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Minnesota Concrete Council

Taking the Mystery out of Mass Concrete

Cement + water = heat

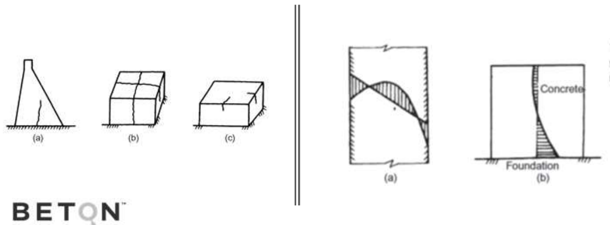
Slag + water = heat

Cement + Water =

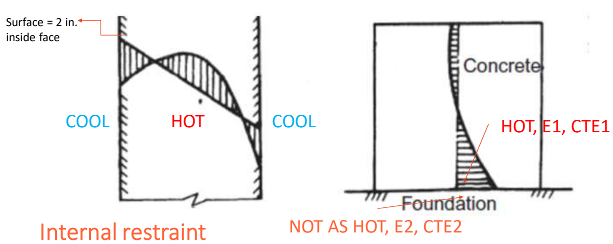
heat + (CH + class F fly ash) = heat

What is Mass Concrete ?

Cracks due to thermal stresses



Delayed Ettringite Formation (DEF)



Internal restraint
Differential between center and surface or surface to ambient (thermal shock)

External restraint
Differential volume change between concrete and base

Heat moves from center to surface then from surface to air

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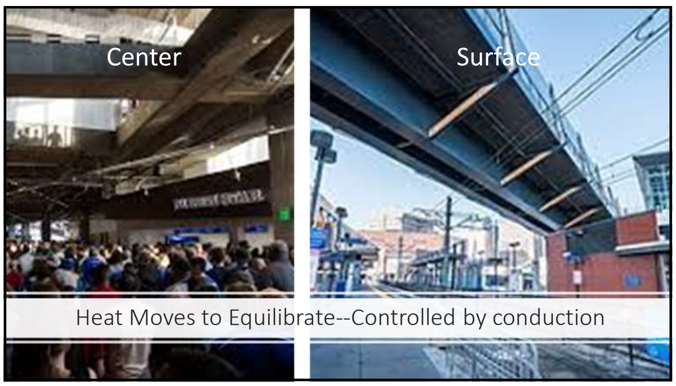


Heat Moves to Equilibrate--Controlled by conduction

Heat moves to Equilibrate--Controlled by Convection

What information do we use to prevent cracks and DEF?

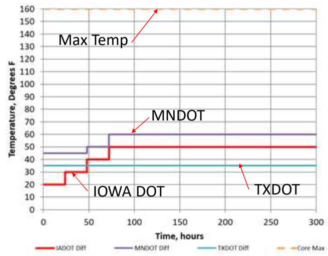
Thermal Control Plans:

- Show core temperature over time
- Estimate differential over time
- Predict how long member will be in thermal control
- Define maximum incoming concrete temperature
- Suggest cover to limit differential

Mass concrete specification
Least dimension
Concrete heat generation
Estimated pour date
Concrete temp as it enters formwork (NOT PUMP HOPPER)
Boundary conditions

Specified Limits

- ACI 301: Structural concrete sets limits on maximum temperature and differential
- 158°F max (because no one has observed DEF below this temperature)
    - Mitigated in many ways, especially with fly ash and slag additions, but we're not certain how much.
- Differential limited to 35°F (conservative)



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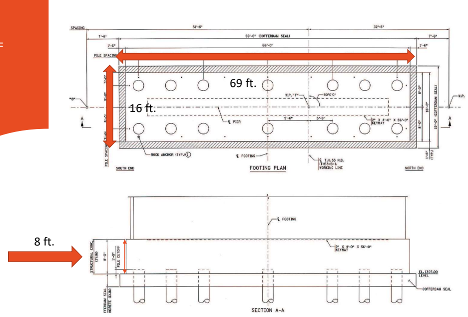
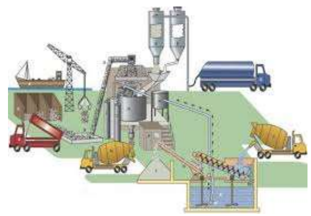
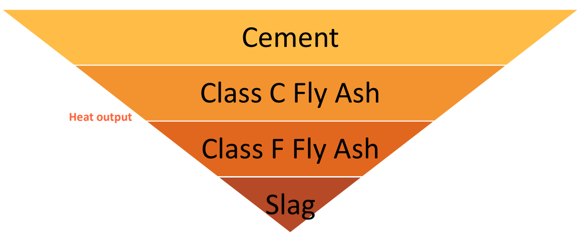
Critical Dimension

Critical Dimension = Least Dimension



Cooling Tubes vs. Mix Design





Quantity and **Type** of cementitious material dictate total heat output

Ambient Temperature

- Good for differential
- Difficult for ready-mix to control concrete temperature

- Challenge to maintain differential
- Less difficult for ready-mix to control concrete temperature

Between really cold and really hot, ambient temp. only moves core temp. a few degrees.

