Sealing Concrete Bridge Decks: Overview of Current Technologies

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Concrete Non-Film Forming Sealers

Overview of most recent and commonly used non-film forming sealer technologies for the protection of concrete bridge decks

Goals:

– Showcase sealers as an cost effective and easy-to-use solution in order to extend the service life of bridge decks

– Recognize sealers as an advanced technology, where Manufacturers have pursued and achieved innovation

– Present sealers as an ideal complement to high performance concrete
Shrinkage cracks are very common. They appear even in high performance concrete with well balanced mix-design. Cracks must be sealed in order maintain concrete in a good state and prevent its deterioration.
Conditions for Concrete Deterioration

- **Porosity**
  - Cracks
  - Capillary Pores (high W/C, poor curing)
  - Macro-voids (improper compaction)

- **Moisture into concrete**

- **Aggressive agents**
  - Air ($O_2, CO_2$)
  - Water ($SO_4, Cl^-, Alkali Ions$)
Bridge Deck Deterioration

Forms of deterioration:

– Spallings
– Delaminations
– Crumbling
– Steel Corrosion
Non Film-Forming Sealers

• Penetrating Silane Sealers:
  – 40% solids
  – 100% solids, neat silanes
  – Organo-functional corrosion inhibitors

• Surface Sealers or Crack Healer-Sealers
  – MMA
  – HMWM
  – Ultra/Very Low Viscosity Epoxy
    • 100% solids, neat epoxy
    • 70% solids epoxy
Common Characteristics

- Prevent water and aggressive agents to enter into concrete
- Ideal with fine cracks
- Continuous application over traffic surface
- Periodic re-applications (recommended)
- Non-specialized application crew
- High daily production
- Basic surface preparation with dry substrate
Surface Preparation

Light shot-blasting is the preferred surface preparation method. It opens up the porosity of concrete surface. Compressive air blowing can be used, also as a complement to shot-blasting. Wet blasting prepares the surface well. Time may be required for the surface to dry.
PENETRATING SEALERS
From Hydrophilic to Hydrophobic

Water repellents penetrate the surface pores and cracks, so that they are internally lined but not filled.

Reduction of concrete surface tension: inter-molecular attraction of water molecules is much higher than the attraction of water into concrete.

From hydrophilic (water-loving) to hydrophobic (water-hating) surface.
A Permanent Link

- Polymerized silane Si-O-Si is attracted by concrete and absorbed into its surface layer.
- A chemical reaction takes place between OH- groups of silane and concrete with formation of water.
- It also creates a stable chemical link Si-O-Ca that fixes silane polymer into concrete.
Types of Silane Water Repellents

• 100% Silanes or Neat Silanes
  – Introduced 5 years ago
  – VOC regulations
  – Deep penetration into concrete

• 40% Silanes in water
  – Porous concrete
  – Sunny, dry environment

• 40% Silanes in solvent
  – Dense concrete
  – Humid environment
Application Conditions

- Low porosity concrete
  - $W/C = < 0.42$
- Widely diffused, random micro-cracks from shrinkage
  - Minimum crack width: 0.001 in.
- Application:
  - 3 to 6 weeks after completion
  - Deck is chloride contaminated
- Re-application
  - 3-5 years for 40% silanes
  - 10+ years for 100% silanes
Application Points

• Viscosity: less 2 cps

• Equipment:
  – Low pressure Hudson sprayer
  – Spray bar

• 1 coat application
  – 2-coats for 40% silane

• Application crew:
  – 3 people (spray bar)

• Daily Production:
  – 100,000 sq.ft (spray bar)
  – 10,000 sq.ft / day / man with Hudson Sprayer

• Traffic Reopening: 1 - 6 hrs.
Organo-Functional Silane Corrosion Inhibitor

- Dual functional products that works as sealers and corrosion inhibitors
  - Corrosion inhibitor amines are bonded to silanes
  - Silanes carry ammine groups to steel bars
  - Silanes bond ammines to steel bars

