FDOT/Concrete Coalition of Florida

Pilot Project for Maximum Heat of Mass Concrete - Research Highlights

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UF/FDOT-SMO

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Background

- The FDOT currently defines mass concrete as:
  - Minimum dimension $\geq$ 3’
  - Ratio of concrete volume to the surface area >1’
- Requires a temperature differential control plan
- Model procedure outlined in ACI 207, also known as the Schmidt Method.

Scope of Research

- Use finite element modeling (FEM) to predict the temperature differentials and peak temperatures in massive concrete structures.
- Determine/Suggest the size of the element that does not need a mass concrete plan
- Determine the R values for soil

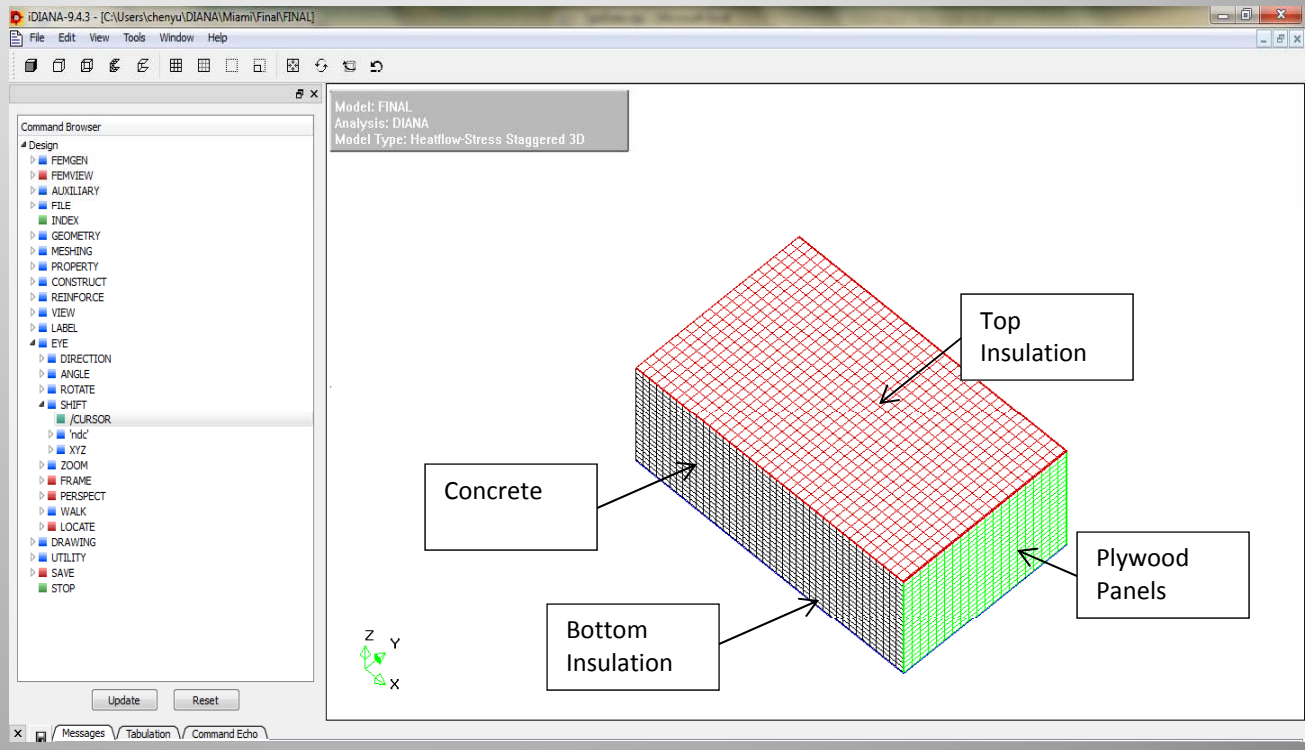
Finite Element Modeling (FEM)

- TNO Diana FEM program
- Adiabatic* temperature rise based on the ratio of cementitious components in a mix design
- Determined from Isothermal Calorimetry Testing

*temperature rise without the loss or gain of heat to/from external sources

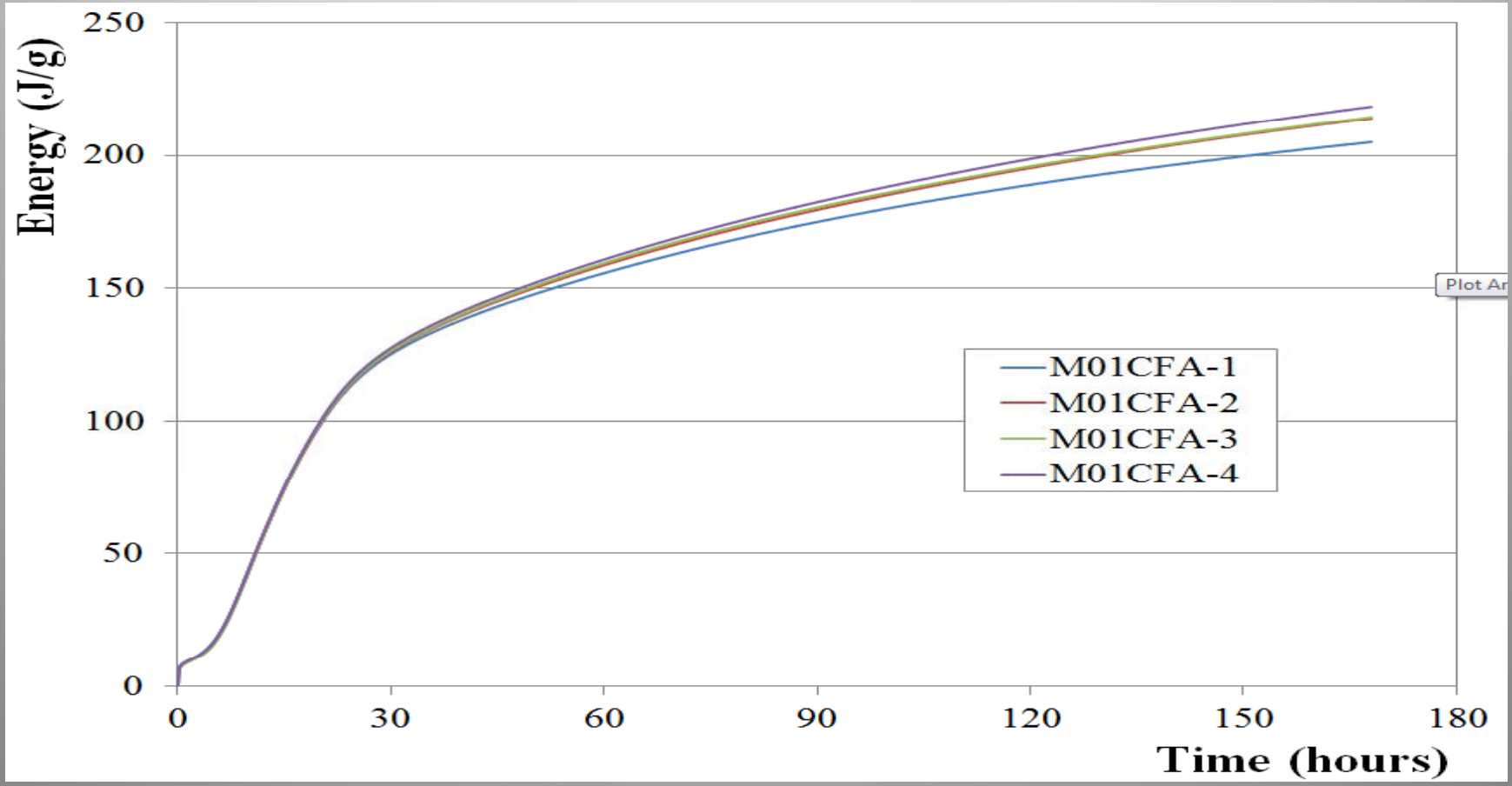
Finite Element Modeling (FEM)

- To construct the model, the hydrating concrete, as well as the formwork and insulating materials are taken into consideration.



