipes to minimise the impact of corrosion* is directly supporting the research initiatives of the ARC Optimal management of corrosion and odour problems in sewer systems (LP0882016), to evaluate the performance of protective lining material in the sewers. Sydney University is collaborating with various water utility industries to undertake a survey to review and evaluate the current practices and technologies used in rehabilitation of sewer pipes, in particular larger pipes with ***spray and trowel applied coatings***.

This review provides an overview of the current state of practices and the state of protective coating technology and performance of coating in sewer, specifically ***sprayed and trowel applied*** coatings. The key items that were examined included the decision tools and approaches for the design of the protective system. This included coating specifications, the water utility industry use of field demonstration in testing emerging technologies, condition assessment of coatings, standards and QC/QA for and procedures for accepting installations.

This report is a culmination of industry survey feedback, teleconference discussion held by Sydney University researchers and the water utilities between 2009-2010 and a workshop on "to Review Historical Field Performance of Repair and Coating Materials for Sewers" on March 12 2009. The industry participants were requested to provide answers to specific questions in a survey followed by teleconference with various operators and engineers. In summary this report documents the Sydney University research team assessment of the needs of wastewater industry rehabilitation through the use of protective coatings.

Decision Support

The technical information or criteria that are used by the utility owners in their decision making was examined in this review. The following were derived from the examination of these tools:

- Selection of spray or trowel applied coatings through material coating specifications short term, and/or longer term trials

It appears that there are currently four types of coating specifications available within the water utilities surveyed in this study. Two qualifies polymeric and two qualifies cement based lining materials. *At the time of this study Water utilities from Brisbane and Gold Coast areas were non participants in this study*.

The coating specifications varied among the various industries and reflected the individual approaches taken by the asset owners to sewer rehabilitation. SW recently introduced two new specifications, AM SS204 and Standard Specification 208 (AMSS204, 2009, Standard-Specification-208, 2011) qualifying coatings based on material composition requirements, chemical and physical testing methodologies to reflect both short and long term performance of the coatings. Whilst the specification used by SA Water, Melbourne Water and Water Corporation, APAS 214, qualify the coatings based only on performance of the coating in the Bolivar biochamber. SA Water TS 137 built the standard around two specific industry products (CAC and calcareous aggregate cements) rather than desired performance from the coatings(APAS, 2003, TS3C, 2007). Examination of UK and US coating specifications also reflects individualised approaches. At the time of this study ***ASTM*** was in the process of ***developing an international standard to evaluate high performance protective coatings for sewer environment***. The testing will involve accelerated chemical testing, which only recognises the effect of sulphuric acid in the liquid phase and H_2S, CO_2 and CH_4 in the gas phase.

In addition to coating specifications, most water utilities are implementing both short term (6 months – 1 year) and long term (3-13 years) trials to validate the performance of the coatings in sewer environment. Although such testing provide real sewer environment, the data is limited to the environment for the specific sewer tested.

- Additionally standards used in selecting applicators and the QC/QA of the surface preparation, application, materials, and warranty

The principle mode of failure of the coating, apart from the natural degradation of the coating, may be introduced by the installation. A range of (quality control/ quality assurance) QC/QA clauses are written into the specifications to address this pathway for failure. However it appears there are certain shortfalls in these specifications linked to lack of jurisdictions and structure to implement particular amendments. It may also be linked to the reliance that what may not be specified would be captured in the warranty clause. Specific examples include:

i) No accreditation over the training processes for applicators

ii) No independent assessment of applicator competency in application and knowledge of the coating system. Although Melbourne Water relies on PCCP (Painting Contractors Certification Program) accredited contractors, who must comply with most of the requirements stipulated in ISO 9001, it is based on quality management rather than technical requirements.

iii) QC on surface preparation and application does not integrate the requirements for cleaning and preparing the surface to the needs of the coatings (e.g., moisture content)

iv) QC on material (e.g., use of dip card) not in place in some specifications.

v) Warranty over long periods (15-50 years) may be difficult to enforce on supplier and applicators.

- Post installation monitoring assessments are inadequate.

Post monitoring is used by the water utilities to gauge the performance and life of the coating and to implement repairing once coating has achieved its service life. Assessments of coatings by all major utilities are based on visual inspection, which is inadequate in providing a true measure of coating performance. SW has been undertaking the test methods recommended in the Sydney University research report for the Scientific Assessment of Epoxy Resins to Protect Sewer Concrete, Tender No. 0310022211. The test is based on extracting cores of coating and subjecting the linings with a series of tests to reflect their adhesion strength, chemical and physical state and the extent of acid permeation.