Courtesy of Evonik
Application Conditions

• New concrete, ordinary and high performance

• Concrete that has restoration patches

• Contaminated concrete
  – Chlorides up to 10 lbs./cu.yd
  – Marine environment

• Re-application time:
  – Average 10+ years

• Penetrate up to 3 - 4 in. in 28 days (2+ applications)

• Reduction of active corrosion rate: up to 85%

• Extension service life: double+ when applied on sound new concrete
CRACK HEALER-SEALERS
Crack Healer-Sealers

• Healer-sealers penetrate and fill concrete cracks
  – Restore concrete integrity
  – Barrier to entrance of water and contaminants

  – Applied on new concrete:
    • Help prevent concrete deterioration
    • Help prevent steel corrosion

  – Applied on already deteriorated concrete:
    • Slow down deterioration process
Technologies

MMA
- Metha Methacrylate

HMWM
- High Molecular Weight Methacrylate

Epoxy
- 100% solids
- 70% solids

Very rapid traffic re-opening
Ultra fine cracks

Slower traffic re-opening
Very fine and larger cracks
MMA & HMWM: Formulations

**MMA**
- 2 components:
  - methyl methacrylate resin
  - Dibenzoyl Peroxider BPO, catalyst – Batch to batch
- 3 components:
  - Add CW additive for temperature applications from 50 to 15 °F

**HMWM**
- 3 components:
  - Methacrylate resin
  - Cumene hydrogen peroxide (CHP) initiator
  - Cobalt promoter
- 2 components:
  - Promoter premixed into resin
## MMA & HMWM: Key Information

<table>
<thead>
<tr>
<th>MMA</th>
<th>HMWM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity: 15 cps</td>
<td>Viscosity: 5-25 cps</td>
</tr>
<tr>
<td>Traffic re-opening: 1 hr.</td>
<td>Traffic re-opening: 2-3 hrs.</td>
</tr>
<tr>
<td>Appl. range: 15 °F - 90 °F</td>
<td>Appl. range: 50 °F - 90 °F</td>
</tr>
<tr>
<td>Elongation: 5%</td>
<td>Elongation: 30%</td>
</tr>
<tr>
<td>Tensile Strength &gt; 8,000 psi</td>
<td>Tensile Strength: &gt; 500 psi</td>
</tr>
<tr>
<td>Comp. Strength &gt; 12,000 psi</td>
<td>Comp. Strength &gt; 3,500 psi</td>
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<tr>
<td>Odor</td>
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<td>Flash Point &gt; 50 °F</td>
<td>Safe, shelf life reduction to 3-4 months.</td>
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- **MMA**
  - Viscosity: 15 cps
  - Traffic re-opening: 1 hr.
  - Appl. range: 15 °F - 90 °F
  - Elongation: 5%
  - Tensile Strength > 8,000 psi
  - Comp. Strength > 12,000 psi
  - Odor
  - Flash Point > 50 °F

- **HMWM**
  - Viscosity: 5-25 cps
  - Traffic re-opening: 2-3 hrs.
  - Appl. range: 50 °F - 90 °F
  - Elongation: 30%
  - Tensile Strength: > 500 psi
  - Comp. Strength > 3,500 psi
  - 2 Components
    - Safe, shelf life reduction to 3-4 months.
Application Conditions

- Shrinkage cracks
- Minimum crack width: 0.001 in.
- Crack depth:
  - No limit for penetration
  - Seal underside of the cracks
- Re-application time
  - 10 - 20 years, if cracks reappear
MMA – Application Cycle

Mixing

Spreading

Sand Broadcasting

Final

Courtesy of BASF
Application Crew

Application crew: 5 people
1 mix, 1 pour, 2 squeegee, 1 sand broadcast
Daily production: 10,000-20,000 sq.ft per day

Courtesy of BASF
Epoxy Healer-Sealers

• Random as well as longitudinal and transverse cracks

• Drying shrinkage cracks

• Minimum crack width: 0.002 in.