Laboratory Testing

- **Hydration Energy curve obtained from Isothermal Calorimetry Testing**



Laboratory Testing

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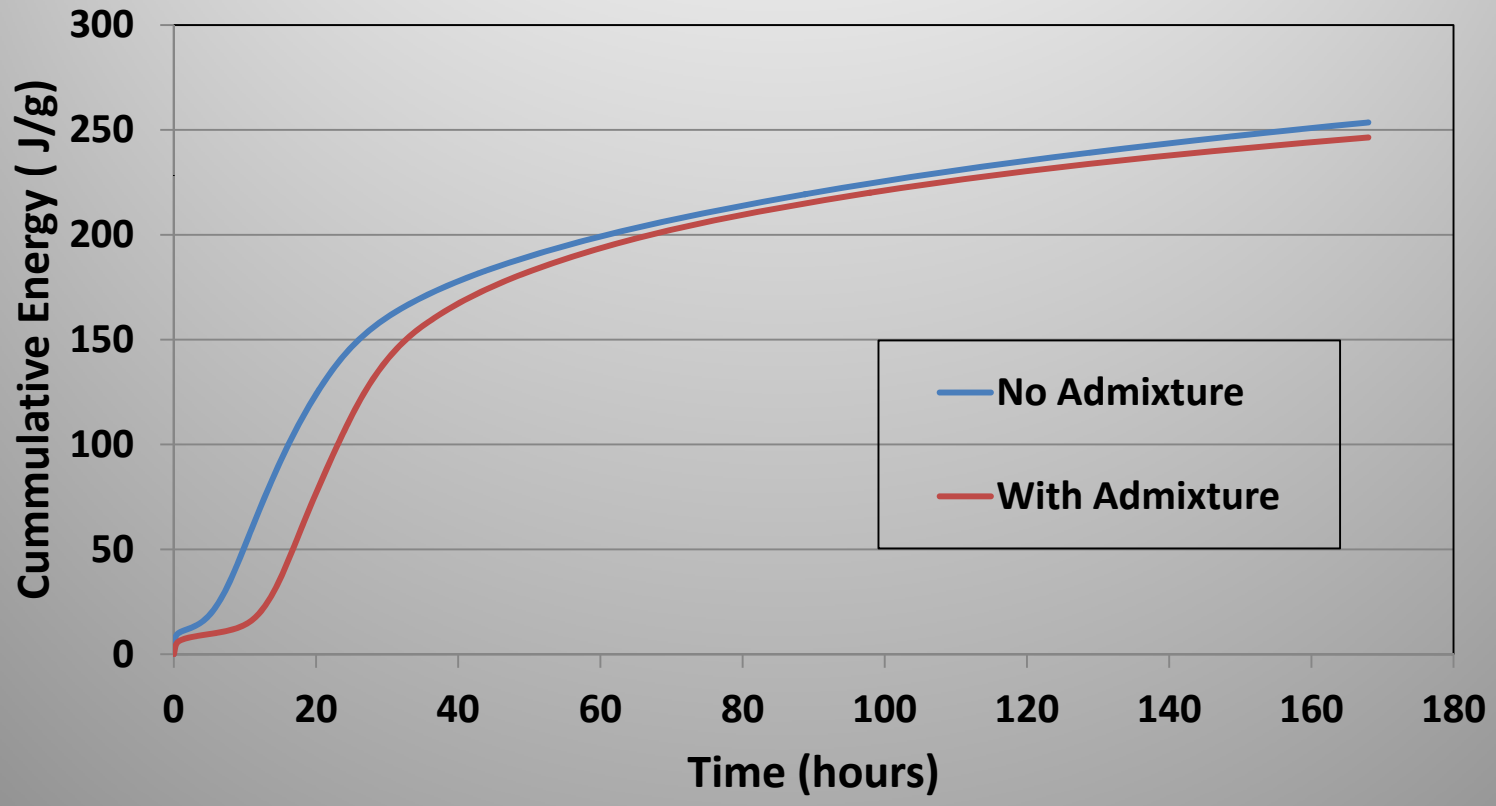
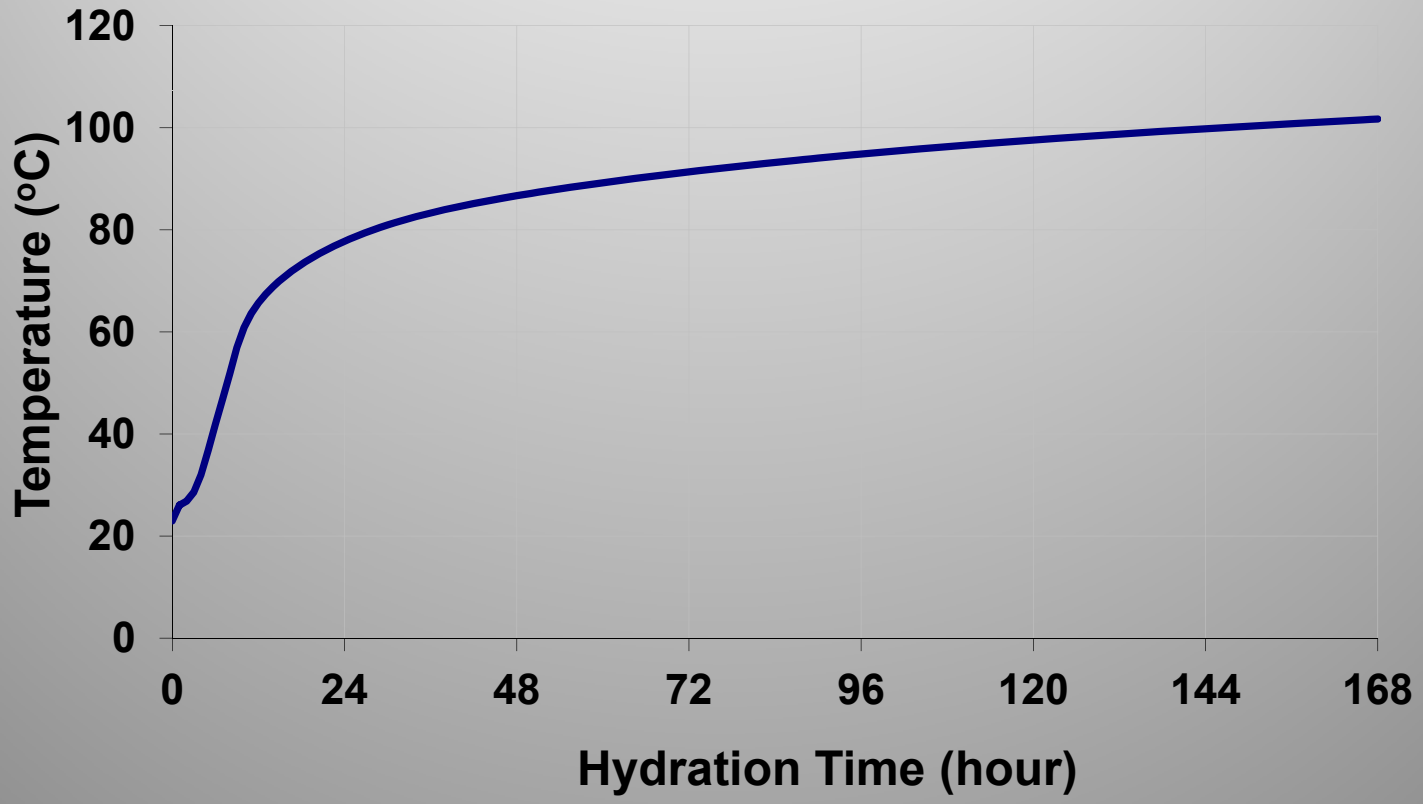


Type D – Water Reducer Retarder
Type F – high range water reducer
Air Entraining

Laboratory Testing

- **Adiabatic Temperature Rise curve obtained from the Hydration Energy Curve**



Field Work

- **Two bridge elements constructed in the field in Florida were monitored for temperature developments**
  - ❑ **Footing at a project in Miami**
  - ❑ **Footing at a project in Orlando**

Field Work

- **Miami, Florida**
  - **Concrete Mix Design:**
    - **Portland Cement - Type I/II**
    - **Fly Ash – Class F**