- Inspection and condition assessment standards for coatings in service

Grading the extent of deterioration of the lining system has been challenging for the industries. It appears that there are currently no common standards for inspecting, noting defects and classifying of conditions of coating in sewer pipes. This is largely attributed to lack of fundamental understanding of coating degradation.

Recommendations

The challenges that will be placed on the cost of rehabilitation and technical issues imposed as sewer conditions becomes more aggressive requires the water utilities to take on a more pro-active and integrated approach in dealing with sewer rehabilitation. This will require more than improvements but a step-change in the decision tools and in the management of knowledge and information that are currently based in different water utilities. Some of the key gaps that were identified in this study include the lack of:

i) Integrated industry knowledge base and experience in regards to coating selection and performance. Each water utility approaches its rehabilitation independently of each other and the potential to learn from their experiences has been missed.

ii) National approaches for the design and decision tools for sewer rehabilitation (including specifications in selection of coating materials that is fit for purpose, material thickness, structural and or protection, life cycle of the lining material). National coating specification should address compositional requirement and testing (inclusive of short and long term trials) to reflect both the short and long term performance requirements of the coating. Such an initiative would give the asset owners the confidence to try new coating systems.

iii) Assessment protocols and monitoring strategies that provide more than visual validation that the coating is degrading. Quantitative performance indicators including chemical and physical state of the coating, adhesion strength and acid permeation.

iv) Standards for inspecting, noting defects and classifying of conditions of coating in sewer pipes

v) Accreditation of applicator training and competency assessment

vi) Review and standardisation of QC/QA for accepting surface preparation, application, materials, and warranty

It is anticipated that the research being undertaken in SP2 would be able to provide the fundamental understanding of coating degradation and performance to support some of these initiatives.

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1.0 INTRODUCTION

1.1 Aim and Approach of the Review

This review was intended to provide an overview of the technology and the practices the water utility industries adopt to rehabilitate large or many entry sewer pipes (> 0.9 m) and manholes. Rehabilitation involves the repair, replacement and/or correction of the system component with the purpose of prolonging the performance of the asset.

This review was generated as part of the objectives of the SP2 project under the ARC Odour and Corrosion Linkage Project to examine the performance of spray and trowel applied coatings for sewers.

The materials included in this review were obtained from:

i) Survey questionnaire of the industry:

   a. Review Historical Field Performance of Repair and Coating Materials for Sewers (see Appendix A)

   b. Coating Delamination (see Appendix B)

ii) Discussion with water utility industries, coating manufacturers and applicators through teleconferences

iii) Access to industry reports and publications

1.2 Industry Participants

We would like to acknowledge various water utility personnel and manufacturers for their participation and input in this survey. These personnel are listed in Table 1 below.

1.3 Structure of Review

The review is structured according to the following areas:

1. Review of current coating technologies

2. Decision Support System

   i) Inspections and Condition Assessment Standards

   ii) Coatings and specifications

   iii) Design of protective system

iv) Standards for surface preparation

v) Standards for application and licensing of applicators

vi) QC/QA for surface preparation and application

vii) Warranty

viii) Post- installation inspection and monitoring

Table 1. Industry participants in rehabilitation and delamination survey

Industry	**Personnel**	**Email Addresses**
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2.0 BACKGROUND

The maintenance of sewer pipes and related structures in Australia are implemented by state owned water utility industries. The cement piping infra-structure used by the Water Industry is valued over \$60 billion and a conservative estimate of 3-5% of the value of the asset is used in the rehabilitation of this infrastructure each year. The cost of rehabilitation has been escalating due to the greater aggressiveness of the gaseous environment in the sewer. This has been attributed to various factors including urban expansion, population growth and development over flat coastal terrains (Aviam et al., 2004, Sand, 1991, Vincke et al., 2001). Various technologies are available today for the rehabilitation and as control measure to protect sewer pipes and related infra structure against microbiologically induced corrosion. Coating system is one such control measure. This review focuses on spray and trowel applied coatings applied to large or man-entry pipes, of which there are two types, polymer based and cement based coatings.

In general the spray and trowel applied polymer coatings are characterised by variable performances. Often coatings that have been designed to last 50 years have been noted to fail prematurely, some in less than a year. This feature is symptomatic of underlying issues in the rehabilitation and protection of these assets. The challenge for the water utilities today appears to be the lack of adequate decision support to select protective coating system, to design, to assess their conditions and to maintain the system.

