Cold Weather Concreting

WHAT'S NEW

Presentation by Robert E. Neal, Lehigh Cement
Central Virginia Concrete Advisory Council 11/18/14

REALLY NOTHING

- When it gets cold, concrete;
  - Sets slower
  - Gains strength slower
  - Can even freeze

Thank you for your attention

Let’s try again, What Else

- Is there a Wind-Chill effect on Concrete?
- Cold subgrades - are they all the same?
- Side Effects of Protective Measures
  - Carbonation
  - Discoloration
  - Corrosion

Wind Chill ?

- If We Feel Colder
- Shouldn’t Concrete Feel Colder Too ?

Wind Chill Effect
Air Movement

Dissipates Heat More Rapidly

Field Investigation
Of Heat Loss
Instrumentation of Precast Units

Exposed Unit

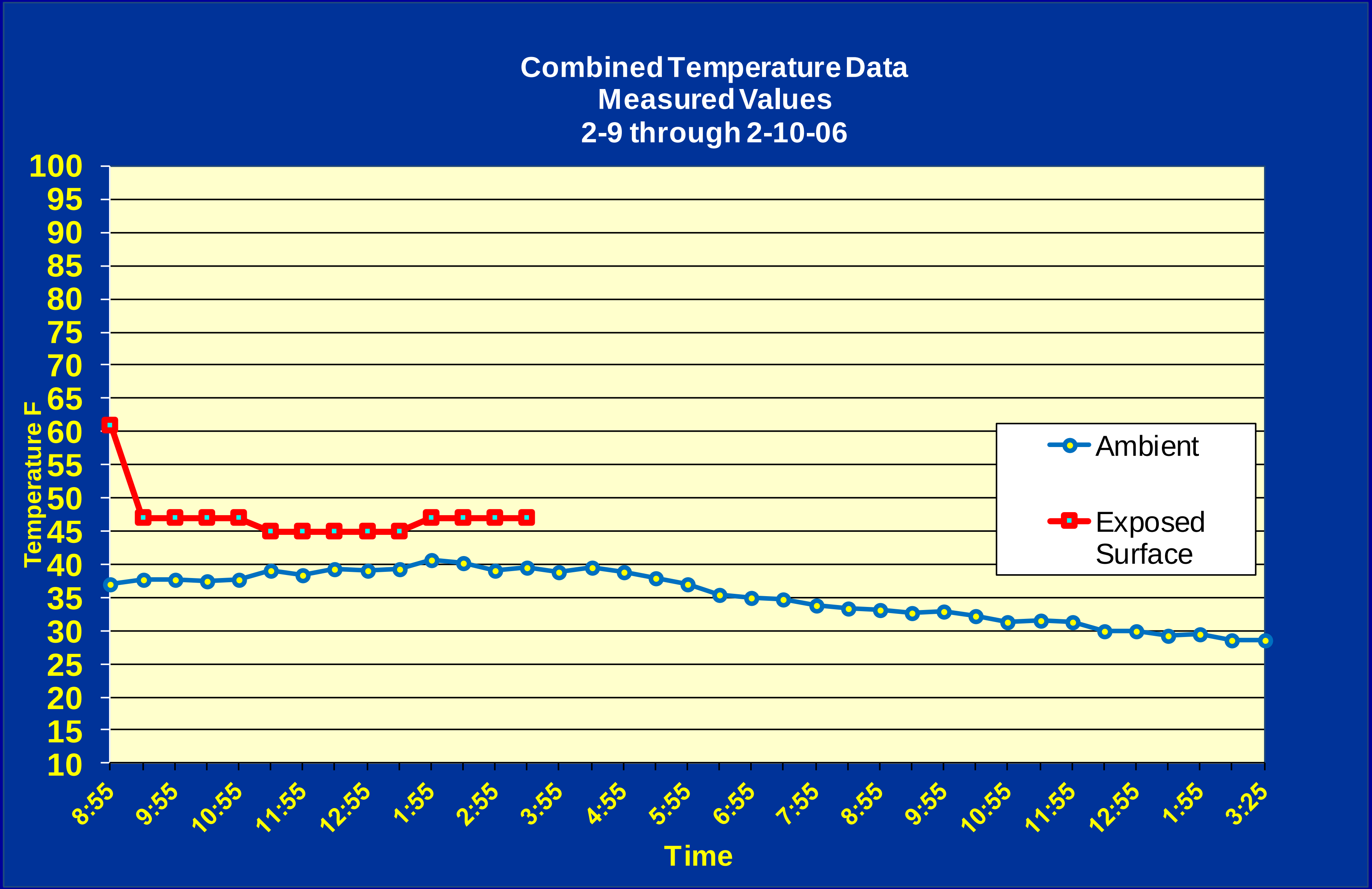
Unit Protected from Wind

Open Building – NO HEAT
Wind Tunnel Effect
Air Movement 10 MPH Ave.

