Outline

• Why
• What is it
• **How**
• When
• How much
Cement Hydration

• Chemical reactions between cement and water

• Will keep going as long as:
  • Sufficient cement
  • Sufficient water
  • Sufficient temperature
Effect of Curing

Good

Inadequate
Effect on properties

- Strength
  - Conventional wisdom
  - Not really

![Compressive strength graph](image)
Effect on properties

• Permeability
  • Yes!!!
  • Because it is a surface effect

<table>
<thead>
<tr>
<th>Water / cement ratio</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.40</td>
<td>3 days</td>
</tr>
<tr>
<td>0.45</td>
<td>7 days</td>
</tr>
<tr>
<td>0.50</td>
<td>28 days</td>
</tr>
<tr>
<td>0.60</td>
<td>6 months</td>
</tr>
<tr>
<td>0.70</td>
<td>1 year</td>
</tr>
<tr>
<td>0.80</td>
<td>Never</td>
</tr>
</tbody>
</table>
Moisture Loss

- Plastic shrinkage (before set)
- Drying shrinkage (after set)
What About Temperature?

• Hydration halves with 18°F decrease in temperature
• But the drying may not be affected

• We want to be like Goldilocks…
  • Not too hot
  • Not too cold
• No shocks
Thermal Shrinkage

- Concrete sets while hot and is expanded – then it shrinks
- Temperature peaks within the first 12 hours
- Air temperature often drops at the same time
- Combined affect can be significant
- All while concrete is very weak

- Differentials >30°F will likely cause cracking
What is too hot?

• Delayed ettringite formation risk increases above ~160°F
What is too cold?

- Hydration stops at about 14°F

- Freezing can occur in the pore solution
  - If mix is <500 psi
At the end of the day

- Wet enough for long enough to achieve desired hydration
- Uniformly enough to reduce drying stresses

- The right temperature to achieve desired hydration
- Avoiding temperature differentials

- Easy right?

*Keep it wet
*Keep it warm*
Moisture control

• Prevent drying
• Add water from the outside
• Add water from within
Prevent drying

• Plastic sheets
Prevent drying

• Evaporation Retarder
  • Between placement and finishing
  • Reduces plastic shrinkage cracking
  • Not a finishing aid – beware of increasing surface w/cm
Prevent drying

• Tent
Prevent drying

- Curing Compound
  - Poly-alpha-methylstyrene
  - ASTM C 309 or local requirements
  - White
  - Allow for effects of texture
Prevent Drying

- Use a machine
- Apply to moist surface
- Protect from wind
- Overlap
- Protect the compound from traffic

a.) Nozzle heights adjusted to obtain 30% overlap of adjacent spray patterns.
b.) Nozzles must be raised to retain 30% overlap for the 250-mm PCCP.
Add water from the outside

• Flood
Add water from the outside

- Flood
- Burlap or absorbent materials
Add water from the outside

- Flood
- Burlap
- Fog
When

• Too early
  • Bleed water is trapped → flakey surface
  • Have to wait for texturing

• Too late
  • Why bother
How Long?

• Until you have required properties at the surface
• When removing covers – avoid moisture and thermal shock
Internal Curing

- Reported Benefits
  - Less shrinkage, cracking, curling
  - Better hydration & SCM reaction
    - Improved durability
    - Less cement
  - Extended service life
  - Increased sustainability
Internal Curing

- Expanded fine aggregate
- Super Absorbent Polymers

- About 7lb IC water for 100 lb cement
Internal Curing

- Place under sprinkler for minimum of 48 hours
- Allow stockpiles to drain for 12 to 15 hours immediately prior to use
Temperature Control

• Hot Weather
  • Prevent evaporation
Temperature Control

- Hot Weather
  - Prevent evaporation
  - As a function of bleeding
Temperature Control

• Hot Weather
  • Cool the mixture
    • Cold water
    • Shade stockpiles
    • Liquid nitrogen
    • Fog sprays

• Hiperpav can model cracking risk
Temperature Control

• Hot Weather
  • Consider placing at night
Temperature Control

- Cold Weather
  - Heat the support system
  - Remove frost
  - Keep it warm
    - Blankets
    - Hydronics
    - Heaters

- Beware of thermal gradients
Keep it wet
Keep it warm