Evaluation of Penetrating Sealers for Concrete

TAC Meeting

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Purpose of the Work

• To evaluate recommended protocols and standards for testing the penetrating sealers

• To select, modify, or update the most appropriate testing protocols

• To examine the selected sealer performance in laboratory and field

• To develop guidelines and protocols for investigating the short- and long-term performance of the sealers
Enhanced Durability, Areas of Interest

- Joints
  - Paste deterioration due to chemical attack
  - Saturated frost damage
  - D-cracking
  - Mechanical damage
  - Early-age drying damage

- Bridge Decks
  - Reinforcement corrosion
  - De-icing salt scaling

Dealing with fluid transport into concrete…
Enhanced Durability, Solutions?

- A low w/cm ratio (i.e., about 0.40 to 0.42)
- Use of SCMs to reduce permeability and improve resistance to oxychloride formation
- Provide an adequate air void system
- Provide an adequate drainage system beneath the concrete
- Optimize the construction techniques
- Limit the use of aggressive salts
- Use of *surface treatments*
### Popular Topical Treatment Families...

<table>
<thead>
<tr>
<th>Sealer Family</th>
<th>Mechanism of action</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silanes, siloxane, and siliconates</td>
<td>Water repellent</td>
<td>Silicon based, react with hydration products</td>
</tr>
<tr>
<td>Epoxies</td>
<td>Pore blocking or barrier coat&lt;sup&gt;i&lt;/sup&gt;</td>
<td>Thermoset polymers</td>
</tr>
<tr>
<td>Gum resins and mineral gums</td>
<td>Pore blocking</td>
<td>Synthetic or natural viscous hydrocarbons</td>
</tr>
<tr>
<td>Linseed oil</td>
<td>Pore blocking</td>
<td>Vegetable oil</td>
</tr>
<tr>
<td>Stearates</td>
<td>Water repellent</td>
<td>Soaps or metallic salts from fatty acids</td>
</tr>
<tr>
<td>Acrylics</td>
<td>Pore blocking or barrier coat&lt;sup&gt;ii&lt;/sup&gt;</td>
<td>Polymers or copolymers of acrylic acid…</td>
</tr>
<tr>
<td>Silicates and fluosilicates</td>
<td>Pore blocking</td>
<td>Silicon based with no organofunctional group</td>
</tr>
<tr>
<td>Urethanes and polyurethanes</td>
<td>Pore blocking or barrier coat&lt;sup&gt;iii&lt;/sup&gt;</td>
<td>Reactive resins</td>
</tr>
<tr>
<td>Polyesters</td>
<td>Pore blocking or barrier coat&lt;sup&gt;iii&lt;/sup&gt;</td>
<td>Synthetic resins</td>
</tr>
<tr>
<td>Chlorinated rubber</td>
<td>Pore blocking or barrier coat&lt;sup&gt;iv&lt;/sup&gt;</td>
<td>Chlorinated polyisoprene</td>
</tr>
<tr>
<td>Silicones</td>
<td>Water repellent</td>
<td>Silicon based with two organofunctional group</td>
</tr>
<tr>
<td>Vinlys</td>
<td>Pore blocking or barrier coat&lt;sup&gt;iii&lt;/sup&gt;</td>
<td>Polymers of acrylic and methacrylic acid</td>
</tr>
</tbody>
</table>

<sup>i</sup> Acting as pore blocker when less than 50% active ingredient  
<sup>ii</sup> Pore blocking if solvent based, barrier coating if water based or high molecule weight  
<sup>iii</sup> Pore blocking if diluted and barrier coat if not diluted  
<sup>iv</sup> Mainly barrier, but can be pore blocker if too diluted
Surface Treatment

Surface coatings  Pore blockers  Pore liners

Medeiros and Helene 2009
Why Penetrating Sealers?

Transport: capillary suction, diffusion, and permeation

Capillary suction: typically considered as the dominant transport mechanism for concrete exposed to atmospheric exposures

\[ \Delta P = \frac{2\sigma \cos \theta}{r} \]

\( \sigma \): surface tension
\( \theta \): contact angle
\( r \): pore radius

Liu and Hansen 2016
Why Penetrating Sealers?

Improved transport properties
Delayed critical saturation

Liu and Hansen 2016
Experimental Program

Four Concrete Types:

- **Control**: SAM number < 0.20, high quality aggregate in terms of resistance to D-cracking, and >25% Class C fly ash.
- **Experimental mixture #1**: Inadequate air void system, with a SAM number > 0.40, high quality aggregate, and >25% Class C fly ash.
- **Experimental mixture #2**: D-cracking susceptible, SAM number < 0.20, poor quality aggregate in terms of resistance to D-cracking, and >25% Class C fly ash.
- **Experimental mixture #3**: Oxychloride susceptible, SAM number < 0.20, high quality aggregate, and 100% ordinary Portland cement.
Five Sealer Types:

- **Silane;** solvent based
- **Acrylic;** solvent based
- **Silicate;** water based lithium silicate or colloidal silica
- **Vegetable oil;** SME solvent based
- **Crystalline water proofer**
Work Plan

- Characterization: contact angle, depth of penetration…
- Laboratory testing: transport, F/T, …
- Establish correlations, select a sealer for field implementation?
- TAC meeting to discuss the findings…
Work Plan

**First Round**

**Round One:**
- Reference concrete
- Without sealer
- With all 5 sealers

**Selected Sealer**

**Second Round**

**Round Two:**
- Mixtures: Exp. 1, 2, 3
- Without sealer
- With selected sealer

**ISU Testing:**
- ASTM C457
- Drop test
- Surface resistivity
- Gas permeability
- Penetration depth
- Contact angle
- LT-DSC

**UMKC Testing:**
- F/T AASHTO T161
- Absorption; ASTM C1585 – 90 days
- UV exposure; ASTM C793 + ASTM C1585

**Expected Improvement Guidelines**

**FIELD IMPLEMENTATION**

**Extent of Improvement for each potential scenario**
Work Plan

- Characterization: contact angle, depth of penetration…
- Laboratory testing: transport, F/T, …
- Establish correlations…

- **UV Exposure**: effective life of sealers
- **Field performance**

- Quantify benefits through life cycle cost analysis (LCCA)
# Time Schedule

| Task / Timeline (month)                        | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
|-----------------------------------------------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Project kick-off meeting                     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Task 1 Literature review                     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Task 2 2.1. Effect of sealers on concrete performance |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Task 2 2.2. Investigation on sealer materials |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Task 3 Field Implementation                 |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Task 4 Economic Analysis                    |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Technology Transfer (development of tech brief) |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| TAC Meetings                                |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Final Report                                |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |