Curing and Sawing Considerations for Good Durability

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Presentation Overview
- Current state of curing
- Best practices for curing
- Current state of sawing
- Discussion of how sawing variables affect performance
- Best practices for sawing
- Discussion of steps towards active management of sawing along with curing
Acknowledgements
Researchers: James A Crovetti – Marquette University; Danny Xiao-UW Platteville, Dan Zollinger-Texas A&M
Students - Matt Eichman, Bethany Buckland, Ellie Shorter, Etienne Nkongolo, Nick Barrios

The Concrete Paving Process

1. Planning
   What do we want? What can we afford?

2. Material Selection
   Materials and mixture proportion development and approval

3. Production
   Mix up some rocks, cement, sand, and water

4. Construction/Finishing
   Get it in place without screwing it up

5. Cure, Saw, and Hope
   What? Who cares? Is anyone actually there?
ACI 308 - Curing

• Curing is an action taken to maintain moisture and temperature conditions in a freshly placed cementitious mixture to allow hydraulic cement hydration and, if pozzolans are used, pozzolanic reactions to occur so that the potential properties of the mixture may develop.

Membrane Forming Curing Compound

Evaporation from water surface

Cure affected zone ~1/2 in.

Partially saturated

Saturated

Curing membrane

Concrete
Under Curing - Scaling
Or Plastic Shrinkage Cracking

Membrane Forming Curing Compounds (State of the practice)

AASHTO T148/ ASTM C309
ASTM C309

- Moisture loss (ASTM C156)
  - <0.55kg/m² @ 100°F/32%RH at 72 hrs @ 200sf/gal
  - Note, this is performed on mortar, w/c = 0.40; 18.6in² and 3/4in thick
- Reflectance (Type 2, ASTM E1347) > 60%
- Drying time < 4hrs @ 73F/50%RH
- Finger test

<table>
<thead>
<tr>
<th>color</th>
<th>Solid Constituent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Types</td>
<td>Description</td>
</tr>
<tr>
<td>1</td>
<td>Clear or Translucent w/out Dye</td>
</tr>
<tr>
<td>1-0</td>
<td>Clear or Translucent w/ Fugitive Dye</td>
</tr>
<tr>
<td>2</td>
<td>White pigmented</td>
</tr>
</tbody>
</table>

Resin, n—a solid or pseudosolid organic material often of high molecular weight, which exhibits a tendency to flow when subjected to stress, usually has a softening or melting range, and usually fractures conchoidally.

DISCUSSION—In a broad sense, the term is used to designate any polymer that is a basic material for plastics.

Select MFCC Specifications

<table>
<thead>
<tr>
<th>Agency</th>
<th>24-Hour Limit (kg/m²)</th>
<th>72-Hour Limit (kg/m²)</th>
<th>Application Rate (ft²/gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virginia DOT</td>
<td>0.20</td>
<td>0.30</td>
<td>100 Class B</td>
</tr>
<tr>
<td>Mississippi DOT</td>
<td>NA</td>
<td>0.55</td>
<td>120</td>
</tr>
<tr>
<td>Iowa DOT</td>
<td>0.20</td>
<td>0.40</td>
<td>135</td>
</tr>
<tr>
<td>South Carolina DOT</td>
<td>NA</td>
<td>0.55</td>
<td>100 Class A, 150 Class B</td>
</tr>
<tr>
<td>Montana DOT</td>
<td>NA</td>
<td>0.55</td>
<td>150</td>
</tr>
<tr>
<td>New York DOT</td>
<td>NA</td>
<td>—</td>
<td>150 in two directional passes</td>
</tr>
<tr>
<td>Texas DOT</td>
<td>NA</td>
<td>0.55</td>
<td>180 in two coats</td>
</tr>
<tr>
<td>Minnesota DOT</td>
<td>0.15</td>
<td>0.40</td>
<td>200</td>
</tr>
<tr>
<td>Delaware DOT</td>
<td>NA</td>
<td>0.55</td>
<td>400 in two applications</td>
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</table>
Techniques to evaluate curing compound effectiveness

- Visual – Eyes...White sheet of paper...image analysis

400sf/gal  180sf/gal

Is this ok?
Techniques to evaluate curing compound effectiveness

Or this?

• Volume/Area – Simple, CT535 (Long: 5 test pads, 3 ft from edge randomly for 50 ft), or
• Volume/Area – Determine volume of CC tank, measure level before and after going a measured distance, calculate application rate
Who puts down the curing compound?

This guy, or your equivalent

When? When there is a break or he gets yelled at
How much?