This review was undertaken to examine the decision tools that are used by the industry in the application of protective coating in rehabilitation of man entry pipes (> 0.9 m) and manholes. The outcomes of this review were also meant to guide the research undertaken under SP2.

3.0 DECISION SUPPORT

The water utility industries must choose appropriate rehabilitation technologies and materials from the range described above. Often this is based on various factors including known performance of the coating system, pipe conditions (protection and/or structural requirements) and pipe properties (size, substrate material, presence of ground water), gas environment, cost and the overall asset management strategy. More recently short term and long term environmental and OHS issues have become of concern and have also been considered. The technical information or criteria that are used by the utility owners in their decision making was examined in this review. Specifically this included:

- Selection of spray or trowel applied coatings through material coating specifications short term, and/or longer term trials

- Additionally standards used in selecting applicators and the QC/QA of the surface preparation, application, materials, and warranty
- Post installation monitoring by the water utilities to gauge the performance and life of the coating and repairing the pipe once coating has achieved its service life.
- Inspection and condition assessment standards for coatings in service

3.1 Coating specifications

Among the industries surveyed, it appears there are only two specifications for qualifying epoxy coatings:

i) Sydney Water's Standard Specification 204 – "Rehabilitation and corrosion protection of sewers using epoxy coating" (AMSS204, 2009) and

ii) APAS (Australian Paint Approval Scheme) Specification 214 – "Coatings for Concrete Used in Sewage Works (APAS, 2003)"

Similarly there are only two specifications for qualifying cement based coatings:

i) Sydney Water's Standard Specification 208 – "Rehabilitation and Corrosion Protection of Sewers using Calcium Aluminate Cement Mortar" (Standard-Specification-208, 2011) and

ii) SA Water TS 137 – "Rehabilitation of Concrete Wastewater Manholes"(TS3C, 2007)

The list of current coating specification used by the Australian water utilities are listed in Table 1. Table 2 shows the specification in the US and UK. The UK specifications are based on coating selection for water mains.

The specification in general outlines: i) the compositional, chemical and physical requirements, ii) specific short term and long term performance and iii) testing required to validate conformance to the required qualifications. Examination of the available specifications shows that all or some of the qualifications terms may be included, but it appears the industries follow different specifications.

Prior to the Sydney University research (Scientific Assessment of Epoxy Resins to Protect Sewer Concrete, Tender No. 0310022211), SW specification called for 'equivalent resistance" to the specified coating systems, which include Nitomortar ELS and Sikadur 41/Sikagard 63 systems. Along with qualitative subjective requirements including suitability to wastewater application, high abrasion and impact

Table 1. Coating Specifications in Australia

Water Utility	Type of Coating	Specification	Date Issued
Sydney Water Corporation	Epoxy	AM SS204 - Rehabilitation and corrosion protection of sewers using epoxy coating	July 1 2009
Sydney Water Corporation	CAC	Standard Specification 208 - Rehabilitation and Corrosion Protection of Sewers using Calcium Aluminate Cement Mortar	January 17 2011
SA Water, Water Corporation, Melbourne Water Corporation	Epoxy	APAS (Australian Paint Approval Scheme) Specification 214 - Coatings for Concrete Used in Sewage Works	October 23 2003
SA Water Water Corporation	CAC and Calcareous aggregate cement	TS 137 - Rehabilitation of Concrete Wastewater Manholes	April 2010
SA Water Water Corporation	Calcareous aggregate	TS 3_C Technical Standard - Fine and coarse calcareous aggregates (marble) for concrete sewerage structures (excluding lightweight aggregate)	January 10 2007

resistance, resistance to H_2S at 20 ppm and the ability of coatings to be applied without pinholes. A revised draft specification SW - AM SS204 have attempted to incorporate more quantitative requirements(AMSS204, 2009).

AM SS204 included specific formulation requirement (e.g., epoxy content) and chemical properties (e.g., interaction between filler and epoxy and hydrophobicity). This is complemented by performance testing under given degradation test conditions. AM SS204 is based on biogenic acid, biological and other sewer effluent contaminants (e.g., soap) tests. The chemical resistance testing specified in SS 204 is a modification of the Pickle Jar Test, which is developed and used by the City of Los Angeles Bureau of Engineering to qualify products used in their sewer assets (Redner, 2004).

APAS 214 qualifies the coatings based only on their performance in the biochamber - Bolivar Test Chamber operated by the Scientific Services Laboratory, as detailed in APAS Document D192 clause 3.6(v)(APAS, 2003). Assessments following the interment of the coatings in the biochamber involved largely visual examination of defects.