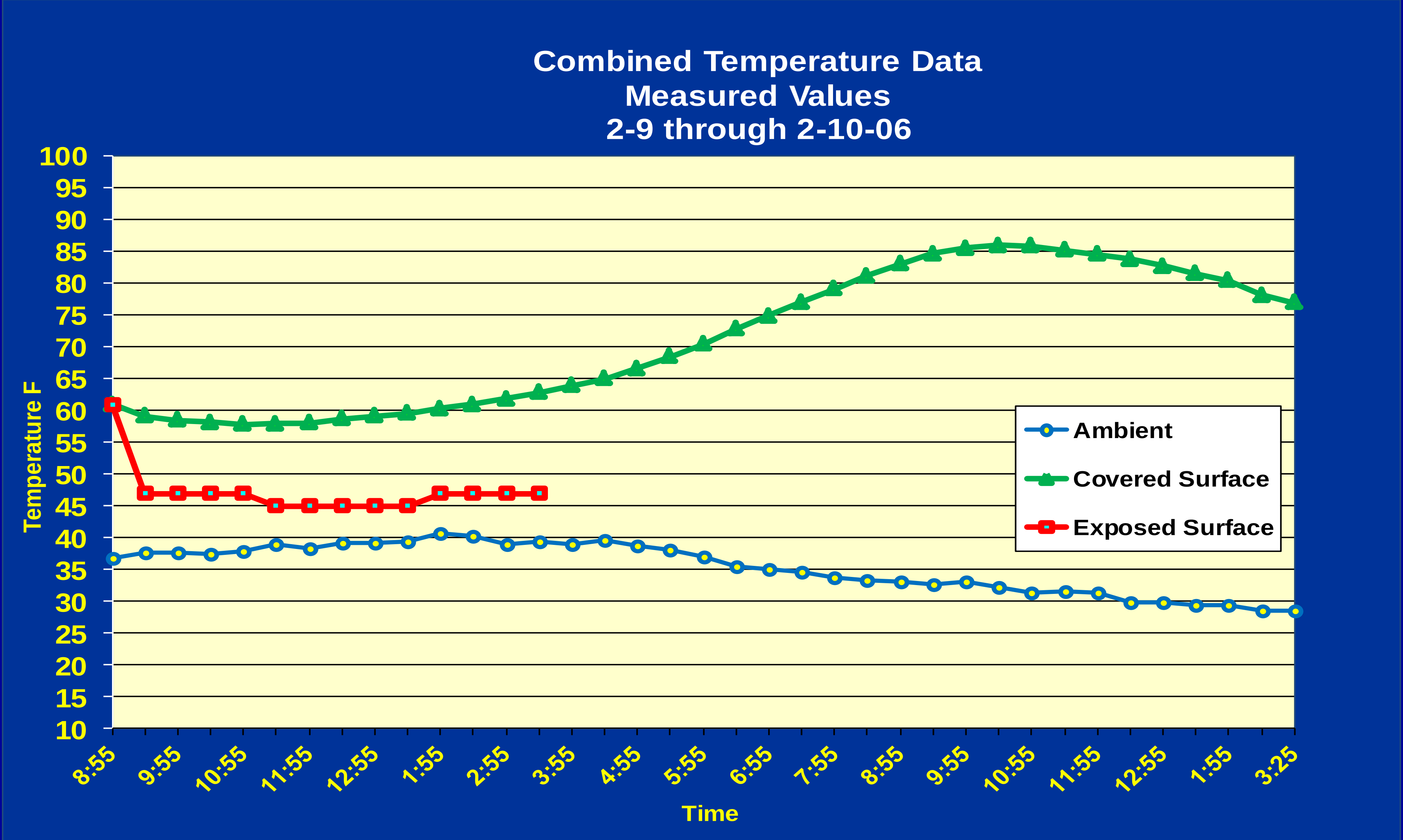
Exposed Unit

Unit Protected from Wind

