Why Best Practices?

• DCE Memo 9-15
  – Made major changes to Section 346-3.3
  – Provided significant relief to contractors.
  – Upon successful performance of MCCP, allowed for reduced monitoring of similar elements.
  – Removed mass concrete control provisions for drilled shafts supporting sign, signal, lighting or intelligent transportation structures (ITS).
Why Best Practices?

• DCE Memo 9-15
  – Gave the contractor the option to omit instrumentation and temperature measuring for any mass concrete substructure element meeting certain requirements.
Why Best Practices?

• DCE Memo 9-15
  • Least cross sectional dimension of six feet or less,
  • Insulation R value of at least 2.5 provided for at least 72 hours following placement,
  • Environmental classification of Slightly Aggressive or Moderately Aggressive,
  • Concrete mix design meets the mass concrete proportioning requirements of 346-2.3

346-2.3 Pozzolans and Slag: Fly ash or slag materials are required in all classes of concrete. Use fly ash or slag materials as a cement replacement, on an equal weight replacement basis with the following limitations:
  1. Mass Concrete:
    a. Fly Ash - Ensure that the quantity of cement replaced with fly ash is 18% to 50% by weight, except where the core temperature is expected to rise above 165°F. In that case, ensure that the percentage of fly ash is 35% to 50% by weight.
    b. Slag - Ensure that the quantity of cement replaced with slag is 50% to 70% by weight. Ensure that slag is 50% to 55% of total cementitious content by weight when used in combination with silica fume, ultrafine fly ash and/or metakaolin.
    c. Fly Ash and Slag (Ternary Blend) - Ensure that there is 10% to 20% fly ash by weight, 50% to 60% slag by weight, and 30% portland cement by weight for mixes containing portland cement, fly ash and slag.
Why Best Practices?

• DCE Memo 9-15
  • Least cross sectional dimension of six feet or less,
  • Insulation R value of at least 2.5 provided for at least 72 hours following placement,
  • Environmental classification of Slightly Aggressive or Moderately Aggressive,
  • Concrete mix design meets the mass concrete proportioning requirements of 346-2.3
  • Total cementitious content of the mix design is 750 lb/yd$^3$ or less
Mass Concrete Control Measures

1. Concrete Mix Design Proportions
2. Casting Procedure
3. Insulation
4. Active Cooling Systems
5. Temperature Monitoring
6. Prevention of Thermal Shock (Timing of Formwork Removal)
Concrete Mix Design

• Use a low heat mix design.
Casting Procedure

• Bucket and Crane, Pump line, Tremie, etc.
• Night placement vs Day time placement
• Take advantage of the cooler ambient temperatures.
  – Placing late in the afternoon so the concrete starts to hydrate at the coolest time of the day into the cool night
Insulation

• Used to reduce the rate of heat loss to the atmosphere.
• Very effective for the control of the temperature differential between the concrete center and its surface.
• Slowing the rate of heat dissipation from the surface reduces the temperature difference and the potential for thermal cracking.
Insulation

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Insulation

Logger Temperatures for 104P2FTG1
Max Delta Temp: 63 °F @ 189 Hrs
Min Temp: 71.6 °F @ 3.07 Hrs, Max Temp: 179.6 °F @ 68.62 Hrs
Logger Start Date: 11/18/2015 2:59:15 AM
Last Download Date: 12/2/2015 5:00:10 PM
Insulation

Logger Temperatures for 104P2FTG1
Max Delta Temp: 63 °F @ 189 Hrs
Min Temp: 71.6 °F @ 3.07 Hrs, Max Temp: 179.6 °F @ 68.62 Hrs
Logger Start Date: 11/18/2015 2:59:15 AM
Last Download Date: 12/2/2015 5:00:10 PM
Insulation

• Needs to be securely wrapped.
• Needs to be the correct R-value (as recommended by the Specialty Engineer).
Insulation - Field Study

• Why insulation Between Footing Bottom and Soil?
  – 16 ft. x 28 ft. x 6 ft. Reinforced Concrete Footing
  – Concrete Mix Design:
    • Portland Cement - Type I/II (52% by weight)
    • Fly Ash – Class F (48% by weight)
Insulation – Field Study

Contractor placed two footings 1 week apart:

- 1\textsuperscript{st} Footing: Tar Paper between footing and soil
- 2\textsuperscript{nd} Footing: No barrier between footing and soil
Insulation – Field Study

With Thermal Barrier

Temperature (°F)

Time (Hours)

Temperature Differential (Middle-Bottom)
Temperature Differential (Top-Middle)
At this point, we noticed a definite trend that would lead to spec violation.

