Protecting & Repairing Structures in Harsh Environments

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360° Protection for Extreme Conditions in Extreme Environments

Abrasion, cracking, and chemical attack reduces the life span of sewers, water treatment structures and other heavy traffic environments, increasing maintenance cost and frequency of repair cycles.
Types of Corrosion in Concrete Structures

- **Chloride induced corrosion**
  - Generally the reason for corrosion in wharfs, piers & all coastal structures

- **Carbonation induced corrosion**
  - Most commonly found in cities & some inland infrastructure

- **Microbial Acid attack (most common in sewers)**
  - Acid attack removes the cement paste making the reinforcing steel vulnerable to corrosion

- **Dis-similar metals**
  - Aluminum or varying steel alloy handrails on a steel reinforced concrete structure
Sewer Infrastructure: What causes sewers to degrade?

- **2. aerobic** (Life Sciences & Allied Applications / Biology) depending on oxygen
  
  - Occurring in the presence of oxygen or requiring oxygen to live. In aerobic respiration, the production of energy from glucose metabolism requires the presence of oxygen.
  
  - Produces acids from the reduction of Hydrogen Sulphide with O₂ resulting in the creation of Biogenic Sulphuric Acid (BSA)

- **1. anaerobic** (Life Sciences & Allied Applications / Biology) requiring the absence of, or not dependent on, the presence of oxygen
  
  - Occurring in the absence of oxygen or not requiring oxygen to live. Anaerobic bacteria produce energy from food molecules without the presence of oxygen
  
  - Produce Hydrogen Sulphide gas (H₂S)
Sewer Infrastructure: Where does the damage occur?

- Predominately in the **crown of the pipe** or the airspace with **acid attack**

- Damage **below the crown** is often due to **abrasion/scouring**, rather than acid attack

- **Access points** like vertical risers & covers and diversion chambers are **particularly vulnerable** as the air movement is restricted

- **pH can be as low as 3**, the cement paste **degrades** (turns into Gypsum), **reducing its strength** and making it vulnerable to abrasion and erosion
Sewer Infrastructure:
Preventative measures include:

- Provide adequate ventilation
  - Forced air movement and venting points to reduce build up of Hydrogen Sulphide gas.

- Bacterial control
  - Addition of Chlorine or other sterilent to kill the bacteria
  - Difficult to do on large scale often used for critical or inaccessible areas.

- Using materials that are unaffected by acid attack
  - PVC or HDPE pipes for smaller diameter pipelines
  - Impervious liners for precast concrete pipes (epoxies etc.)
Sewer Infrastructure: Repair & Protection measures include:

» **Brick-Lined Sewers**
  - Apply via dry-spray, a high alumina *Calcium Aluminate Cement (CAC) mortar*, re-profiling the joints between bricks

» **Concrete Sewers & Manholes**
  - For structural repair, apply via dry-spray, an *Ordinary Portland Cement (OPC) mortar*
  - Followed by a sacrificial layer, via dry, wet spray or hand applied, of a *CAC mortar*

» **Coatings**
  - *Polyester/Vinylester*
  - *Novolac Epoxies*
  - *Polyurea*
  - *Hybrid Polyurethanes*
  - *Others (Magnesium Hydroxide Liquid (MHL), Cementitious, Polymer based)*

» **Joint Sealants**
  - Polyurea
  - Polysulphide
Sewer Infrastructure: High Aluminate (CAC) materials

» Repairs to brick, cast in place concrete and precast concrete sewers
  » Mortars are made of CAC cement & clinker, fibres and some supplementary pozzolans

» CAC cement & clinker are reactive and form an acid resistant matrix, that is self healing

» Ideal for reinstatement of linings of risers and other access ways (hand applied)

» Requires no specific primer just a damp substrate, with surface prepared by high pressure water blasting

» Fast hardening to allow reopening of sewer without jeopardizing the integrity of the repairs

» A sacrificial layer, with around 1 mm per year erosion rate often adopted
Sewer Infrastructure: Brick Lined Sewer repair

Project: BOOS (Bondi Ocean Outfall Sewer), Sydney, 2011 (~50T)

MasterEmaco S 680 is a dry-spray applied Calcium Alumina Cement (CAC) based repair mortar

The dry-spray material is designed to penetrate into mortar gaps between the bricks, with best compaction for long term durability

Major challenges included:
- Some joints were down to less than 7 mm width, with a minimum of 40 mm deep filling required. Cores indicated excellent compaction achieved
- Inability to completely shutoff sewer, working between peak flow periods