Field Work

- **Miami, Florida**

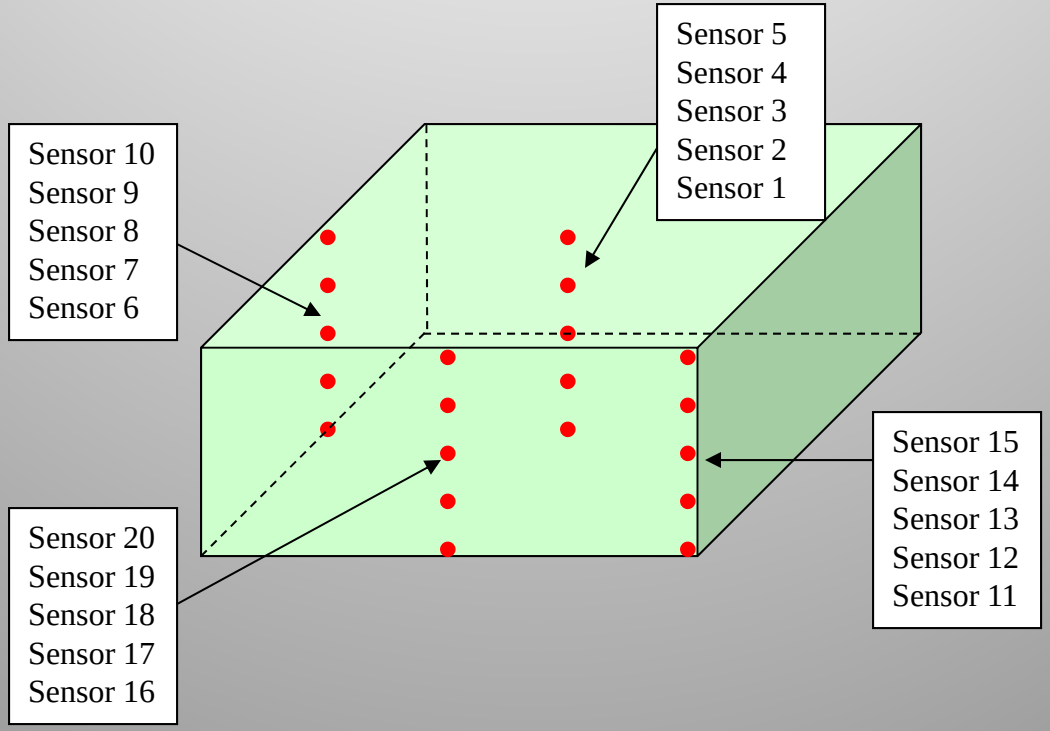
Contractor opted to place concrete directly on top of the soil