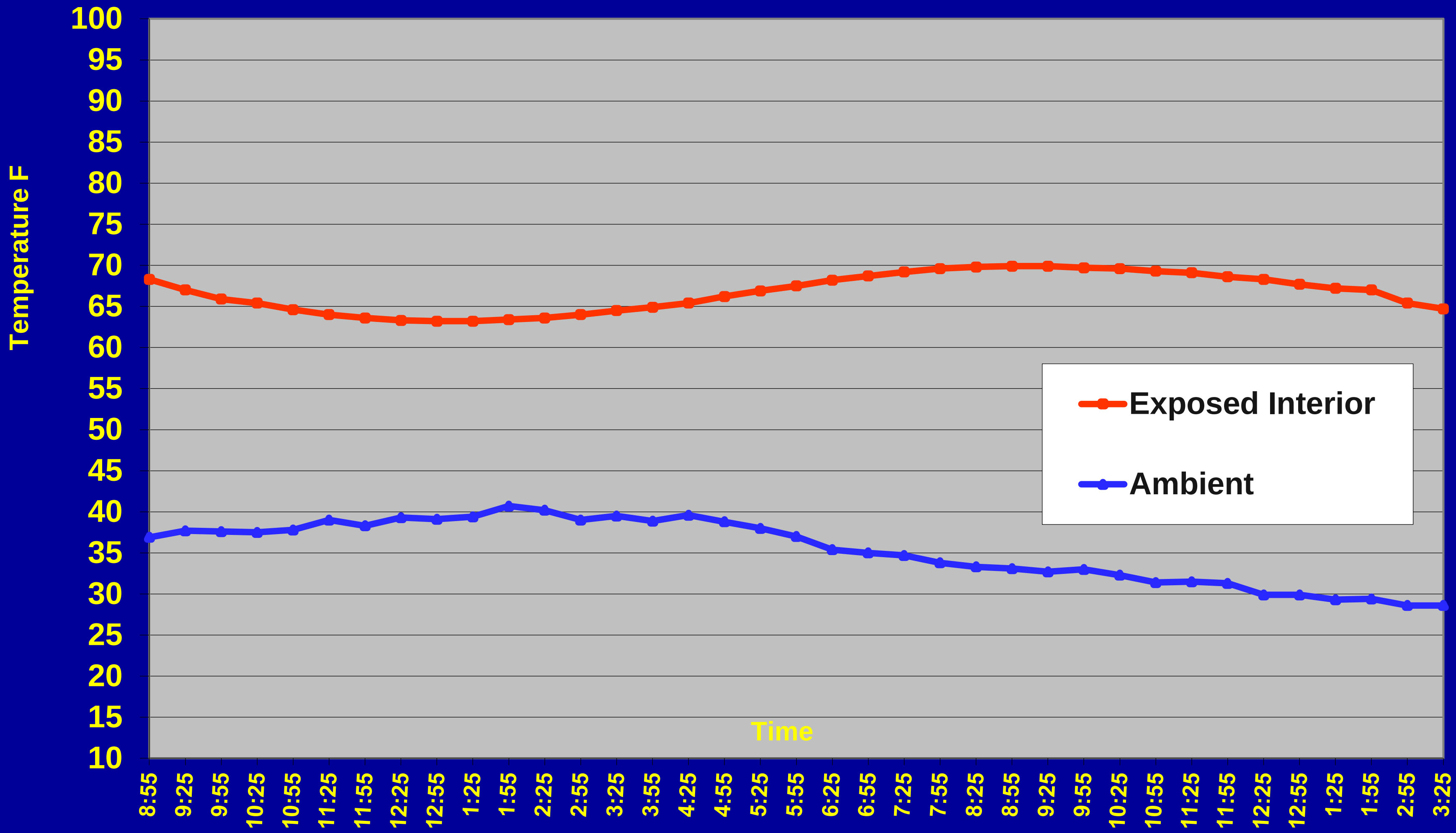
Results of Field Measurements Near Surface