Material requires only the addition of potable water for mixing or spraying, has low rebound and dust generation, with long open time
Sewer Infrastructure:
Brick Lined Sewer repair

Project: BOOS (Bondi Ocean Outfall Sewer), Sydney, 2011 (~50T)

Application video
Sewer Infrastructure: Concrete Sewer repair

Project: SWSOOS (South West Sydney Ocean Outfall Sewer), 2012/13 (~1000T each)

Initial layer of MasterEmaco S 820 (dry-spray applied structural mortar where required) followed by a 25 mm “sacrificial” layer of MasterEmaco S 680 as a dry-spray applied Calcium Alumina Cement (CAC) mortar

Major challenges included:

- **3 cell box tunnel** sections, repaired one at a time
- **Logistics of mobilizing** large quantities of materials & equipment into a **1 km long tunnel**
- Vertical risers allowed hoses to be connected
Sewer Infrastructure: Concrete Sewer

Project: SWSOOS (South West Sydney Ocean Outfall Sewer), 2012/13 (~1000T)

Temporary timber stop ends were installed to divert flows to other 2 tunnels, enabled works to be done in a relatively clean environment.
Sewer Infrastructure: Concrete Sewer repair

- Project: SWSOOS (South West Sydney Ocean Outfall Sewer), 2012/13 (~1000T)

- Many major structural repairs required – some form and pour
- Erosion exposing large aggregate
- OPC then CAC layers
Sewer Infrastructure: Concrete Sewer repair

Project: SWSOOS (South West Sydney Ocean Outfall Sewer), 2012/13 (~1000T)

Crown erosion was particularly bad
Sewer & Waste Water Treatment Plants: Designing & Constructing for Durability

In building new STP/WWTP’s, preventative techniques exist to extend the design & service life like:

- **Increase reinforcement cover**
- **Increased amount of reinforcement** (better crack control)
- Adopt special *concrete mix designs* including:
  - Various *admixtures* delivering higher durability with lower shrinkage, better compaction & reduced porosity
  - *Geopolymer* concrete (with improved acid resistance)

For *enclosed settlement tanks* where the build up of anaerobic and aerobic bacteria can exist, repair of these tanks is *significantly easier* and more techniques are available, as they normally *can be taken off line*

Refurbishment options include the use of traditional *OPC* or *CAC* repairs to reinstate the concrete and/or the use of *protective coating materials*
Sewer & Waste Water Treatment Plants: Protective coatings

Linings like chemically resistant *Epoxies* coatings can be used very effectively, as much of the *attack is abrasion*, not acid attack.

Other linings like pure *Polyureas*, can be used in these areas especially if you have the potential for some movement of the structure.

In extreme cases, *Novalac Epoxies* or *Polyesters/Vinylesters* can be used but they are often too moisture sensitive (the structure needs to be substantially dry) limiting their use for breakdown, refurbishment or maintenance work.
Sewer & Waste Water Treatment Plants: Epoxy coatings

- Use epoxies that are **highly cross linked resins**, where the stoichiometry is very exact, leaving almost no unreacted end chains (eg MasterProtect 1812)

- Highly cross linked materials have
  - **excellent chemical resistance**
  - a **high shore hardness**, providing high abrasion resistance
  - a **very fine surface texture**, reducing the growth of algae and barnacles in marine environments as they find it hard to attach (slippery)

- These materials can be used as the **wearing floor surface** in chemical storage areas, plants rooms and bin rooms
MasterSeal 7000 CR is a new technology, 2-part water based product, that when mixed forms a cross-linked interpenetrating network (IPN), which combines high chemical resistance, with effective crack bridging:

- **Very high chemical resistance** especially to biogenic sulphuric acid (BSA) attack and organic acids (in sewers), according to accelerated testing by Fraunhofer Institute

- **Crack-bridging** for gaps of up to 0.7 mm

- **Maximum moisture tolerance**, including application on damp (humid) concrete substrates (SSD) and steel

- **Fast and easy application** by rolling (or spray for large areas), at temperatures from 5 °C to 35 °C

- **Excellent fast curing properties**, which reduce downtime, critical in reopening sewers

- **Temperature resistance up to 60°C** (more than enough for a sewer)