Field Work

- Installation of temperature sensors into the footing cage

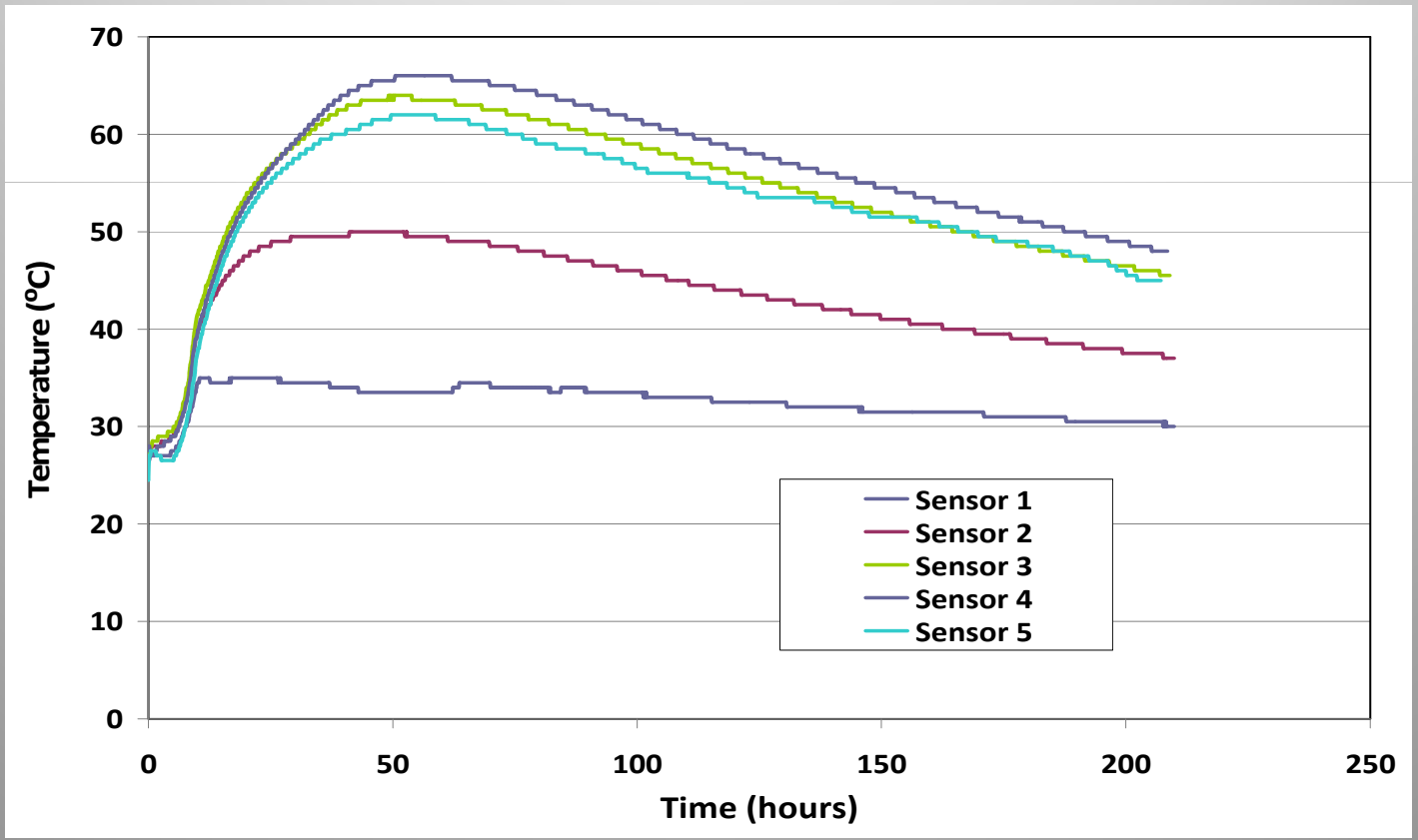
Field Work

- Location of temperature sensors in pier footing



Field Work

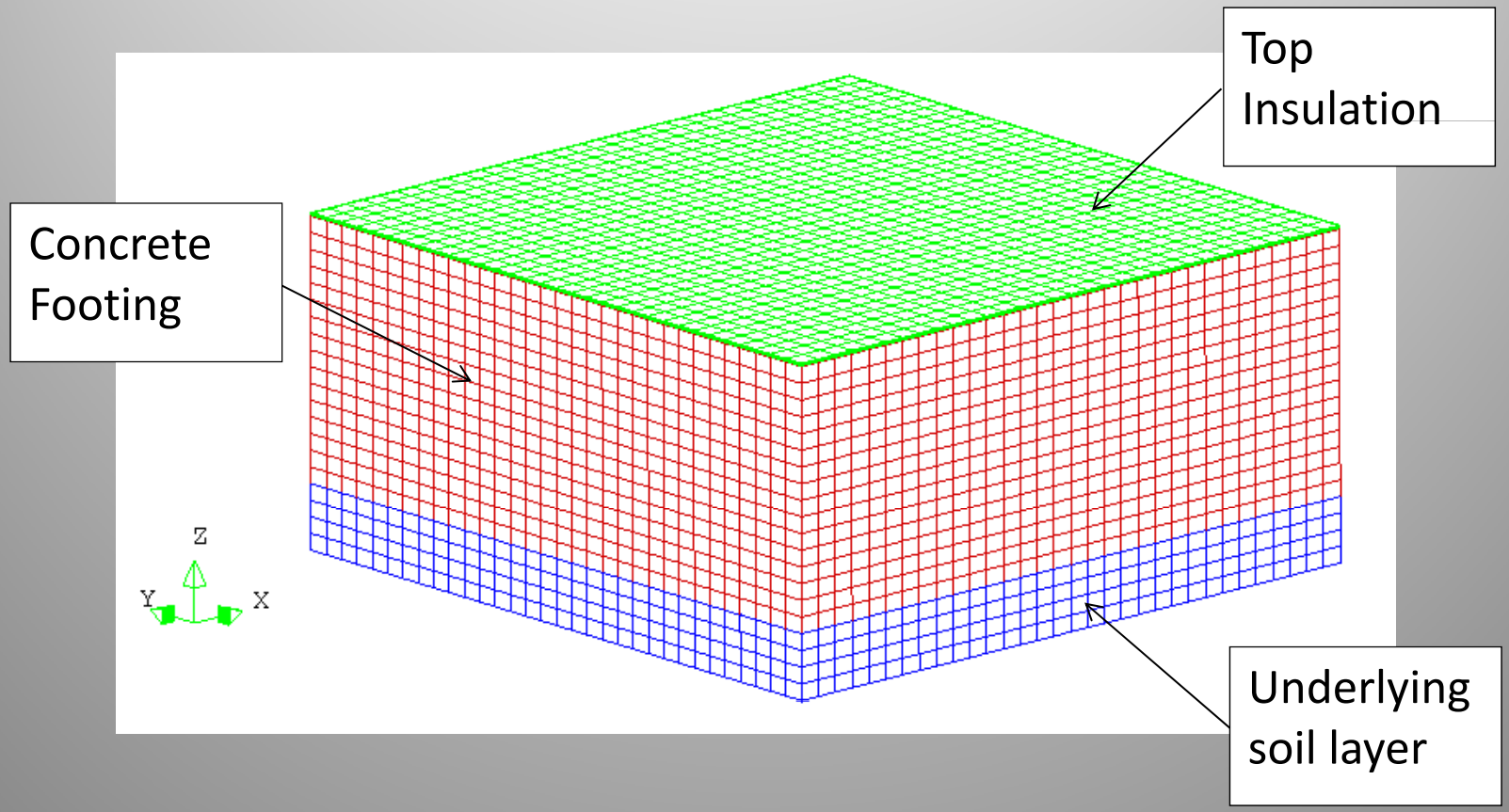
- Footing, Miami, FL



Measured temperatures along vertical centerline of footing