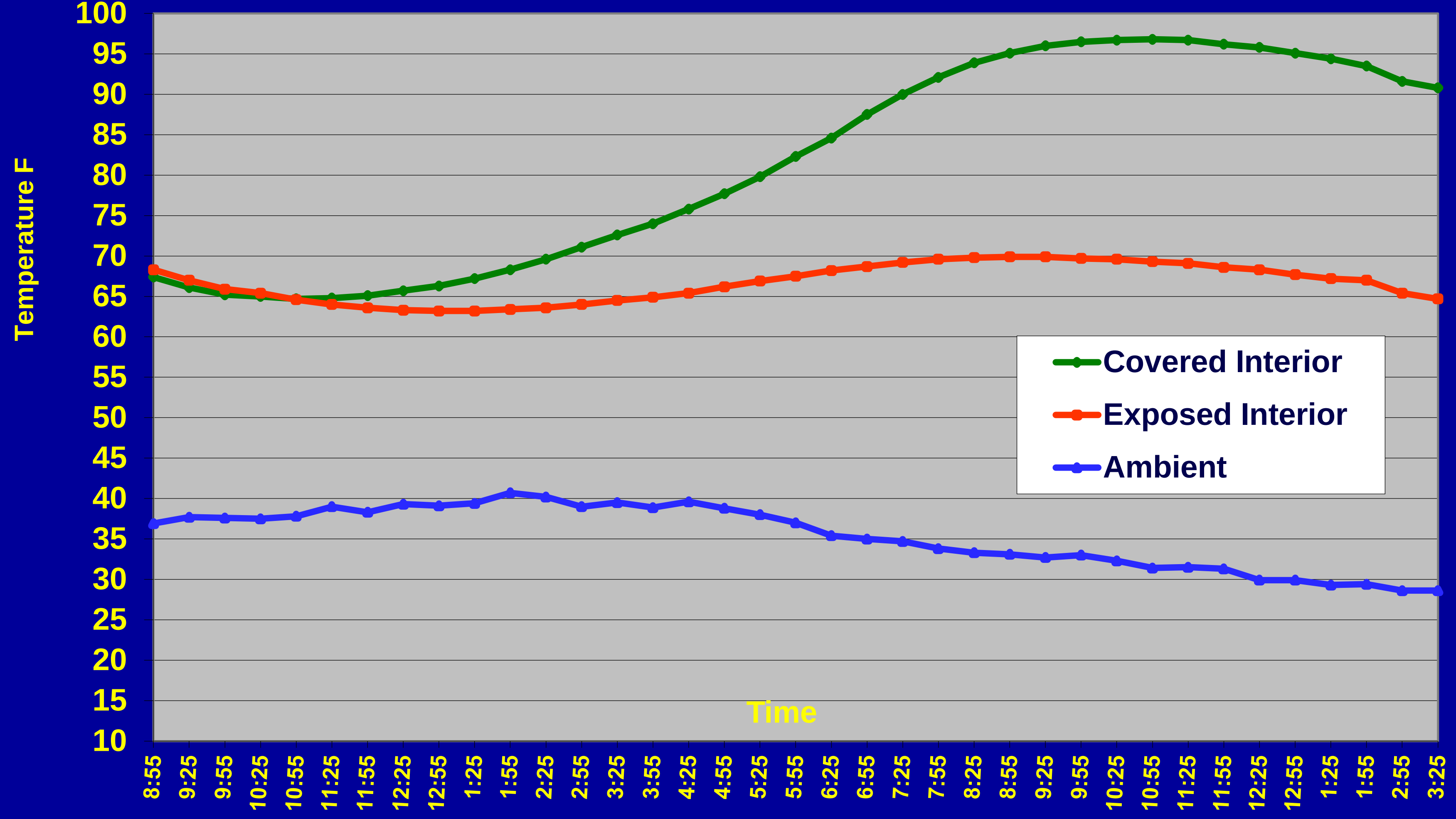
Results of Field Measurements Near Surface