Table 2. Coating Specifications in the US and UK.

Country	Type of Coating	Specification	Date Issued	References
US	Epoxy	Standard Cement Materials NASSCO (National Association of Sewer Service Companies) Specification for Applying A Protective High Build Epoxy Coating to a Concrete Sewer Manhole	NA	http://www.nassco.org/publications/p_spec_guidelines.html
US	Epoxy, CAC	Rummel, Klepper, Kahl, LLP, Sewer Manhole Rehabilitation, Blue Plains Influent Sewer Rehabilitation	January 18 2009	http://www.ullimanschutte.com/documents/projects/Blue%20Plains%20Sewer%20Rehab/Specifications/02707%20Sewer%20Manhole%20Rahabilitation.pdf
US	Epoxy	City of Savannah: Section 02555 Protective Coating for Existing and New Concrete and Masonry Sanitary Sewer Structures		http://www.ci.savannah.ga.us/spr/SPRGuide.nsf/DocID/27139AA74AA17AA5852568A90060F060/$FILE/02555-4-14-11.pdf
US	Epoxy	EPA/600/R-11/017 Quality Assurance and Quality Control Practices for Rehabilitation of Sewer and Water Mains	February 2011	http://www.epa.gov/nrmrl/pubs/600r11017/600r11017.pdf
US	Epoxy	ANSI/AWWA C620-07, AWWA Standard for Spray-Applied In-Place Epoxy Lining of Water Pipelines, 3 In. and Larger		http://www.awwa.org/publications/MainStreamArticle.cfm?itemnumber=35303&showLogin=N
	Epoxy	Standard to Evaluate High Performance Coatings for Sewer Systems	Proposed Nov 16-17 2011	http://www.astmnewsroom.org/default.aspx?pageid=2591
UK	Epoxy	WIS 4-02-01 - Operational Requirements: *In Situ* Resin Lining of Water Mains (UK Water Industry)	March 31 2007	http://www.water.org.uk/home/member-services/wis-and-ign/archived-documents/wis-4-02-01.pdf
UK	Epoxy	IGN 4-02-02: Code of Practice: *In Situ* Resin Lining of Water Mains (UK Water Industry)	March 31 2007	http://www.water.org.uk/home/member-services/wis-and-ign/archived-documents/ign-4-02-02.pdf

SA Water TS 137 built the standard around two specific industry products (CAC and calcareous aggregate cement) rather than desired performance from the coatings. The lack of commonality in coating specification reflects the independent ways by which the water utilities have approached their sewer rehabilitation.

ASTM is in the process of developing an international standard to evaluate high performance protective coatings for sewer environment. The testing involves accelerated chemical testing, which only recognises the effect of sulphuric acid in the liquid phase and H_2S, CO_2 and CH_4 in the gas phase(ASTM, 2011).

In an attempt to validate the performance of the coatings, the asset owner implement short and long term trials to subject the coatings to real sewer conditions.

3.1.1 Short term performance testing

SW implements a series of immersion tests based on ASTM D543 as stipulated in AM SS204 (AMSS204, 2009). The coatings are examined through the tests to reflect acid permeation, and chemical and physical degradation. These controlled tests provide measures of acid permeation and coating adhesion. Melbourne and SA water uses the Bolivar Test chamber as a form of accelerated biodegradation to qualify the coatings (Vuong & O'Driscoll, 2010). The testing of the coating after the biodegradation is based on qualitative visual inspection of defects (including cracks, blisters, bulging and delamination) but do not give quantitative measures of performance of the coating.

3.1.2 Trial field performance testing

Another option for assessing the coating is the actual application of the coating in selected sewer sites (Wubben., 2008, Wubben, 1999). Although more costly because of the need to access the sewer, the use of a live sewer subjects the coating to real sewer environment, albeit only to conditions specific to the particular sewer. Data obtained from such test may be more difficult to extrapolate to other sewer conditions. In addition, such tests are longer. Field trials may take between 3-13 years or longer. Although the exposure of the coating to sewer provides a real test environment, the test itself may not fully achieve true assessment of the coating performance. Assessment of the degradation of the coatings have been based on visual inspection of surface defects (Wubben., 2008, Wubben, 1999), which as discussed provides limited assessment of the coating performance. Water utilities (SW and more recently Water Corporation) are incorporating a more quantitative assessment of coating performance by taking cores of the lining followed by chemical and physical testing of the lining material (see section 3.2.5.2.).