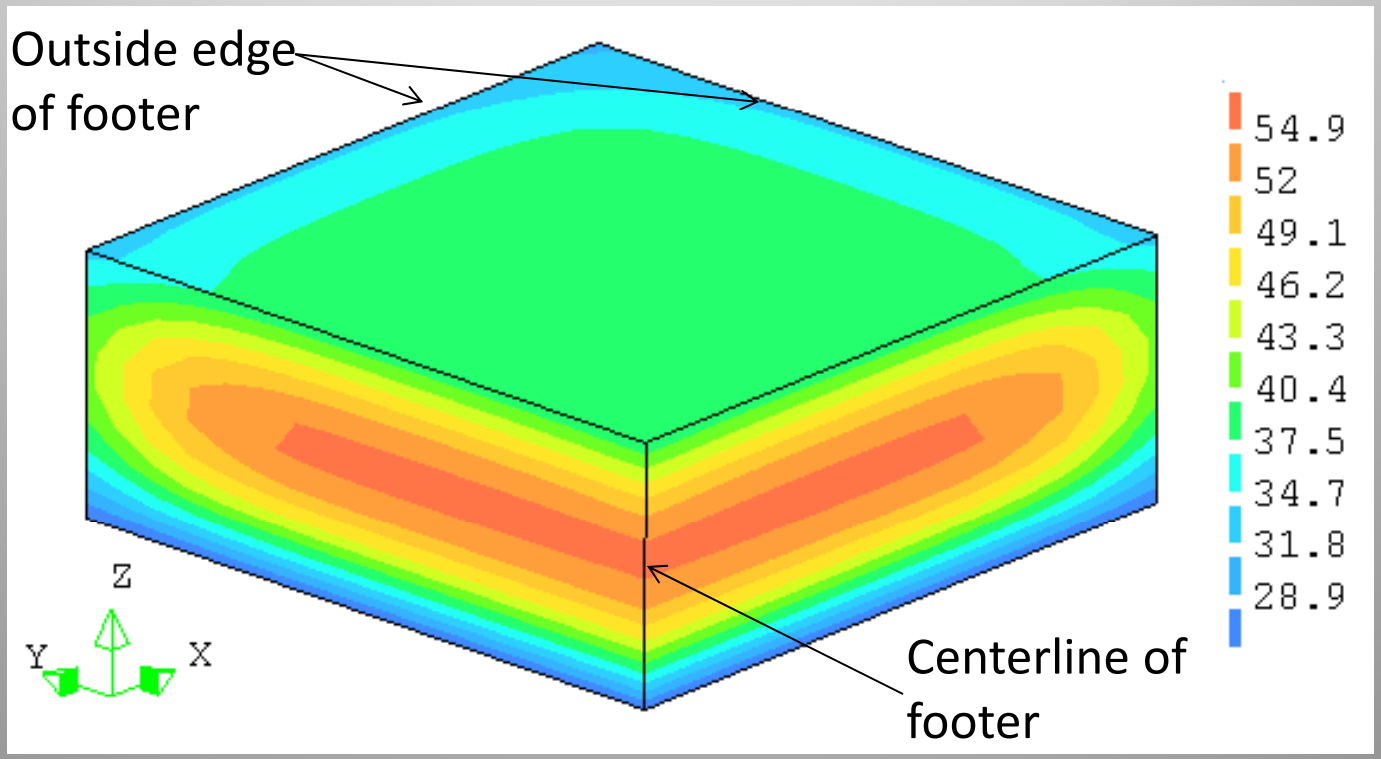
Modeling

- **Finite element mesh**



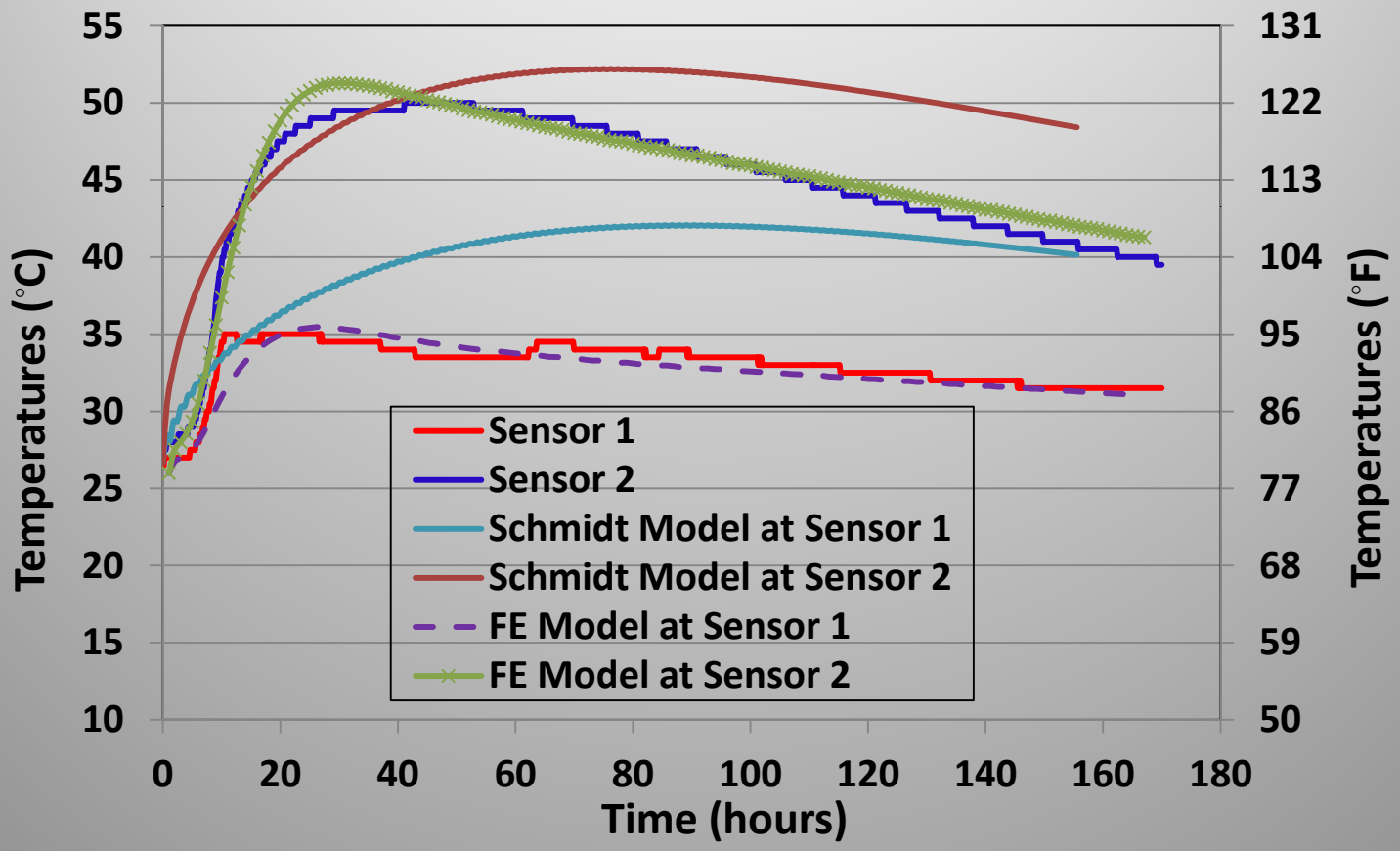
Modeling

- **Predicted temperature distribution 167 hours (7 days) after concrete placement**



Comparisons

- Footing, Miami, FL



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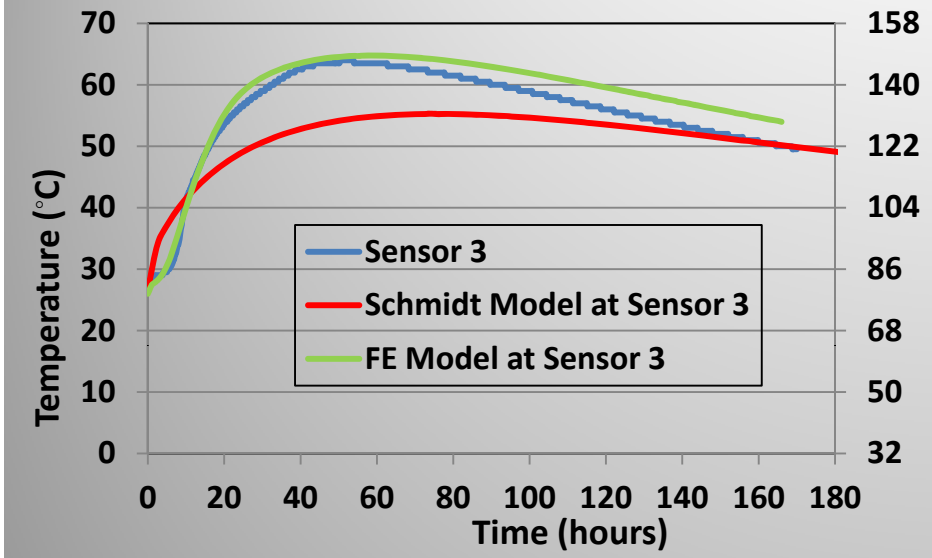