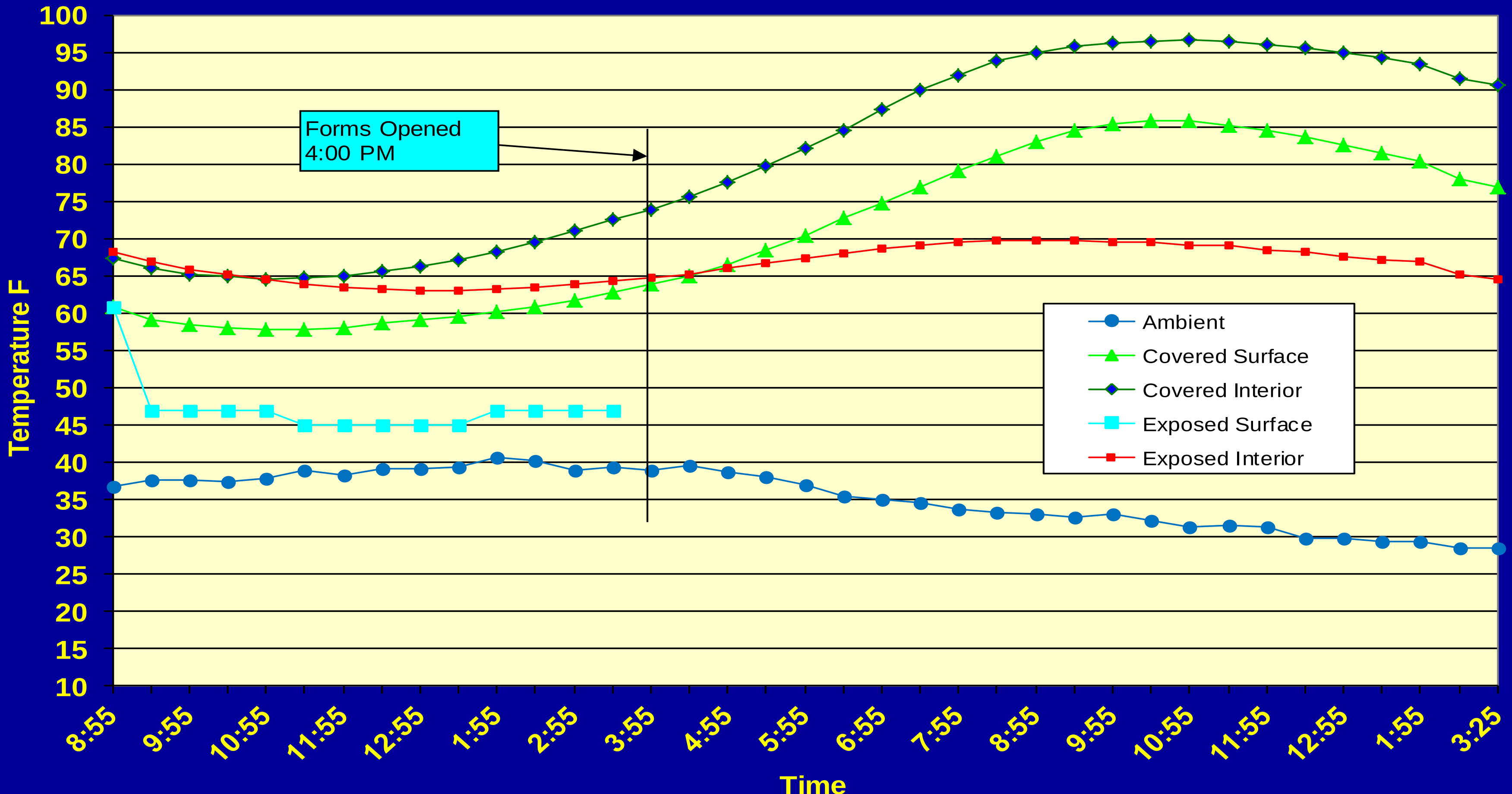
Results of Field Measurements
Interior Temperatures



Results of Field Measurements Interior Temperatures



Combined Results of Field Measurements



Conclusions

- Wind Has a Significant Impact on In-Place Concrete Temperature
  - Surface Temperature
  - Internal Temperature
- Simply Shielding Concrete From Wind Very Effective

Cold Subgrades
Are They All Equal?