Although the qualifying specification used by the water utility industries address some of the needs for selecting coating system, the areas that need to be further developed include:

- Quantitative testing methodologies that better reflect the state of the coating as an environmental barrier (e.g., acid permeation, adhesion)
- A standardised national specification and the testing protocols to meet the short term and long term performance need for the coatings. This would give the utility industries greater confidence in trialling new coating systems and would provide the supplier only one specification by which to conform.
- Central database of coatings, performance and documentations of failures.

3.2 Quality Control and Quality Assessment

3.2.1 Selecting Applicators

Premature failure of coating has also been attributed to poor or error application, which puts into question the adequacy of the selection criteria for applicators. The formal process of selecting applicators, as written in most coating specification, has a strong reliance on the recommendation of the supplier. Although records of the applicator based on similar work may also be examined, the assessment however is only cross-checked with data submitted by the applicator prior to the work. Accurate assessment of the applicator competency may not be adequately covered by the above criteria. Instituting improvements in applicator selection may be challenging as the structure required to implement these are currently not available. For example it appears:

- The industries do not have control over the type of training and knowledge received by the applicator as this is currently provided in-house by the supplier.
- There is no accreditation over these training processes.
- There is no cross-check of the competency achieved by the applicator upon completion of training.
- The industries do not have an independent way of checking the applicators real history are these are not documented by a central body unless the job was performed in the same industry.

These could be potential issues and by no means constitute an exhaustive list of areas that could be improved in selecting applicators.

3.2.2 Surface Preparation

Adequate surface preparation protocols are written into the coating specifications (AMSS204, 2009, Standard-Specification-208, 2011, TS-137, 2010). Surface preparation protocols address the issues of removal of corrosion products and other laitance material, cleaning, surface restoration and inspection and testing of surface preparation.

Surface preparation specifications are instituted by manufacturers. Although the surface preparation protocol address the restoration of the concrete substrate to as close as its ideal conditions, none appear to address the actual requirements of the coatings that will be applied. These include:

i) *Moisture content on the substrate*. The ability of most monomers to cure and thus adhere is strongly influence by the available moisture in its environment.
ii) *Surface roughness*. Epoxy adhesion could be improved if it is able to fill into pores structures. Primers may be used, but only if the manufacturers makes this recommendation.

3.2.3 Coating Application

Assessments of the coating applications are currently based on bond strength and visual inspection for coating defects including crazing, crack, blisters and delamination.

Again such testing overlooks the most important aspect of the coating application, and that it is the *epoxy curing*.

3.2.4 Material

Storage, handling, noting of the age of the coating raw materials are typically written into the coating specification. However, quality control over the material composition is not written into the specification. UK specifications (IGN 4-02-02 and WIS 4-02-01) writes in the use of dip cards to be taken immediately before the start of the work and after completion. None of the Australian specification examined in this survey instituted this form of quality control. Such practice may be useful in deciphering if the failure occurred as a result of poor material and/or applicator error. It also appears the specifications do not have control should the applicator decide to include additional materials (e.g., solvent) to the coating systems. This decision process relies heavily on the supplier approval and the industries reliance on the applicator and supplier warranty.

3.2.5 Warranty

The industries are writing in warranty requirements for the applicator and supplier to guarantee the workmanship for example for 15 years (e.g., AM SS204) (SW Survey 2009, SA Water Survey 2009). Warranty periods are easy to add to specifications, but are often difficult to enforce in practice, and long warranty periods are very problematic for contractors in insurance companies willing to take such a long-term performance risk. Experience from the US indicate that warranties of 1 to 2 years do not present special problems, but warranties of 3 years or more may significantly restrict the companies that can bid on the work (EPA/600/R-11/017, 2011). Other issues with warranties are the need to prove that the loss of performance was caused by the product or its installation, not some other aspect of system performance or maintenance.

3.3 Coating Monitoring and Maintenance

3.3.1 Inspection and Condition Grading Standards

Grading the extent of deterioration of the lining system has been challenging for the industries. It appears that there are currently no common standards for inspecting, noting defects and classifying of conditions of coating in sewer pipes. Even with in-house grading systems, the grading are subjective to what the industry constitutes as 'defects' and their impact on the coating performance. Defects can include blistering, cracking, sagging, bulging, loss of hardness, delamination and infiltration. Apart for the obvious effect and impact of coating delamination and infiltration, there is little understanding of the effect of the other defects on the remaining service life of the coatings, the foundation on which the condition grading should be based.

