28 Day Concrete Strength - Proactive vs. Reactive
PRESENTED TO: MN CONCRETE FORUM
JOHN HAUPT - NOVEMBER 8, 2017

Low 28 Day Compression Strength
NOW WHAT?

Preparing for the Concrete Placement
- Preconstruction Meeting
  - Discuss placement, testing, and other issues
- Mix Designs
  - Submitted for approval by the design team prior to placement.
  - ID number, type of aggregate, cementitious material, water cement ratio.
- Weather Issues
  - Hot and cold, wind
- Logistics
  - How it is placed on site after it leaves the truck
- Sampling Location
  - From truck or end of placement
On-Site Testing

An ACI Certified Technician will follow ASTM Testing Procedures

- C31: Standard Practice for Making and Curing Test Specimens in the Field
  - Most commonly used
  - Calibration not to exceed three months
- C231: Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
  - Used lightweight aggregate mixes
- C173: Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
  - Considered applicable to plastic concrete having coarse aggregate up to 1-1/2 inch in size
- C143: Standard Test Method for Slump of Hydraulic-Cement Concrete
  - Condition of mold may influence test results, calibration at least annually

ASTM Procedures

- C31
- C231/173
- C143

On-Site Testing

- C1064: Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
  - Device accurate to ± 1 deg. F and verified at least every 12 months
  - Verification of measuring device to National Institute of Standards and Technology (NIST)
- C1611: Standard Test Method for Slump Flow of Self-Consolidating Concrete
  - Used to monitor the consistency of fresh unhardened self-consolidating concrete and its confined flow

Visual Stability

Index Values

<table>
<thead>
<tr>
<th>Visual Stability Index Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
</tr>
<tr>
<td>Gray</td>
</tr>
<tr>
<td>Gray</td>
</tr>
<tr>
<td>Gray</td>
</tr>
</tbody>
</table>

Field Cured Cylinders

- Sometimes required on projects, especially during cold weather. Very hard to have the samples match the in-place temperatures of the structure.
- Not very representative.

Maturity Curve & Cippecs

11/8/2017
Site Storage and Transportation of Test Samples

- **Initial Curing**
  - Store immediately after casting
  - Temperature: 60-80 deg. F < 6000 psi
  - Time on-site up to 48 hrs.

- **MnDOT Intermediate Curing Period**
  - Specification 2401.5.G.S
  - Time period: less than 7 days

- **Safe Transportation of Test Specimens**
  - Transport 8 hours after initial set
  - Protect samples
  - Transportation time less than 4 hours

Laboratory Testing

- Certified Lab / Calibrated Equipment
- Final Curing ASTM C31
- Testing C39 or C78
- Capping / Pad Caps
- Alignment
- Size measurements
- Load rate: 35 - 70 psi per second

<table>
<thead>
<tr>
<th>Cylinder (in)</th>
<th>Low Rate (lb/m)</th>
<th>High Rate (lb/m)</th>
<th>Average Rate (lb/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>21,120</td>
<td>31,680</td>
<td>26,400</td>
</tr>
<tr>
<td>6</td>
<td>47,480</td>
<td>71,220</td>
<td>59,350</td>
</tr>
</tbody>
</table>

Review of Strength Test Results

- **7 Day Test Results**
  - Indicate test usually a top strength will achieve between 67% to 75% of the 28 day test. Depends on amount and type cementitious material content.

- **28 Day Average Strength**
  - ACI 318-14: average of two 6x12in or three 4x8in cylinders of the same sample tested at 28 days, or test age designated for f'c.

- **Breaks**
  - ASTM-C39 list six types of fractures types.

- **Possible Reasons for Low Strength**
  - Reviewing of Field Test Results
  - Air content, concrete temperature, slump
Extended Tests

- 56 Day Tests
  - If 28-day test is low, the 56-day Cylinder is tested.
- Slow Strength Gaining Concrete
  - Used in mass concrete applications.
  - Compressive strength for acceptance is usually tested at 56 or 90 days.

ACI 318-14 Chapter 26 – Construction Documents and Inspection

- Qualified Testing Staff
  - ACI Grade 1 Certified concrete field testing technician per ASTM C1077, or equivalent program.
- 26.12.3.1 (b)
  - Strength of concrete is satisfactory if both requirements are met:
    - Every arithmetic average of any three consecutive tests equals or exceeds $f'_{c}$
    - No strength test falls below $f_{c}$, by more than 500 psi when $f_{c}$ is 5000 psi or less, or by more than 0.10 $f_{c}$, if $f_{c}$ exceeds 5000 psi.

<table>
<thead>
<tr>
<th>Test Duration</th>
<th>28 Day Test</th>
<th>56 Day Test</th>
<th>90 Day Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days</td>
<td>14</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>Days</td>
<td>14</td>
<td>28</td>
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ACI 318-14 Chapter 26 – Construction Documents and Inspection

- Chapter 27.4 Load Testing
  - Not used much for new concrete
  - Can determine the capacity of a structure with questionable strength
  - New or additional loading
ASTM C42 – Testing Concrete Cores and Beams

Concrete Strength (ACI 214.4R)
- Core Location: bottom of the structure is stronger than top
- Core Orientation: lower strength when measured parallel to the casting plane

Core Size
- Use 4 in. core bit with a diameter at least 3.70 in., or at least 2X nominal size of coarse aggregate which ever is larger

Coring of Drilling
- Report if drills make the direction of the load on the specimen with respect to the horizontal/casting plane of the concrete as placed.

Storage
- After coring, wipe off surface. Place and keep in plastic bags or nonabsorbent containers at all times except during preparation for a maximum time of 2 hours to permit capping before testing.

ASTM C42 – Testing Concrete Cores and Beams (continued)

Length to Diameter
- If the ratio of length to diameter (L/D) of the specimen is 1.75 or less, correct the result by multiplying it by the appropriate factor given in the table in Section 7.9.1. Lengths less than its diameter after capping shall not be tested.

Capping
- Perpendicularity and planeness of the ends of the core needs to meet the specification in ASTM C39. Bonded capping is acceptable for the core to be cored. Unbonded caps are allowed as long as the gap between the core and retaining ring conforms to requirements of ASTM C1231.

Accepted Strength (ACI 318-14 Section 26.12.4.1.d)
- Concrete in an area represented by core tests shall be considered structurally adequate if:
  - 1. The average of three cores is equal to or more than 85 percent of $f'c$
  - 2. No single core is less than 75 percent of $f'c$

Ultimate acceptance is by the accepting agency typically the structural engineer.
Petrographic Analysis

Petrographic is the microscopic analysis of concrete and its aggregate mixes.

ASTM C457 Air Void
- Determines the air content of hardened concrete, void frequency, spacing factor, and paste-air ratio of the air-void system in hardened concrete.

Other Tests
- Carbonation
- Aggregate Types
- Water/Cement Ratio
- Bond/Water Tracks
- Cracking

Thank you!