The Heat Flux

Ability to Transfer Heat

Heat Flux

Specific Heat Capacity

Thermal Conductivity

Heat Flux

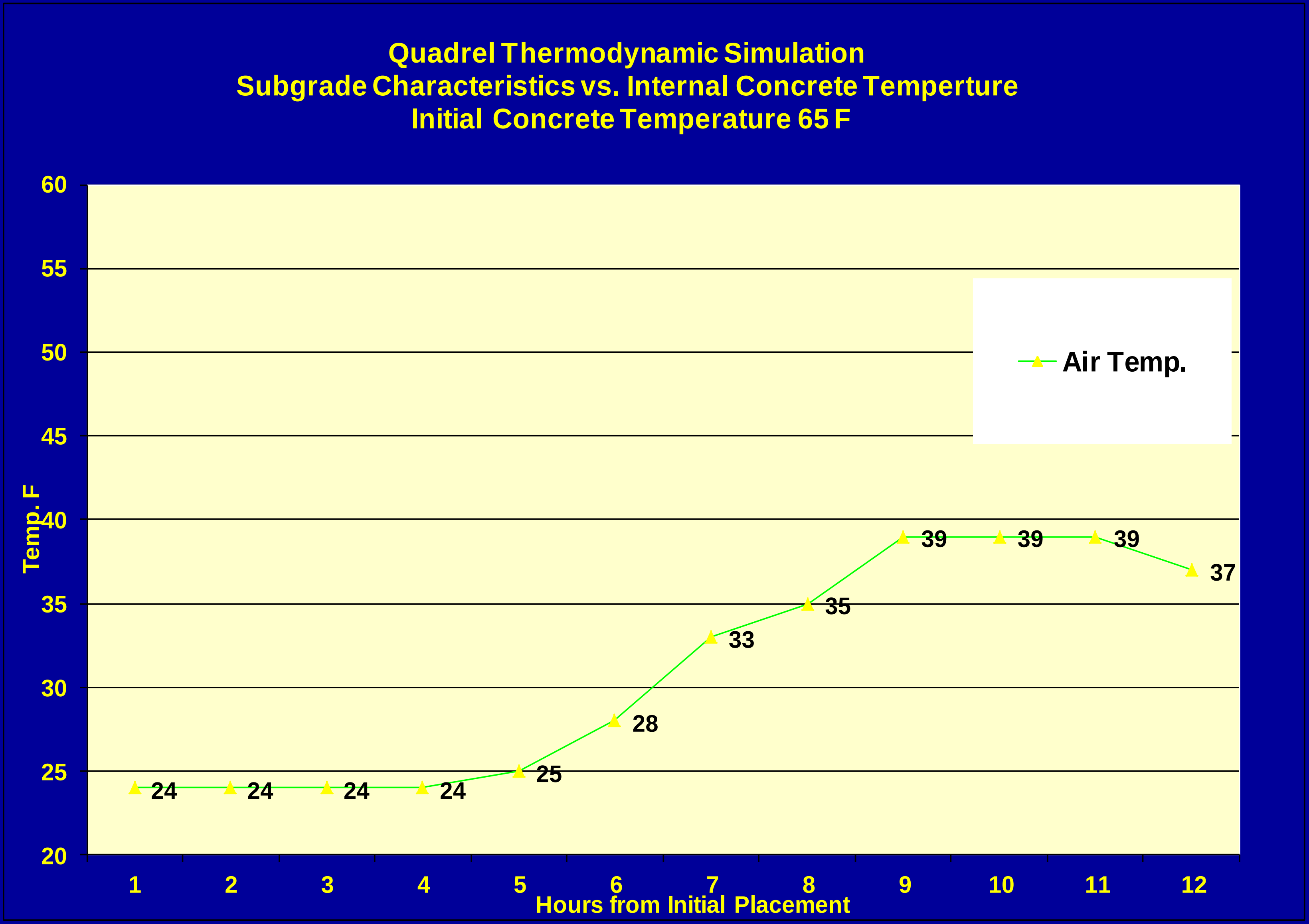
Soil Density

Moisture Content

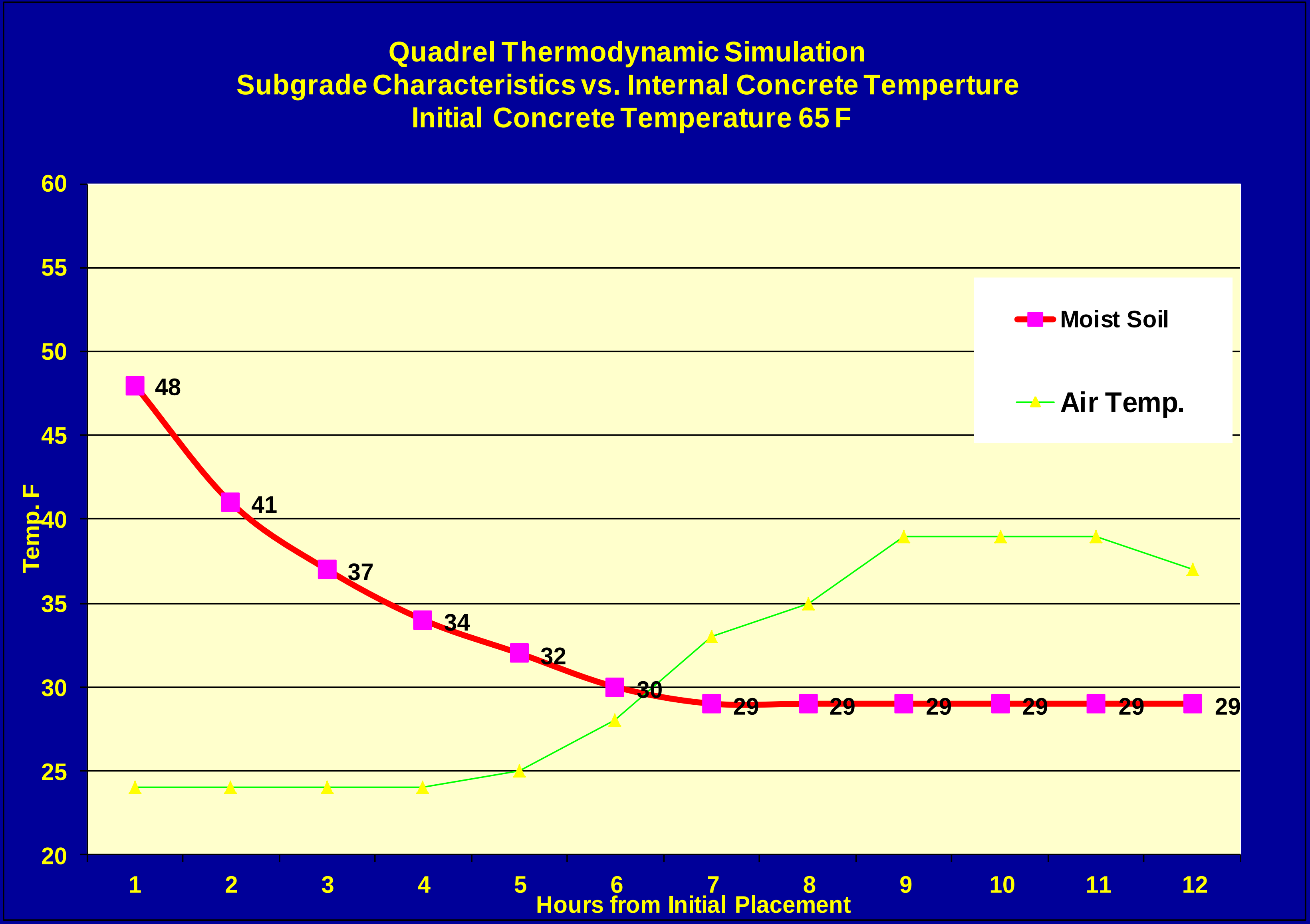
Heat Flux

Table 1: Thermal Properties of Various Materials		
Material	Specific Heat Capacity Btu/lb ºF	Thermal Conductivity Btu/ft hr ºF
Air	0.24	0.041
Water	1.0	1.0
Ice	0.50	3.8
Clay – dry	0.19	0.26
Clay – moist	0.35	3.12