The process of inspection involves consultants performing the examination, assessments and recommendations for repairs which are then submitted to the asset managers. As such the assessment could be subjective to the consultants used. According to SW, all of the assessments are conducted largely by visual inspection. Without the correlation of these assessments to the performance of the linings, it is practically impossible to provide an accurate assessment of the state and performance of the coating. For example the loss of hardness may indicate some chemical and physical changes are occurring in the coating but its exact effect would be difficult to interpret as epoxy will soften and harden depending on state of degradation. SW has adopted some of the test methods recommended in the Sydney University research report for the Scientific Assessment of Epoxy Resins to Protect Sewer Concrete, Tender No. 0310022211(Valix, 2008). This includes surface pH, acid permeation, thermal analysis, surface chemical analysis and physical analysis including hardness and bond strength. Shore D hardness, core samples bond strength, pH test is now used regularly by their consultants, along with the traditional visual examination.

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APPENDIX A: SURVEY QUESTIONNAIRE ON HISTORICAL FIELD PERFORMANCE OF REPAIR AND COATING MATERIALS FOR SEWERS

Background:

A collaborative research project has been established with a combination of ARC and industry partner funds that aims to bring together leading researchers from Australia and overseas in the field of corrosion and odour in sewers and link those with Australian utilities who have extensive practical experience in this field, to produce practical outcomes based on fundamental scientific knowledge.

The project currently has 9 integrated sub-projects which will focus on specific corrosion and odour management issues with linkages and sharing of results and resources between the sub-projects.

The aim of Sub-project 2 is to gain a better understanding of the chemical, physical and microbiological processes involved in the corrosion of concrete sewer pipes and determine the effectiveness of coating materials to protect the pipes. Outcomes from the sub-project include guidelines for the selection and use of coatings, both permanent and sacrificial, and monitoring protocols to enable industry to estimate the life expectancy of coatings.

One of the first stages of this sub-project is to gather good historical data on the field performance of coating systems that have been used by Australian water utilities.

Some discussions have already taken place with industry partners and a preliminary list of coating materials that are being considered for analysis and field testing has been developed. The coatings currently being considered are in two groups:

a) Epoxy Mortars:
    - Sikagard 62T
    - Nitomortar (Pharchem)
    - Ameron CC703 UHB
    - Wattyl Sigmaguard CSF75
    - Epigen 1311
    - Sikadur 41
    - Hychem TL5
    - Fernco S301
b) Sacrificial Coatings
    - Calcium Aluminate Cements (CAC)
    - Magnesium Hydroxide Gels

Objectives of the Workshop:

The aim of this workshop will be to draw on the expertise and experience of WSAA members to identify industry experience with repair and coating materials for corrosion in sewers.

1. What repair and coating materials have been used by water utilities in Australia.
2. Confirm the shortlist of coating materials that should be analysed and field-tested.
3. Confirm sites that may be suitable for field-testing of existing coatings.
4. Identify and collate any records on the performance of the coating materials used.
5. Identify any new coating materials that water utilities are considering using.

Some specific details about existing epoxy coatings used by water utilities that would be useful includes:

1. Monitoring procedures (including analytical testing) of coating in the field and criteria used in establishing if coatings are performing of have or is about to fail. Are monitoring procedures different depending on the size of the pipes (e.g., smaller pipes that are more difficult to access, how are there assessed?). What proportion of the existing pipes is difficult to access? Frequency of assessment.

2. Current selection criteria or specifications for coatings

3. Observed changes in coatings during service:
    a. colour change
    b. hardness (loss of rigidity or sagging)
    c. Biofilm growth (patches of highly coloured to dark spots) on epoxy on the crown space.
    d. Change in surface pH (linear change or exponential)
    e. Others
    f. With formation of pinholes in coatings during service:
    g. What types of coatings were being used?
    h. Conditions of the sewer i.e. acidity level?
    i. How long did it take for pinholes to form during service?
    j. Were there any changes in hardness of the coating during service (i.e., softening and or increased hardness)?
    k. Where de-bonding of coatings have occurred:
    l. What types of coatings were being used?
    m. Were bonding agents used?
    n. Surface preparation
    o. How long were the coatings been in service before debonding occurred?
    p. Conditions in the sewer i.e. acidity levels?

q. What thickness of coatings debonded?
r. Was debonding prevalent in concrete pipes exposed to underground water source i.e. were the pipes under the water table?
s. Did temperature fluctuations contribute to greater rate of debonding?