A variant of the technology is a fairing coat/primer (1), complete with two top coats (2)
Chemical resistance represents one of the key factors in substrate protection. The exceptional durability of MasterSeal 7000 CR was successfully tested at the Fraunhofer Institute, under real conditions. The test simulated the conditions of a real sewer during 5 years of use and clearly showed that there were no significant changes on the properties of MasterSeal 7000 CR sample.
Sewer & Waste Water Treatment Plants: Hybrid Polyurethanes (new Xolutec technology)

The combination of 0.7mm+ crack bridging, chemical resistance and ease of use offers clear benefits compared to current systems.
# Sewer & Waste Water Treatment Plants:
## Application – Chemical Resistance & Methods (Roller & Spray)

| Media | Temperature | Duration of impact | Resistance*
|-------|-------------|--------------------|-------------
| **Acids** | | | |
| Sulphuric acid 20% (DF 10 acc. to EN 13529) | 20° C | 170 h | ++
| Sulphuric acid 50% | 50° C | 170 h | ++
| Acetic acid 10% (DF 9 acc. to EN13529) | 20° C | 310 h | ++
| Acetic acid 20% | 20° C | 310 h | ++
| Lactic acid 30% | 20° C | 170 h | ++
| Sulphuric acid 20% + lactic acid 5% | 50° C | 170 h | ++
| **Lyes** | | | |
| Sodium hydroxide 20% (DF 11 acc. to EN13529) | 20° C | 310 h | ++
| Potassium hydroxide 20% | 20° C | 310 h | +
| Ammonia 25% | 20° C | 310 h | -
| **Organic chemicals** | | | |
| Ethanol 50% | 20° C | 310 h | O
| 48% Methanol + 48% isopropanol + 4% Water (DF5) | 20° C | 500 h | O
| Methanol 100% (DF 5a acc. to EN13529) | 20° C | 500 h | O
| 50% Ethylacetate + 50% methylisobutylketone (DF7) | 20° C | 500 h | -
| Toluene | 20° C | 500 h | O
| Gasoline acc. to EN 228 and DIN51626-1 | 20° C | 500 h | ++
| **Specific solutions** | | | |
| Silage water (3% milk + 1.5% vinegar +0.5% butyric acid) | 40 °C | 500 h | ++
| Liquid manure (7% ammoniumhydrogenphosphate) | 40 °C | 500 h | ++
| Distilled water | 40 °C | 500 h | ++
| Chlorine bleaching | 50 °C | 170 h | ++
| Chlorinated water | 20 °C | 500 h | ++

*++ resistant without any changes longer term
+ moderate resistance medium term
O short term resistant (occasional contact or splashing mode)
- not resistant

Roller application

Spray application
Sewer & Waste Water Treatment Plants: Hybrid Polyurethanes (new Xolutec technology)

Recently completed projects include:

- Sino-French Water (Shanghai), 12,000 m²
  - Secondary sedimentation concrete tank
- Burra Foods (Victoria), 300 m²
  - WWTP steel tank (concrete base)
- Trials currently underway with major Australian Water Authorities
Extreme FRP Strengthening: Power Station Cooling Tower

- **Project: Loy Yang Cooling Tower, Vic, 2015**

- **MasterBrace FRP MBAR (10 mm diameter)** was used to replace corroded hoop reinforcement (circumferential, ~170 m)

- Many challenges

  - **Difficult access** – Helicopter required for gantry installation, on non vertical face

  - **Extreme wind effects** - Height above ground ~105 m

  - **Top 11 rows of reinforcement replaced** (top 3 during shutdown), remainder installed whilst back on-line

  - **Near Surface Mounted (NSM)** technique employed, requiring horizontal groove cut
Extreme FRP Strengthening: Power Station Cooling Tower
Conclusions

Repairs to concrete and steel structures are required in extreme environments.

These range from marine structures, through to sewers and wastewater, the power and heavy industry.

In terms of sewers & wastewater, a wide variety of options are available for consideration including:

- Cement based mortars – OPC, CAC and geopolymer materials.
- Resin based coatings – Epoxies, Poly/Vinylesters, Polyureas and new technology Hybrid Polyurethanes.

Examples of repairs were given in harsh environments, including an extreme FRP strengthening repair of an operating cooling tower. Proper application by trained personnel is the key to success.

The right solution involves:

- careful consideration of the latent and operating environments,
- a full understanding of the material performance properties, both during application and final conditions.

Resulting in delivery of longer maintenance cycles and lower life cycle costs, as well as reducing the total cost of ownership.
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Thank-you. Any Questions?