Extensive airing out of the footing via the top of the footing.
Insulation – Field Study

Comparison Plot

Temperature (°F)

Time (Hours)

Extensive airing out of the footing via the top of the footing

No Thermal Barrier
Thermal Barrier
Soil As Thermal Insulator

- Thermal Properties of Sand and Clay

<table>
<thead>
<tr>
<th>Material</th>
<th>Conductivity (J/sec-m-° C)</th>
<th>R-value/inch (ft²-° F-h/BTU-in)</th>
<th>Heat Capacity (J/m³-° C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Sand</td>
<td>0.27</td>
<td>R-0.53</td>
<td>1.212×10⁶</td>
</tr>
<tr>
<td>Moist Sand</td>
<td>2.0</td>
<td>R-0.072</td>
<td>1.56×10⁶</td>
</tr>
<tr>
<td>Saturated Sand</td>
<td>4.0</td>
<td>R-0.036</td>
<td>1.92×10⁶</td>
</tr>
<tr>
<td>Dry Clay</td>
<td>0.15</td>
<td>R-0.96</td>
<td>1.285×10⁶</td>
</tr>
<tr>
<td>Moist Clay</td>
<td>0.9</td>
<td>R-0.16</td>
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<tr>
<td>Saturated Clay</td>
<td>2.5</td>
<td>R-0.058</td>
<td>1.285×10⁶</td>
</tr>
<tr>
<td>Sand/Clay</td>
<td>0.35</td>
<td>R-0.41</td>
<td>1.212×10⁶</td>
</tr>
<tr>
<td>Sand/Clay</td>
<td>0.4</td>
<td>R-0.36</td>
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</tr>
<tr>
<td>Sand/Clay</td>
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<td>R-0.29</td>
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</tr>
<tr>
<td>Sand/Clay</td>
<td>0.6</td>
<td>R-0.24</td>
<td>1.212×10⁶</td>
</tr>
</tbody>
</table>
Soil As Thermal Insulator

- **Soil Temperature Distribution**
  - We conducted a finite element study of a footing on soil.
  - Two cases: dry sand and saturated sand, were analyzed.

A) Dry sand
B) Saturated sand.
Temperature distribution in soil 7 days after concrete placement.
Soil As Thermal Insulator

- **Soil Temperature Distribution**

A) Dry sand

B) Saturated sand.

Lower R-value of saturated sand allowed heat to transfer to a greater depth, meaning that the concrete is losing more heat.
We found:

- The footing lost more heat more rapidly through its bottom surface without the thermal barrier (insulation).
- This caused the temperature at the centroid of the footing to be lower therefore increasing its differential with the top surface.
- The cost of airing out the top of the footing was higher than placing thermal barrier on the bottom surface in the first place.
Active Cooling Systems

- Heat removal by cooling pipes depends on location, size and spacing, flow rate and temperature of the chilled water. Cooling pipes must be pressure grouted once cooling measures end.
Prevention of Thermal Shock

- Will occur if water contact the outside edge of the concrete, or the forms.
- Will also occur if the insulation and formwork are prematurely removed.

Crack
Prevention of Thermal Shock

- Dade County, Florida
  - Reinforced Concrete Footing
  - Concrete Mix Design:
    - Portland Cement - Type I/II (52% by weight)
    - Fly Ash – Class F (48% by weight)
  - High water table so water pumps were used to lower the water level in the excavation area.
Prevention of Thermal Shock

- FDOT/UF installed companion temperature sensors into the footing cage
Prevention of Thermal Shock

- Location of temperature sensors in pier footing

```plaintext
Sensor 5
Sensor 4
Sensor 3
Sensor 2
Sensor 1
```
Prevention of Thermal Shock

– Footing, Dade County, FL

Contractor’s sensors recorded low temperatures and we were asked to verify.

Measured temperatures along vertical centerline of footing
Prevention of Thermal Shock

• Had the footing not been instrumented, we would never have known that the water table had risen and infiltrated the footing concrete.

• **Suggestion:** *In areas with a high water table, it is good engineering practice to install temperature monitoring sensors in foundation footings.*
Crack Inspection

• When the 35°F differential has been exceeded and an inspection for adverse effects (i.e. cracks) will be requested:
Crack Inspection

• Generally the crack will start at the top surface close to the center then propagate towards and down the edge of an element:
Crack Inspection

• If cracks are observed, they must be repaired according to the guidelines provided in Table 1 of Section 400 in the Specifications:
Thanks- Any Questions?