Desired Outcomes of the Workshop:

The desired outcomes of the workshop are to provide ARC Corrosion and Odour Sub-project 2 management team (Technical Advisory Committee) with sufficient information and recommendations from the industry representatives to:

1. Confirm the list of coating materials to be analysed and field tested.
2. Confirm the field testing sites.
3. Confirm outcomes that the water industry is seeking from the ARC Corrosion and Odour sub-project 2 especially regarding coating material types, specifications and performance.

Ultra High Build Epoxy Coating

The product used for providing protective coating shall be a proprietary epoxy based coating specifically designed for sewer applications. The coating shall be able to build to a minimum thickness of 10 mm in one pass i.e. ultra high build. It may be trowelled or sprayed applied. The product shall conform to the following requirements.

Composition

The material shall:

a) be a mix of epoxy resin and inorganic filler;

b) have a maximum filler content of 40% by weight;

c) have silicon oxide as the filler main ingredient; and

d) Have a maximum filler particle size of 250 microns.

Performance

The material shall have:

a) a minimum interaction of filler and epoxy (metal-carbon over metal-oxide) of 60% as measured using a Fourier Transform Infrared (FTIR) spectroscopy instrument;

b) a minimum thermal decomposition temperature of 360°C as measured using a Thermogravimetric Analysis (TGA) instrument;

c) a satisfactory chemical resistance to solutions of (% in v/v):

1. 20% Sulphuric acid
2. 5% Sodium hydroxide
3. 5% Ammonium hydroxide
4. 1% Nitric acid
5. 1% Ferric chloride
6. 1% Sodium hypochlorite
7. 5% Oxalic acid
8. 1% Citric acid
9. 0.1% Soap
10. 0.1% Detergent
11. Diesel
12. Gasoline
13. Kerosene
14. Vegetable oil

The test method shall be a modified ASTM D-543 with a total exposure period of 112 days. If any sample fails to meet the requirements specified below, the material will be deemed not to be satisfactory. A satisfactory chemical resistance is defined as having a maximum of:

1. 10% variation from the initial weight;
2. 10% variation from the initial dimension;
3. 5% reduction from the initial compressive strength;
4. 5% reduction from the initial tensile strength;
5. 5% reduction from the initial flexural strength;
6. 10% reduction from the initial material shore D hardness; and
7. 5% reduction from the initial thermal decomposition temperature.

d) a minimum compressive strength of 40 MPa when tested according ASTM D-695 or equivalent;

e) a minimum tensile strength of 6 MPa when tested according to ASTM D-638 or equivalent;

f) a minimum flexural strength of 40 MPa when tested according to ASTM D-790

g) a maximum elongation at maximum load of 2% when tested according to ASTM D-638;

h) a minimum shore D hardness scale of 70 when tested in accordance to ASTM D-2240 or equivalent;

Application

The material shall:

a) be 100% solid (VOC and solvent free);

b) be suitable for application in the prevailing work site conditions i.e. confined space with limited of application time;

c) be able to bond to the substrate material with bond strength no less than 1 MPa;

d) have a surface finish of light colour e.g. cream, light grey, or ivory;

e) have a smooth profile surface finish;

f) be able to accommodate differences in sewer geometry within the internal repair length;

g) be able to accommodate existing cracks in the host structure with size up to 2.5 mm; and

h) Have a compatible hydrophobic primer or bonding agent for application where the substrate is likely to remain permanently damp or wet.

Approved Products

The following spray applied products have been found to meet the requirements.

- Nitomortar ELS (Parchem Construction
- Sikagard 62T (Sika Australia)
- Ultracoat (Fernco (Australia)

APPENDIX B: SURVEY QUESTIONNAIRE ON COATING DELAMINATION

Background: As part of the Linkage Project on 'Odour and Corrosion' we are undertaking a study of coating delamination.

Purpose: This survey is the first part of this work and aims to establish the current industry, applicator and manufacturers practices (methods and techniques) in regard to:
(i) surface preparation
(ii) use of moisture barrier and primers with coatings
(iii) Other information, which may be relevant to this study

Date: July 27 2010

SEWER ENVIRONMENT

(1) In order to replicate the surface preparation process, please help us understand the sewer environment by filling up the table below. Please add any relevant condition(s) under *Item.*

Item	[Min,Max]	Comment
Temperature (^{O}C)		
Relative Humidity (%)		
Work Duration (hr)		

SURFACE CLEANING/PREPARATION

(2) In cleaning the surface of the concrete, what types of laitance materials do you specifically remove and what combination of methods and the order you would use these methods (please order by placing 1 to 1st step - 8 to the last step)?