Boundary Conditions

- Convection—air
  1. Formwork
  2. White polyethylene sheeting
  3. Insulating blankets
  4. Heated enclosure
- Soil
- Hardened concrete
- Water

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We didn't pay attention to mass concrete 15 years ago, why now?

- Dams
- Typical Structural Members
- High Maintenance Structural Members

Dams

- Mass produced concrete onsite
- Low strength
- Little to no reinforcement
- BIG
- Thermal control for entire service life
- Only mass concrete considered when ACI 207 was written

Typical mass concrete structural members

- 4-5 ksi ready-mix concrete
- 3-6 ft. critical dimension
- Steel reinforced
- Accessible
- Ex: Mat slabs, footings, columns, piers, pier caps, walls

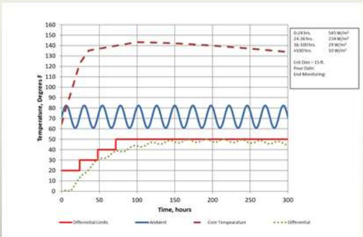
High-maintenance mass concrete

- Greater than 5 ksi concrete
- High early strength (i.e. 5 ksi at 18 hours)
- So much steel reinforcing, why call it concrete
- Not accessible
- Designer fail—can't have your cake and eat it too

Thermal Models

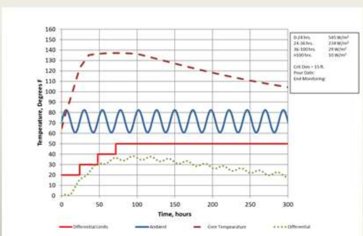
Change in Critical Dimension

15 ft.



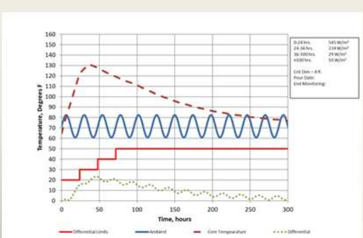
Change in Critical Dimension

8 ft.



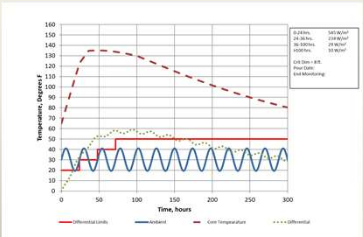
Change in Critical Dimension

4 ft.



Change in Ambient Temperature

8 ft.
30 F



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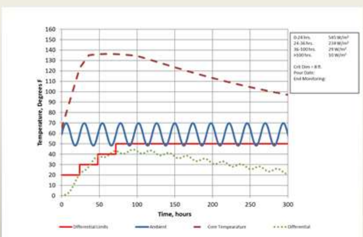
Change in Ambient Temperature

8 ft.
60 F



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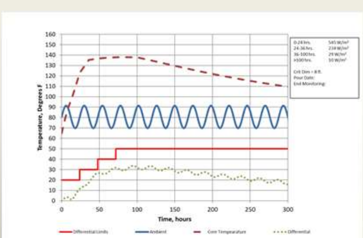
Change in Ambient Temperature

8 ft.
80 F



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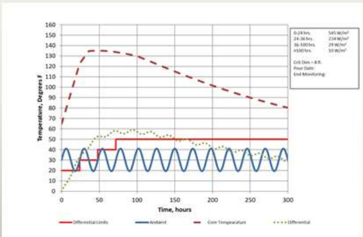
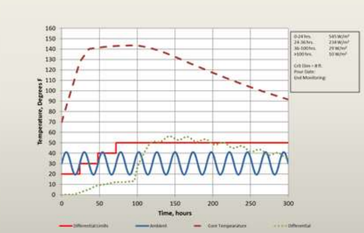
No Insulation

8 ft.
30 F



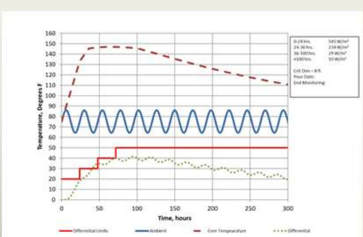
Insulation

8 ft.
30 F



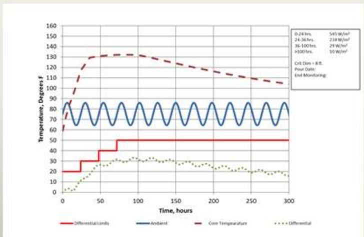
Incoming Concrete Temperature

8 ft.
70 F



Incoming Concrete Temperature

8 ft.
60 F



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What can go wrong?

- Cover not tight and its windy or raining
- Change in seasons and no insulating blankets nearby
- Heater fails
- Heater gets too hot (inverted differential)
- Property of cement or fly ash changes and mix gets much warmer than predicted
- Dewatering system fails (cofferdams)
- Cofferdam and formwork are the same structure
- Measure concrete temp out of truck—not as its going into formwork
- Formwork and reinforcing baking in hot sun before placing concrete