Courtesy of Dayton
Neat & Solvent-based: Characteristics

**Solvent-based, 70% solids epoxy**
- Viscosity: 40 cps
- Plastic shrinkage cracks
- Elongation: 50 - 65%
- Tensile Strength: 2,500 psi

**Neat, 100% solids epoxy**
- Viscosity: 80-120 cps
- Drying shrinkage cracks
- Elongation: 5-10%
- Tensile Strength > 5,000 psi
- Comp. Strength > 10,000 psi

Courtesy of Dayton

Courtesy of Sika
Application

Broadcast dried silica sand immediately after epoxy application

Application crew: 5 people, 1 mix, 1 pour, 2 squeegee, 1 sand broadcast

Daily production: 1,000 sq.ft/ hour /person

Traffic reopening: 4 - 8 hrs.
### Where to Apply

<table>
<thead>
<tr>
<th>Penetrating Sealer</th>
<th>Impregnate Cracks</th>
<th>Fill Cracks</th>
<th>Protective Film over Steel</th>
<th>Fine Cracks</th>
<th>Larger Cracks</th>
<th>New Concrete</th>
<th>Concrete with Cl-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Repellents</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes, not first choice</td>
<td>Yes, not first choice</td>
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<td>Anti-Corrosion</td>
<td>Yes</td>
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<td>Epoxy</td>
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## Application Features

<table>
<thead>
<tr>
<th>Component Type</th>
<th>Dry Substrate</th>
<th>Mix Components</th>
<th>Spray Bar</th>
<th>Sand Broadcast</th>
<th>Fast Traffic Opening</th>
<th>Extended Temp. Range</th>
</tr>
</thead>
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<tr>
<td>Penetrating Sealers</td>
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<td>Anti-Corrosion</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes, depending on brands</td>
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</tr>
<tr>
<td>Crack Healer Sealers</td>
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## Efficiency

<table>
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<tr>
<th>Penetrating Sealers</th>
<th>Water Repellents</th>
<th>Daily Production (sq.ft)</th>
<th>Cost $/sq.ft</th>
<th>Re-application Time Yrs</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Crew People</td>
<td>3</td>
<td>0.15 - 0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Daily Production (sq.ft)</td>
<td>100,000 with spray bar</td>
<td>0.15 - 0.25</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>30,000 with Hudson sprayer</td>
<td>0.15 - 0.25</td>
</tr>
<tr>
<td>Anti-Corrosion Sealers</td>
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<td>Crew People</td>
<td>3</td>
<td>0.75 - 1.00</td>
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<td></td>
<td></td>
<td>Daily Production (sq.ft)</td>
<td>100,000 with spray bar</td>
<td>0.75 - 1.00</td>
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<tr>
<td>Crack Healer-Sealers</td>
<td>HMWM MMA</td>
<td>Crew People</td>
<td>4 - 6</td>
<td>0.65 - 1.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Daily Production (sq.ft)</td>
<td>10,000 - 20,000</td>
<td>0.65 - 1.00</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>30,000 (HMWM spray bar)</td>
<td>0.65 - 1.00</td>
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<tr>
<td></td>
<td>Epoxy</td>
<td>Crew People</td>
<td>4 - 6</td>
<td>0.25 - 0.50</td>
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<td>Daily Production (sq.ft)</td>
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Due to low cost and highly daily production, sealers are a very cost-effective solution. Their cost is not even comparable to bridge deck reconstruction, or even repair.
Concrete Enhancement

Sealers are concrete enhancers... as pills for the body
Water Repellent Tests and Specifications

- **NCHRP Series II & IV**
  - Water capillary uptake
  - Chloride penetration
  - Water vapor transmission
  - Accelerated weathering - Northern and Southern climates

- **Penetration**
  - OK DOT and SC DOT: 0.16 in (4 mm) minimum
  - TX DOT: 0.23 in (6 mm) minimum
  - MI DOT: 0.25 in minimum

- **Alberta DOT AT&U**
  - Vapor transmission
  - Alkaline Resistance
  - Waterproofing
    - Before abrasion
    - After abrasion
      (A measure of depth of penetration)
Recommendations

- Create unity of specifications at Regional level:
  - Sustain industry innovation effort
  - Simplify communication between States
  - Simplify communication between States and Manufacturers
  - Reduce test costs for both Manufacturers and States
Thank you 🌸

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