Types Laitance Removed	**Y/N**	**Method of Removal (Y/N)**							
		High Pressure Water Jetting	Abrasive Blast	Steam Wash	Detergent Scrubbing	Proprietary Degreaser	Acid Etch	Chlorine Wash	Light Abrasion *
Softened concrete									
Order									
Organics (e.g., PVA, grease)									
Order									
Micro-organisms									
Order									

e.g. mechanical wire brush, needle gun etc

(3) What other laitance materials would you remove that is not included in the list above?

Other Laitance Materials

(4) Please provide the conditions, types of equipment and reagents that would be used for the specific surface preparation methods you would use.

Method	Equipment	Pressure (kPa)	Period (min)	Reagents /Conc. (wt%)	Comment
Abrasive Blast		NA			Abrasive size(microns):
Light Abrasion*		NA			
Breakout		NA		NA	max b/out weight allowed (kg):
Acid Etch					
Chlorine Wash					
Detergent Scrubbing		NA			
Proprietary Degreaser		NA			
Steam Wash				NA	
HP Water Jetting					
Hand Wash		NA			

e.g. mechanical wire brush, needle gun etc

(5) Is achieving surface roughness a part of your surface preparation (Y/N)?

6) What method would you use to measure surface roughness?

7) What surface roughness would you attempt to achieve for:

- Epoxy based coating
- Cement based coating

7) Could you please indicate below which method(s) you would use to achieve the required surface roughness, the equipment and conditions used.

Method	Method Used (Y/N)	Equipment	Period (min)	Abrasive size (microns)	Comment
Breakout					
Abrasive Blast					
Light Abrasion*				NA	

e.g. mechanical wire brush, needle gun etc

8) Do you attempt to achieve a certain surface dryness as part of your surface preparation (Y/N)?

9) What surface moisture content(s) would you require for:

- Epoxy based coating
- Cement based coatings

10) Please identify the methods you use to achieve these surface dryness and the equipment and conditions:

Method	Equipment	Period (min)	Ave. Surface Wetness Achieved (%)	Comment

MOISTURE BARRIER AND PRIMERS

11) Do you use moisture barriers and primers with your coatings (Y/N)?

If yes, please list the types of moisture barriers and primers that you have used. Please include the corresponding protective coating for each moisture barrier and primer

12) Are there any other types of materials aside from moisture barriers and primers that are used in your coating matrix (Y/N)?

13) Please list the names of these additional materials and their purpose.

Other materials used in coating matrix	Purpose

POST INSPECTIONS OF SURFACE PREPARATION

14) Do you inspect the surface after surface preparation has been conducted (Y/N)?

If yes, who does the inspection?

15) What criteria and the corresponding test methods are used to indicate the surface preparation is adequate? Please add any missing criteria.

Criteria	Test Method	Pass Result	Comment
Cleanliness			
pH			
Structural Soundness			
Surface Roughness			

PROTECTIVE COATING APPLICATION

16) Please fill in the table below the method of application for each coating. If coating is not listed, please add under *Types of Coating*.

Types of Coating	Equipment	Require multiple layers (Y/N)?	Do you change the direction of application between layers (Y/N)?	Interval time between layers (min)	Require surface treatment between layers (Y/N)?	Method for surface treatment
Sikagard 63N						
Sikagard 62T						
Nitomortar ELS						
Hychem TL5						
Polibrid						
Fernco S301						

OBSERVED DELAMINATIONS

17) Please indicate below observed delamination in your sewer pipes. If coating is not listed, please add under *Types of Coating*.

Types of Coating	Sewer Location	Observed Delamination (Y/N)	Installation Date	Thickness (mm)	Presence of H_2S (Y/N)?	Is this pipe under ground water (Y/N)?	Was moisture barrier used (Y/N)? *	Was primer used (Y/N)? *	Other signs of degradation with delamination (Y/N)			
									Softening	Blisters	Cracking	Loss of thickness
Sikagard 63N												
Sikagard 62T												
Nitomortar ELS												
Hychem TL5												
Polibrid												
Fernco S301												

**please indicate name*

CONTRACTOR'S DETAILS

18) Please include contact details of contractors who performed surface preparation work and coating application for your organisation.

Company	Contact Person	Address	Telephone	Email	Contract Work (Y/N)	
					Surface Preparation	Coating Application*

**if possible, please specify type of coating(s*