Mass Placement of Concrete

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History of Mass Concrete in Texas Bridges

Pre 1980’s:
- Early bridges did not typically contain large elements and cement chemistry and heat of hydration did not lend toward DEF initiation.

1980’s and on:
- Elements started getting larger
- Prestressed Prefabricated Beams
- Time constraints and accelerated construction became desirable
  1. High Early Strength Cements (TY III)
  2. Early Form Removal
ACI Definition

- Mass concrete is defined by the American Concrete Institute as: “any volume of concrete in which a combination of dimensions of the member being cast, the boundary conditions, the characteristics of the concrete mixture, and the ambient conditions can lead to undesirable thermal stresses, cracking, deleterious chemical reactions, or reduction in the long-term strength as a result of elevated concrete temperature due to heat from hydration.” (ACI 207.1R).

- Mass concrete has been historically associated with large structures such as dams, bridge piers, and other large volume placements. However, due to the increasingly common use of fast-track construction practices and high-performance concretes with high cementitious contents, mass concrete issues are being experienced in typical bridge and building placements. Understanding the causes of mass concrete issues (high internal temperatures and temperature-related cracking) is the key to producing a structure that provides many years of service.
Mass placements are defined as placements with a least dimension greater than or equal to 5 ft., or designated on the plans.

- 2004 Standard Specifications
  Item 420.4

**Mass Placements.** Develop and obtain approval for a heat control plan for monolithic placements designated on the plans as mass concrete to ensure the following during the heat dissipation period:

- The temperature differential between the central core of the placement and the exposed concrete surface does not exceed 35°F and

- The temperature at the central core of the placement does not exceed 160°F

- Section 4.7.14

**Recommendations:**

5’ minimum dimension for regular concrete
6’ minimum dimension for HPC
The heat control plan may include a combination of the following elements:

- Selection of concrete ingredients including aggregates, gradation, and cement types, to minimize heat of hydration;
- Use of ice or other concrete cooling ingredients;
- Use of liquid nitrogen dosing systems;
- Controlling rate or time of concrete placement;
- Use of insulation or supplemental external heat to control heat loss;
- Use of supplementary cementing materials;
- Use of cooling system to control the core temperature; or
- Vary the duration formwork remains in place.

- *Item 420, Section 4.7.14*
Temperature Recording Equipment – Use strip chart temperature recording devices, recording maturity meters in accordance with Tex-426-A, or other approved devices that are accurate to within ± 2°F within the range of 32°F to 212°F for mass concrete operations, cold weather placements, and as otherwise specified.

- Section 3.3

Removal of Forms and Falsework – Keep in place weight-supporting forms and falsework for bridge components and culvert slabs until the concrete has attained a compressive strength of 2,500 psi in accordance with Section 420.4.11., “Removal of Forms and Falsework.” Keep all forms for mass placements in place for 4 days following concrete placement unless otherwise approved based on the outcome of the heat control plan outlined in Section 420.4.7.14., “Mass Placements.”

- Section 4.1.2
**Item 416.3.6.** Perform all work in accordance with Item 420, “Concrete Substructures.” Provide concrete with maximum placement temperatures as specified in Table 4. Provide thermal analysis to show and temperature recording devices to verify maximum core temperature requirements are met as specified in Section 420.4.7.14., “Mass Placements,” as directed.

<table>
<thead>
<tr>
<th>Shaft Size</th>
<th>Mix Design Options 1-5</th>
<th>Mix Design Options 6-8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter &lt; 5’</td>
<td>95°F</td>
<td>95°F</td>
</tr>
<tr>
<td>5’ ≤ Diameter ≤ 7’</td>
<td>95°F</td>
<td>85°F</td>
</tr>
<tr>
<td>7’ &lt; Diameter</td>
<td>85°F</td>
<td>75°F</td>
</tr>
</tbody>
</table>
Use the ConcreteWorks© software available from the Department, or another approved method based on the guidelines in ACI 207, “Mass Concrete,” to develop the heat control plan...

- Item 420, Section 4.7.14

Software is available on TxDOT website under tab:
- Inside TxDOT
  - Divisions
  - Information Technology
  - Engineering Software
Maximum Core Temperature 139 deg. F. < 160 deg. F.

Apply heat to enclosed area until temperature delta reduces to 35 deg. F.
Defining Mass Concrete for Bridge Elements

Defining Mass Concrete:

- Concrete Temperatures are the Key Component in Cracking and DEF

Contributing Factors are:

1. Element Size
2. Concrete Materials
3. Construction (Environmental) Conditions
Defining Mass Concrete for Bridge Elements

Problems associated with Mass Concrete Placements are due to heat generation from cement hydration.

- Maximum Temperature exceeding 160°F may cause DEF (a form of internal sulfate attack)
- Maximum Temperature difference exceeding 35°F may cause cracking (due to volume change causing thermal stresses above the tensile strength of the concrete).
Defining Mass Concrete for Bridge Elements
The Question is When to Specify “Mass Concrete”:

- Element Size

- High Strength Concrete/Rapid Strength

- Environmental Conditions
Specifying Mass Concrete for Bridge Elements

Element Size is typically defined by design code

- However, Other factors may contribute to identification of “mass concrete”
  1. High Strength Concrete
  2. Small Coarse Aggregate resulting in high paste volume

A Thermal Analysis could identify the following examples as Mass Concrete:

A 36” column with high cement content or TY III for early strength gain could result in the element being identified as “Mass Concrete”

Congested reinforcement details could result in smaller coarse aggregate requirements, thus increasing paste volume and cement content to achieve design strength.
Specifying Mass Concrete for Bridge Elements
Specifying Mass Concrete for Bridge Elements

TxDOT Specifications will require, Item 420.4.7.14:
1. Thermal Control Plan
2. Temperature Monitoring Sensors
3. Construction Controls

This all results in higher priced construction.

Special Provision 416-XXX
Special Provision 420-XXX

Although the specifications do not discuss options yet, things to consider:

• Repeating elements vs single elements
• Engineered details to mitigate concerns
  1. Internal Voids
  2. Concrete Mix Design Requirements
Construction Controls

Controlling Materials through Mixture Proportioning Requirements:

- Workable
- Strength
- Durability
- Lower heat of hydration/temperature increase

Possible Controls:

Reduce Cementitious Materials
Replace cement with other SCMs
Improve aggregate gradation – Optimized Aggregate Gradation
Use largest maximum size aggregate for element
Construction (Environmental) Conditions can be controlled with:

1. Internal Cooling
2. Shading or cooling aggregate stockpiles
3. Liquid Nitrogen, Chilled Water, or Ice
4. Insulation or Artificial Heat
5. Construction sequencing and concrete placement
Construction Controls
We can all agree, this is certainly a Mass Concrete application. Defining other bridge elements may be more difficult.
QUESTIONS?

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