Troubleshooting Myths in Concrete Construction

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Ms. Wilson holds a B.S. in Architectural Engineering from Milwaukee School of Engineering, with an emphasis in structural engineering and concrete materials. Prior to joining PCA in 1999, she worked for Construction Technology Laboratories, PCA’s sole subsidiary, specializing in concrete evaluation and troubleshooting on various projects throughout the United States and previous to this she worked as a field inspector performing quality control for STS Consultants, Ltd. in Milwaukee, Wisconsin.

She is a member of ASTM Committee C09 Concrete and Concrete Aggregates, and ACI International Committees 201 Durability, 311 Inspection of Concrete, and 301 Specifications for Concrete (Chair 301 D). She was awarded the prestigious ACI Young Member Award for Professional Achievement in 2008.

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Sources of Authority & Information

- American Concrete Institute (ACI)
  www.concrete.org

- Canadian Standards Association (CSA)
  www.csa.ca

- American Society of Testing Materials (ASTM)
  www.astm.org

- Portland Cement Association (PCA)
  www.cement.org

- International Concrete Repair Institute (ICRI)
  www.icri.org
**Troubleshooting Concrete**

- Popular myths about concrete
- Constructability issues and poor specifications
- Testing bloopers
- Mistakes made in the field
- Durability failures
- How to avoid problems

**Popular Myths**

- Proper Cement & Water Content
- Importance of Slump
- Curing
- Cracking
- Permeability
- Strength vs. Durability

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**Myth**

- More cement makes better concrete.

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**Designing Concrete Mixtures**

**Objective:**

To determine the most economical and practical combination of readily available materials to produce a concrete that will satisfy the performance requirements under particular conditions of use.

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**The Water-Cement Ratio Law**

For given materials the strength of the concrete (so long as we have a plastic mix) depends solely on the relative quantity of water as compared with the cement, regardless of mix or size and grading of aggregate.

Duff A. Abrams
May, 1918

\[
\text{w/c: } \frac{\text{Quantity of Water}}{\text{Quantity of Cement}}
\]
**Myth**

- Slump is a measure of the quality of concrete.

![ASTM C143](image1)

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**Controlling Slump**  
(Control Consistency)

- w/cm
- Wash Water
- Aggregate Moisture
- Temperature
- Haul Time
- Mixing Time
- Admixture Dosage
  - Water Reducers
  - Air-Entrainers

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**How about water added on site?**

- ACI 301, ACI 302, ASTM C94  
  all allow limited addition of water...

- If water addition is allowed, slump must be specified as either a "maximum" or a "not-to-exceed" and the w/c ratio may not be exceeded

So... would you add more water?

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**Curing is a Process - Continues Hydration**

- Maintaining a satisfactory moisture content (>80% RH) and temperature (>40 °F) within concrete.

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**Myth**

- Curing concrete means letting it dry and harden.

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**Cement Hydrates in Layers...**

- Concrete cures from outside in.
### Strength vs. Curing Temperature

![Graph showing strength vs. curing temperature](image)

**Design and Control of Concrete, PCA 2002**

### Controlling Temperature

- **ACI 305- Hot Weather Concreting**
- **ACI 306- Cold Weather Concreting**

### Myth

- **Reinforced concrete won't crack.**

### Factors Impacting Volume Stability

- Restraint, Jointing
- w/cm
- Amount of Aggregate
- Properties of Aggregate
- Size & Shape of Member
- RH and Temp
- Method of Curing & Drying
- Degree of Hydration
- Time

### Tolerable Crack Widths for Reinforced Concrete

<table>
<thead>
<tr>
<th>Exposure condition</th>
<th>Tolerable crack width</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in.</td>
</tr>
<tr>
<td>Dry air or protective membrane</td>
<td>0.016</td>
</tr>
<tr>
<td>Humidity, moist air, soil</td>
<td>0.012</td>
</tr>
<tr>
<td>Deicing salts</td>
<td>0.007</td>
</tr>
<tr>
<td>Seawater and seawater spray, wetting and drying</td>
<td>0.006</td>
</tr>
<tr>
<td>Water-retaining structures</td>
<td>0.004</td>
</tr>
</tbody>
</table>