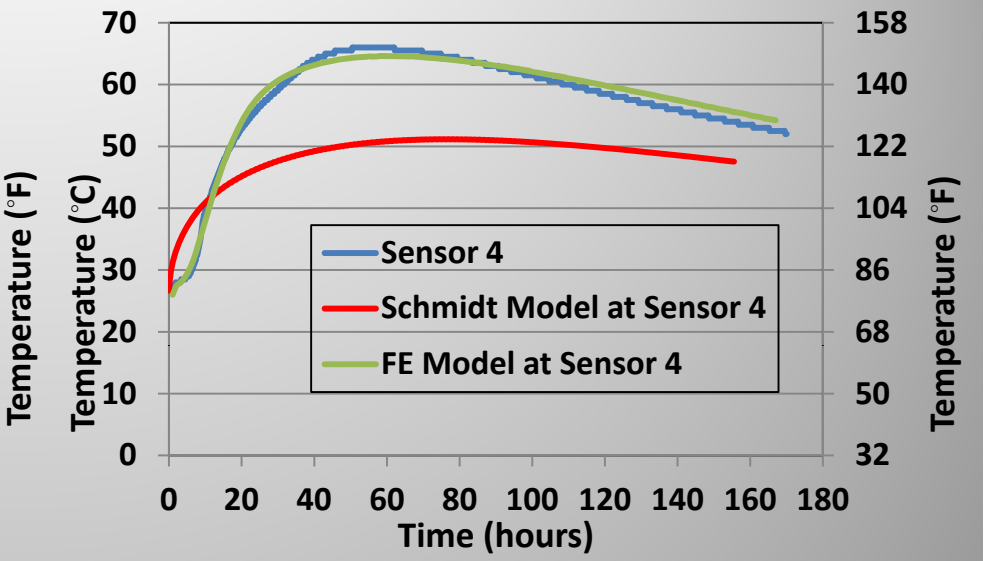

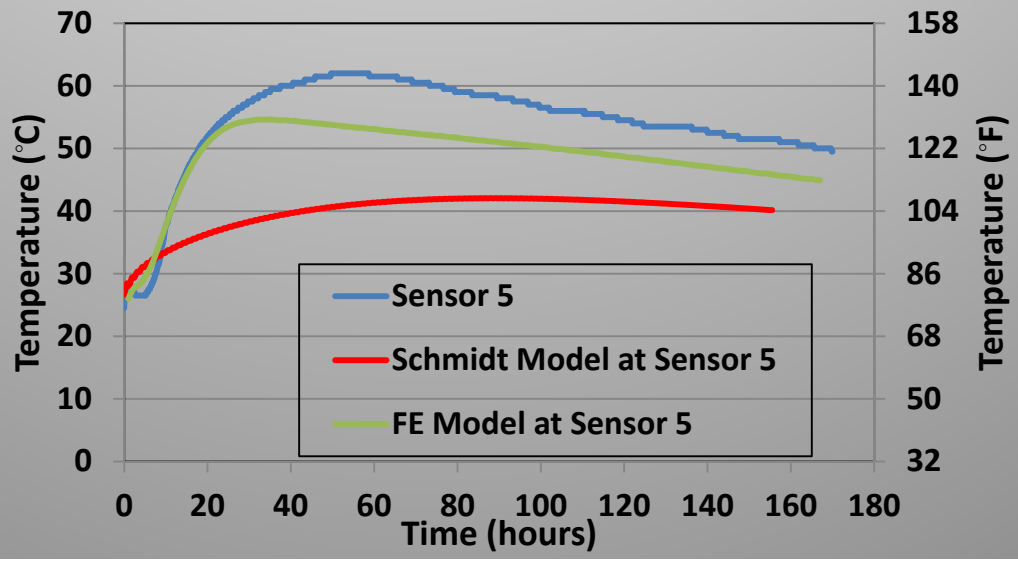

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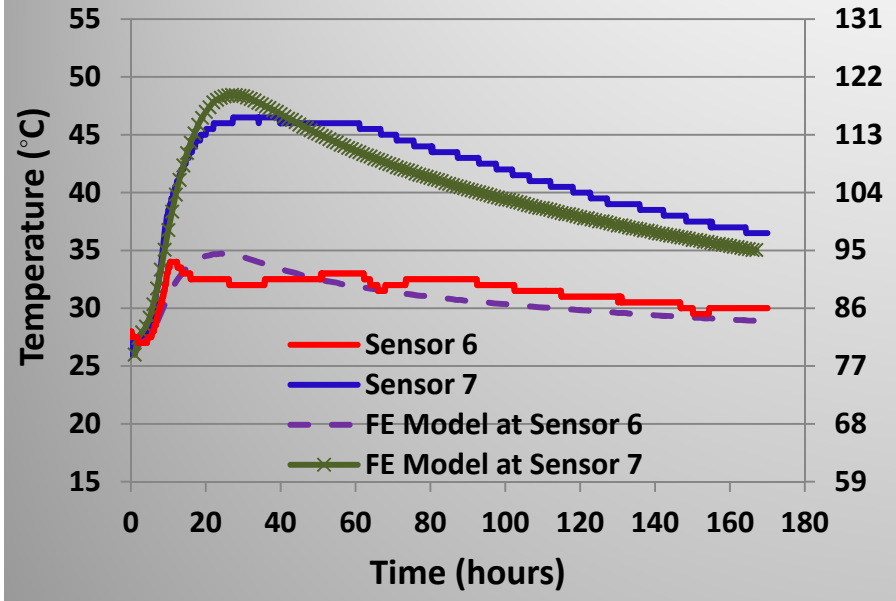
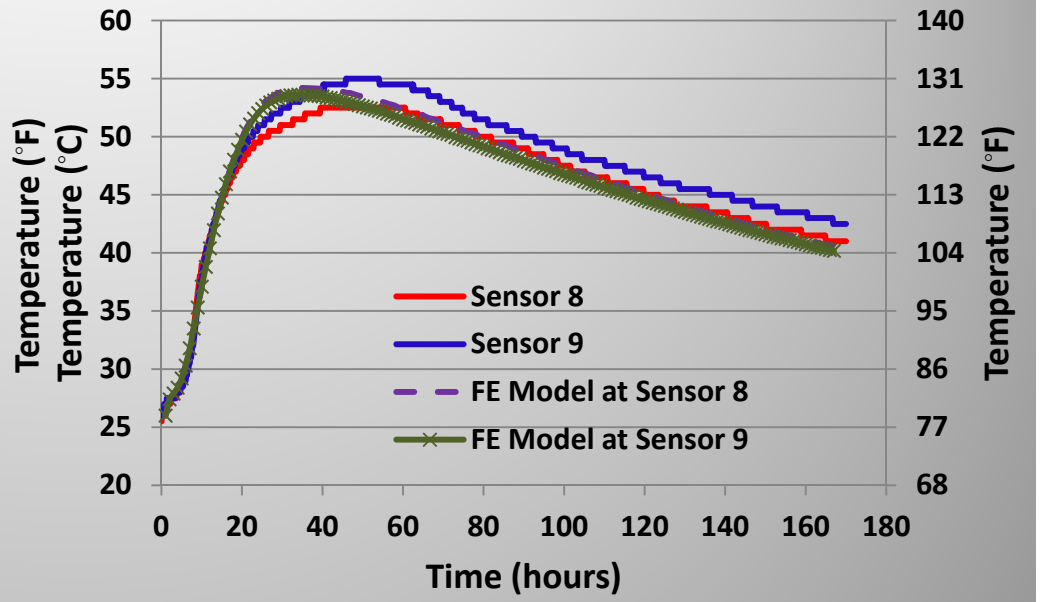
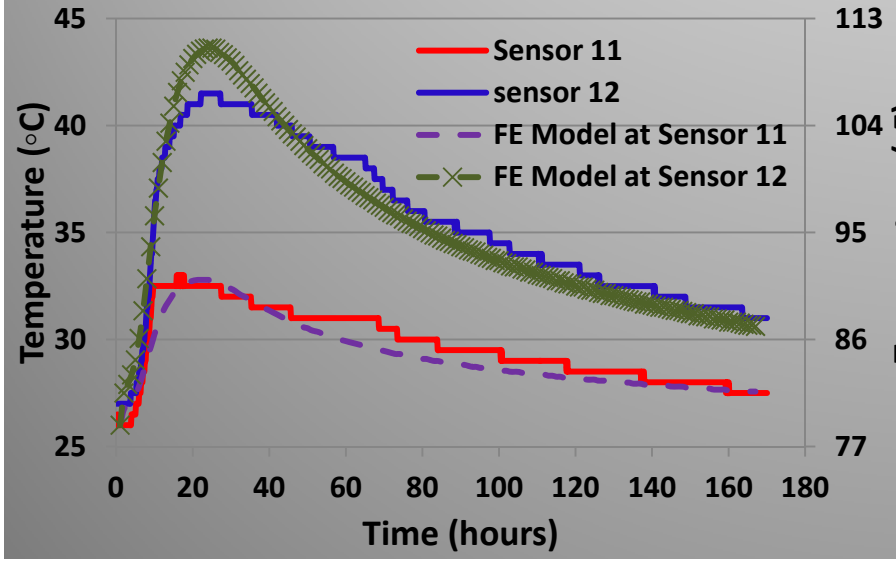
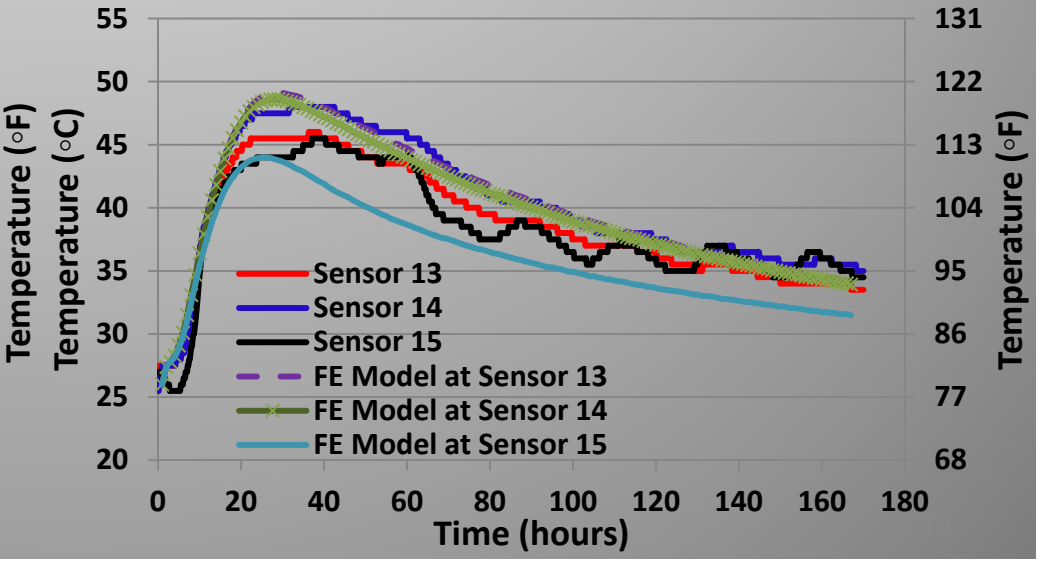