• When?
• How much?
• Trouble shooting?
Field Evaluation-Results

• Comparing Caltrans (pee pad) and area volume

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>A (275 ft²/gal)</th>
<th>B (167 ft²/gal)</th>
<th>C (275 ft²/gal)</th>
<th>D (167 ft²/gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>331</td>
<td>245</td>
<td>235</td>
<td>148</td>
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<td>2</td>
<td>158</td>
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<td>4</td>
<td>374</td>
<td>190</td>
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<tr>
<td>5</td>
<td>261</td>
<td>190</td>
<td>138</td>
<td></td>
</tr>
<tr>
<td>Avg</td>
<td>227</td>
<td>300</td>
<td>198</td>
<td>136</td>
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<tr>
<td>Std Dev</td>
<td>91</td>
<td>91</td>
<td>23</td>
<td>24</td>
</tr>
<tr>
<td>COV (%)</td>
<td>40%</td>
<td>30%</td>
<td>12%</td>
<td>18%</td>
</tr>
</tbody>
</table>

Fast     Slow     Fast     Slow

Observation of Curing using Embedded Resistance

- Resistance increases as structure gets denser during hydration (Good)
- Resistance increases as concrete dries out (Bad)
- Drying happens much faster than hydration at early ages
At low evaporative conditions, drying in the surface was similar between uniform and non-uniformly applied MFCC.

At high evaporative conditions, uniformity matters.
Does Rate Matter? YES!!!!

Steps Towards Active Curing Management

- Current Technologies
  - Ensure appropriate/consistent spray bar height with 30% nozzle overlap (Vandenbossche 1999)
  - Calibrate and verify application rate and consistency
  - Enforce tank stirring

Which of these has a higher application Rate?
Steps Towards Active Curing Management

- Next Steps
  - Instrument curing cart with real-time display
  - Maybe adjust curing rate and timing for weather

Steps Towards Active Curing Management

- Future Opportunities
  - Define evaporative behavior of a mixture and curing compound across anticipated environmental conditions and evaporation rates
  - Predict evaporative conditions from on-site weather stations and forecast to determine timing and rate
  - Monitor actual concrete properties (resistance, humidity, dielectric constant)
  - Confirm coverage (doped visual, GPR)
  - Pay for performance
What’s Next?

• So you’ve listened to Dr. Kevern and cured perfectly, are you ok?
• Let’s be honest, who determines “optimal” saw timing?

Likely not this many inspectors

Symptoms of a Bigger Problem

- Shallow Spalling
- Cracking
- Joint Spalling
- Shadowing
- Freeze-Thaw Joint Deterioration
To Seal or Not To Seal

Sawing Damage

Fig 1.2.5. Raveling due to poor sawing practice (Source: Iowa Department of Transportation)
Freeze Thaw Damage (Sawing?)

D-cracking

Poor air void system

Freeze Thaw Damage

Figure 1. Evidence of joints that are draining well
CP Tech Center 2011
WisDOT-Influence of Joint Sawing Factors on Concrete Pavement Durability

- Factor 1 - Coarse Aggregate Types (2)
  - Soft Limestone & Hard Igneous Gravel
- Factor 2 - Saw Types (2)
  - Conventional & Early Entry
- Factor 3 – Saw Timing (2+1)
  - Early or Late with optimal control
- Factor 4 - Blade Type (2)
  - Soft/Hard
- Factor 5 – Blade Wear (2)
  - New or aged
- Joint Sealer/Water Proofer
Absorption Testing

Figure 3.2.1. Sample for absorption testing

Limestone Absorption - Examples

Early entry saw, early sawing window, new limestone blade

Early entry saw, early sawing window, old limestone blade

In all cases, old/worn blades caused measurable and significant increases in absorption
Granite Absorption - Examples

In all cases, old/worn blades caused measurable and significant increases in absorption.

Sawing Summary

- Excessive raveling is more a function of the mix (aggregate gradation) and not necessarily sawing too early.
- Sawing does impact microstructure and material properties.
- Timing is important and earlier is better if the correct and properly-maintained blade is used.
- Old blades/equipment cause significant damage.
- Later in the sawing window was less sensitive to variables.
- In all cases, optimal timing produced the worst absorption.
Curing Summary

• Curing is critical for short and long-term performance
• Curing is often overlooked and right now there really isn’t a good way to quantitatively measure
• Calculate the volume needed for an area and get it visually uniform
• New technologies are emerging

The FUTURE

• We have the ability to actively manage the process from curing through sawing.
THANK YOU!

Questions?