*ACI 224R*
**Jointing-Crack Control**

- Specify Joint Spacing

  **Rule of Thumb:** 30 t, ¼ d

  **Table E-1a. Spacing of Contraction Joints in Meters**

<table>
<thead>
<tr>
<th>Concrete Slump, cm</th>
<th>Maximum Size of Aggregate 15 mm</th>
<th>Maximum Size of Aggregate 10 mm and Larger</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td>3.8</td>
<td>3.25</td>
</tr>
<tr>
<td>150</td>
<td>3.75</td>
<td>4.5</td>
</tr>
<tr>
<td>175</td>
<td>3.6</td>
<td>5.0†</td>
</tr>
<tr>
<td>200</td>
<td>3.5†</td>
<td>6.0†</td>
</tr>
<tr>
<td>225</td>
<td>3.5</td>
<td>7.0†</td>
</tr>
<tr>
<td>250</td>
<td>3.4†</td>
<td>7.5†</td>
</tr>
</tbody>
</table>

**Volume Stability—Low Shrinkage Concrete**

- Low Shrinkage Concrete
  - ASTM C 157
- Less Than 400 millionths

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**Myth**

- Concrete is impermeable.

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**Effect of water-cement ratio on Permeability**


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**Factors Impacting Permeability & Watertightness**

- Material Fineness
  - Cement
  - Use of SCM’s
- Aggregate Gradation
- Paste/Aggregate Ratio
- Aggregate Paste Bond
- Curing
- Sealers
- Vapor Retarders/Barriers

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**Myth**

- The higher the concrete strength, the more durable the concrete.
Strength vs. Durability

- **Compressive Strength** - Measured Resistance of Concrete to Axial Loading.
- **Durability** - Ability of Concrete to Resist Weathering Action, Chemical Attack, and Abrasion While Maintaining its Desired Engineering Properties.

Factors Impacting Strength

- w/cm
- Age
- Air Content
- Aggregate Bond
- Handling
- Curing Temperature
- Testing Errors

Factors Impacting Durability

- Abrasion
- Carbonation
- Corrosion
- Reactive Aggregate
- Chemical Attack
  - Sulfate Attack
- Seawater Exposure

More Myths...

1. Concrete Temperature must be below 95°F
2. Using a retarding admixture allows you to go beyond the 90 minute window of placement specified in ASTM C94 and ACI 301.
3. You should hard trowel driveways and garage slabs exposed to cold weather.
4. ???

Poor Specifications

- Prescription vs. Performance
- w/cm vs. Strength
- Constructability
- Adequate Cover
- Acceptability

Confusion in Concrete Specifications

- CAN/CSA-A23.1 / CAN/CSA-A23.2: Concrete Materials and Methods of Concrete Construction/Methods of Test for Concrete
- ACI 318 Building Code Requirements for Structural Concrete
- ACI 301 Specifications for Structural Concrete
- ASTM C94: Standard Specification for Ready-Mixed Concrete
Acceptance Criteria

- General Acceptance criteria:
  - Architecturally acceptable concrete surfaces should be aesthetically compatible with minimal color and texture variations and minimal surface defects when viewed at a distance of approximately 20 ft (6m) or more as agreed upon by architect, owner, and contractor, or as otherwise specified.

QA/QC

- Preconstruction meeting
- Prequalification of finishing crew
- Test panels, Mock ups

Testing Bloopers

- Fresh Concrete Tests
- Slump Test
- Testing at Point of Placement
- Handling of Cylinders
- Interpreting Field Data

Mistakes in the Field

- Blessing
- Use of Evaporation Retardants as “Finishing Aids”
- Sealing the Surface (Overfinishing)
- Unventilated Heaters
- Poor Consolidation
- Cold Joints
- Discoloration

Durability Failures

- Surface Defects- Popouts, Scaling Spalling
- And of course, Cracking… Due to???
  - Freeze-Thaw
  - Corrosion
  - ASR
  - Sulfate Attack

Avoiding Problems

- Design- Constructability
- Mix Design
- Materials Selection
- Placement Procedures
- Environment

Design

Workmanship

Environment