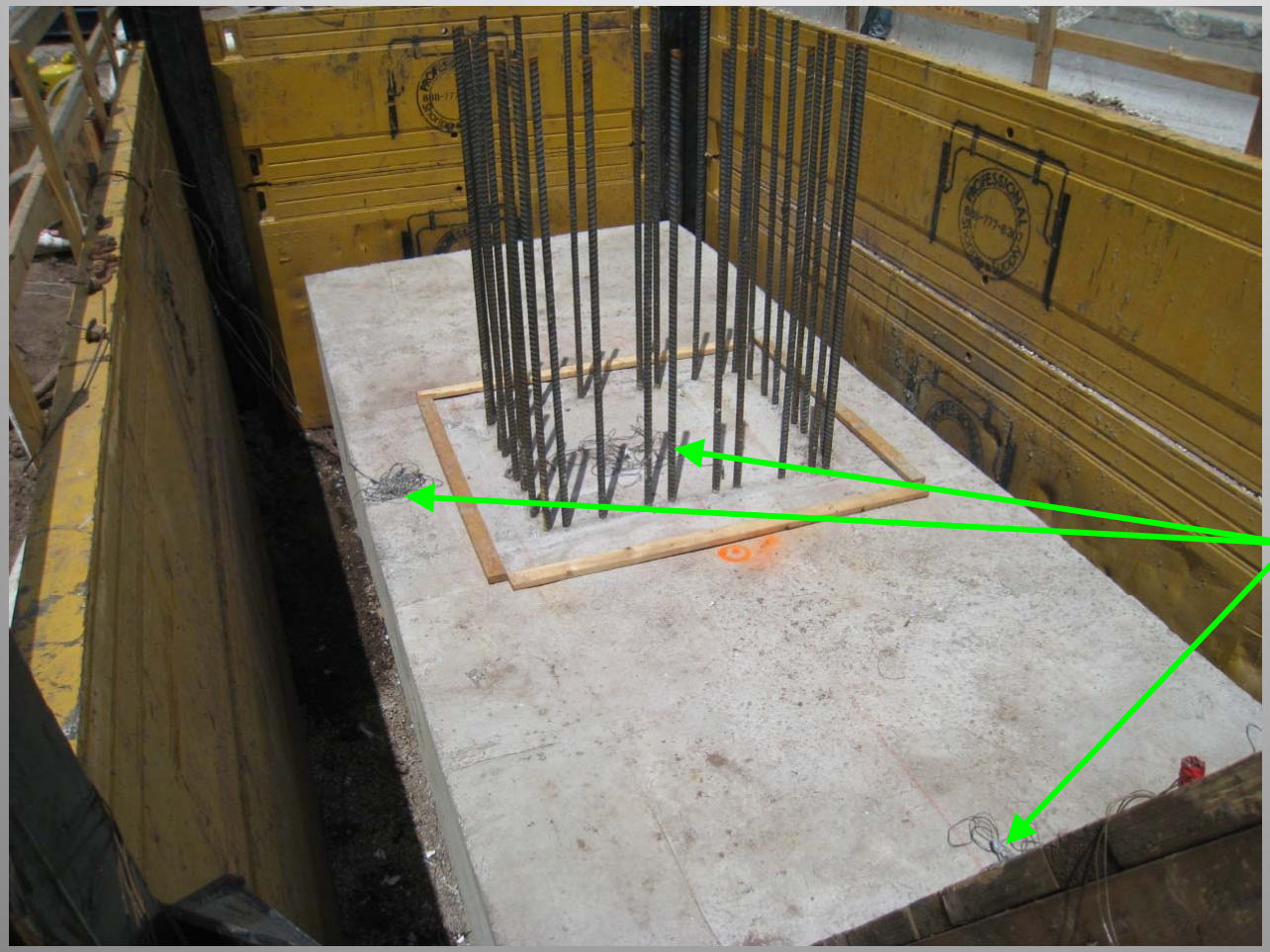






Field Work

- **Orlando, Florida**



Temperature sensor wires

Field Work

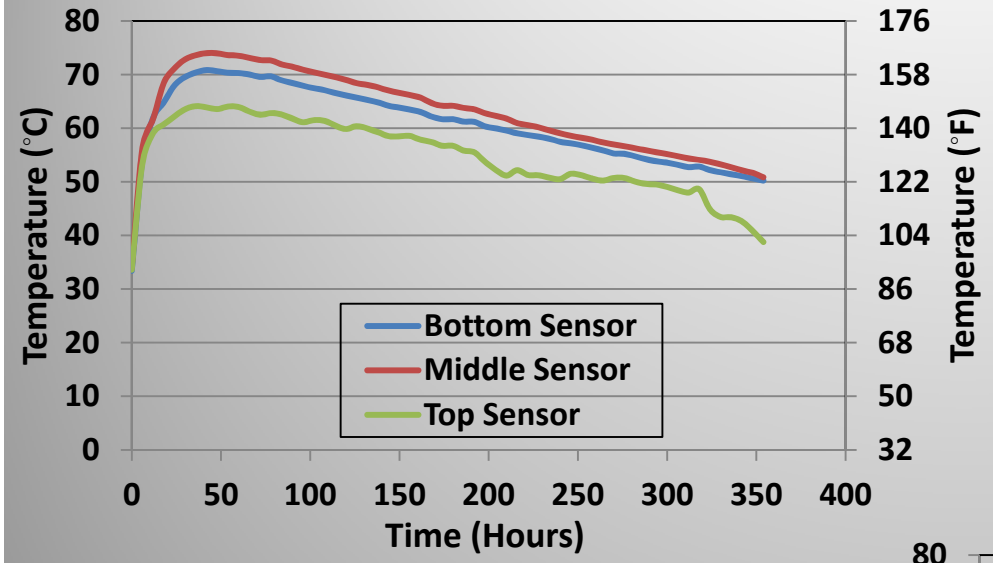
- **Concrete Mix Design:**
  - **Portland Cement – Type I/II**
  - **Fly Ash – Class F**
  - **Ultra-Fine Fly Ash***

***- Used for Strength Only. Not as a requirement for Durability.**

Field Work

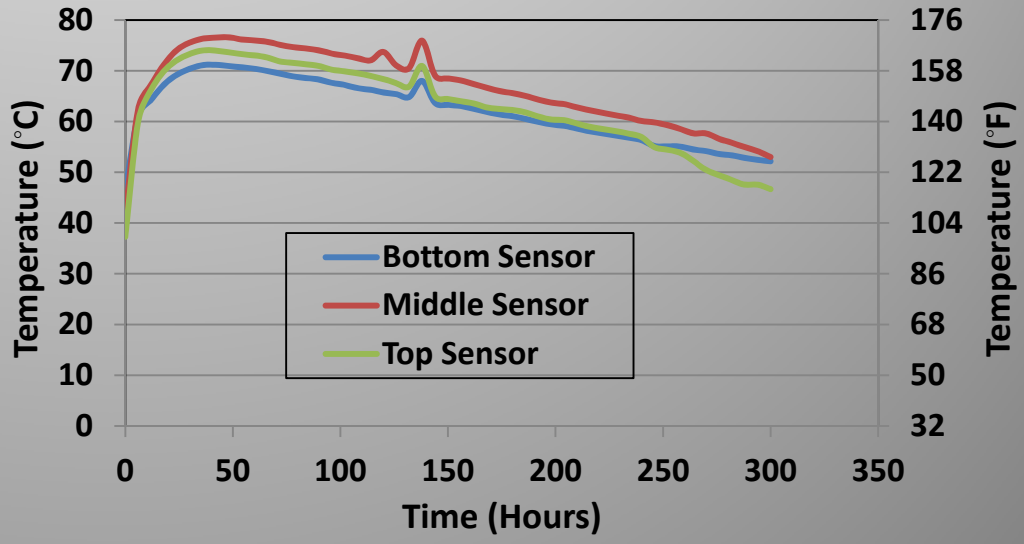
- **Two methods of insulating the elements were employed:**
  - **Placing 2” thick Styrofoam (R-5/inch) on the outside of the plywood formwork**
  - **Placing 2” thick Styrofoam (R-5/inch) on the inside of the plywood formwork**

Comparisons



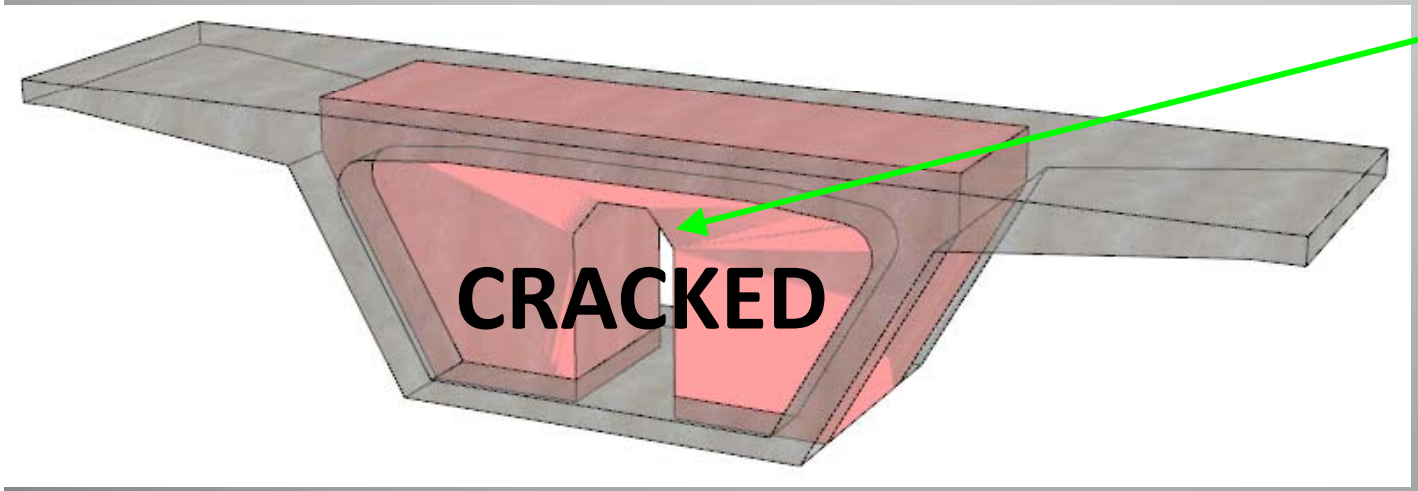
Insulation Placed on the Outside of Formwork

Insulation Placed on the Inside of Formwork



Segmental Bridge Pier Segment

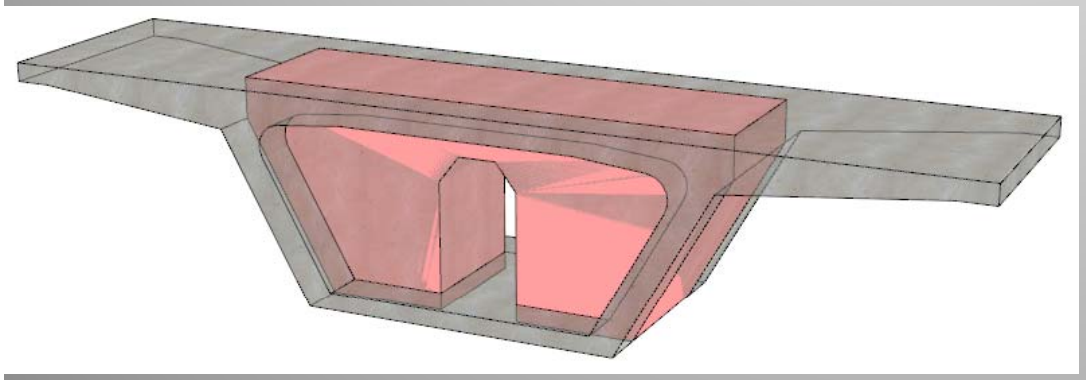
- High-strength concrete: 8500 psi
- Volume to Surface Area ratio: 0.97 ft.
- Was not deemed Mass Concrete

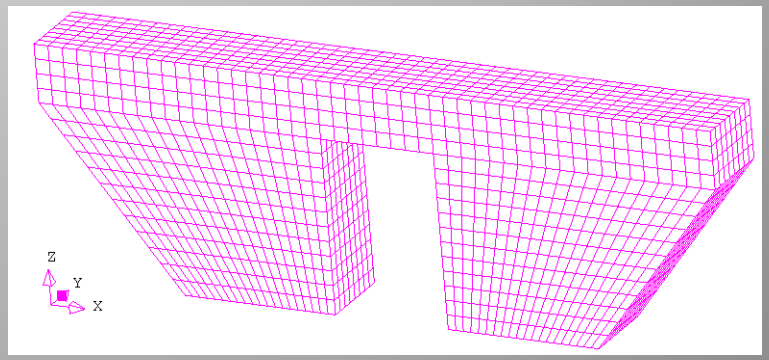


core of the segment was used to calculate the volume to surface area ratio

Segmental Bridge Pier Segment

- Should the V/A threshold of 1.0 be reduced when high strength mixes are used?
- What should that threshold be?



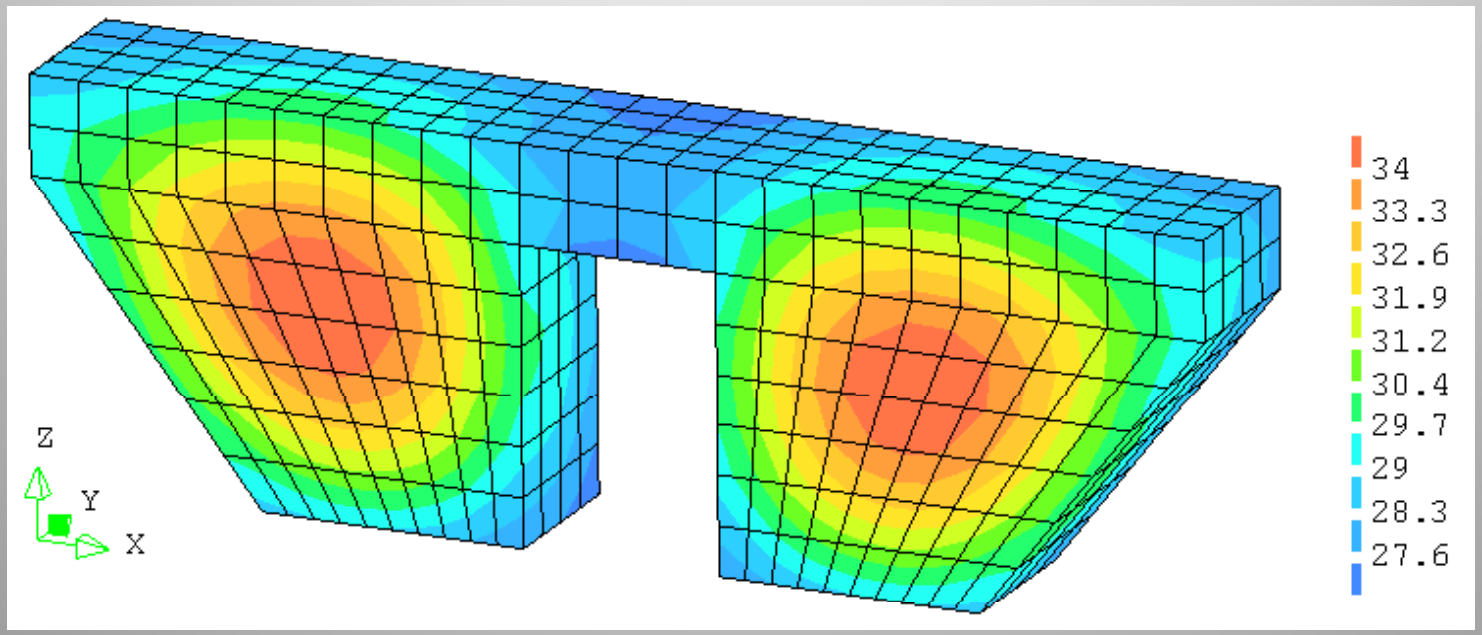


Segmental Bridge Pier Segment

- Core length: 18 ft
- Core height: 6 ft
- Two core thicknesses were considered:
  - 5 ft $\rightarrow$ volume to surface area ratio = 0.97 ft
  - 4 ft $\rightarrow$ volume to surface area ratio = 0.89 ft
- Hydration data from a normal strength concrete mix design used.

Segmental Bridge Pier Segment

- **Temperature distribution at 7 days**



V/A 0.97: maximum temperature differential = 28.4 °C (51 °F)

V/A 0.89: maximum temperature differential = 26.2 °C (47 °F)

Summary of Findings

- At locations with a high water table (above the footer bottom) soil should not be relied on as a good insulator, it is therefore highly recommended to place a layer of insulating material between the concrete and the soil.

- Placing insulation on the inside of the formwork improves the performance of mass concrete placements in terms of maintaining low delta temperatures.

Summary of Findings

- **Preliminary data suggests that the volume to surface area requirements should be reduced when high strength concrete is used for segmental bridge pier structures.**

- **Structures with least dimension of 6 ft and smaller, concrete with up 48% of the Portland cement replaced with Class F Fly Ash, insulation with R-values 2.5 or greater, consistently maintained delta temperatures below the 35 °F.**

Thanks- Any Questions?