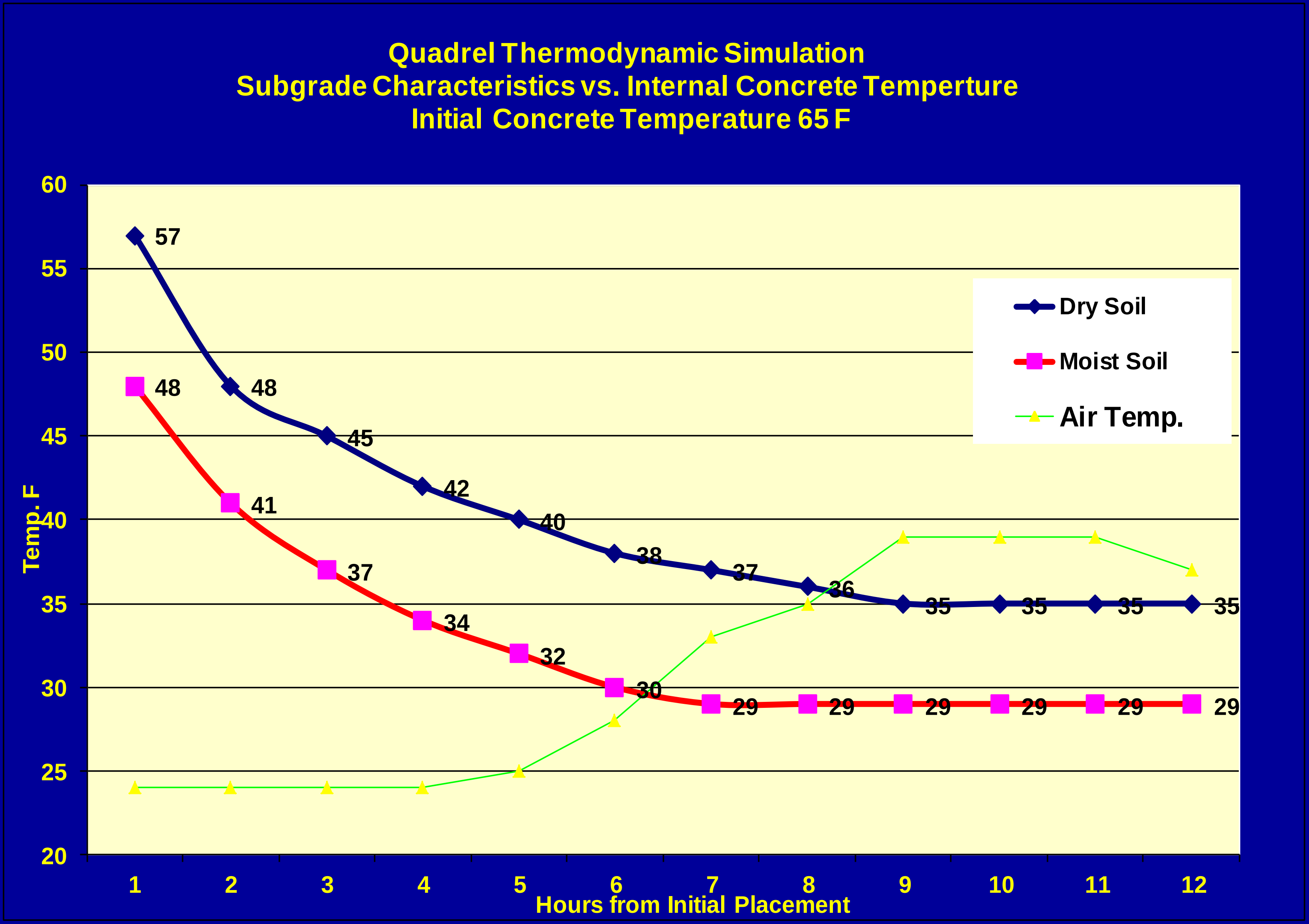
Thermodynamic Modeling



Thermodynamic Modeling



Thermodynamic Modeling



Reported Time of Set vs. Concrete Temperature

Table 3 – Typical Values of Time to Initial Set vs. Concrete Temperature		
Concrete Temperature ºF	Initial Set – Hours	Increase in Set Time From 70º F Reference
70	6	---
60	8	33%
50	11	83%
40	14	133%
30	19	217%

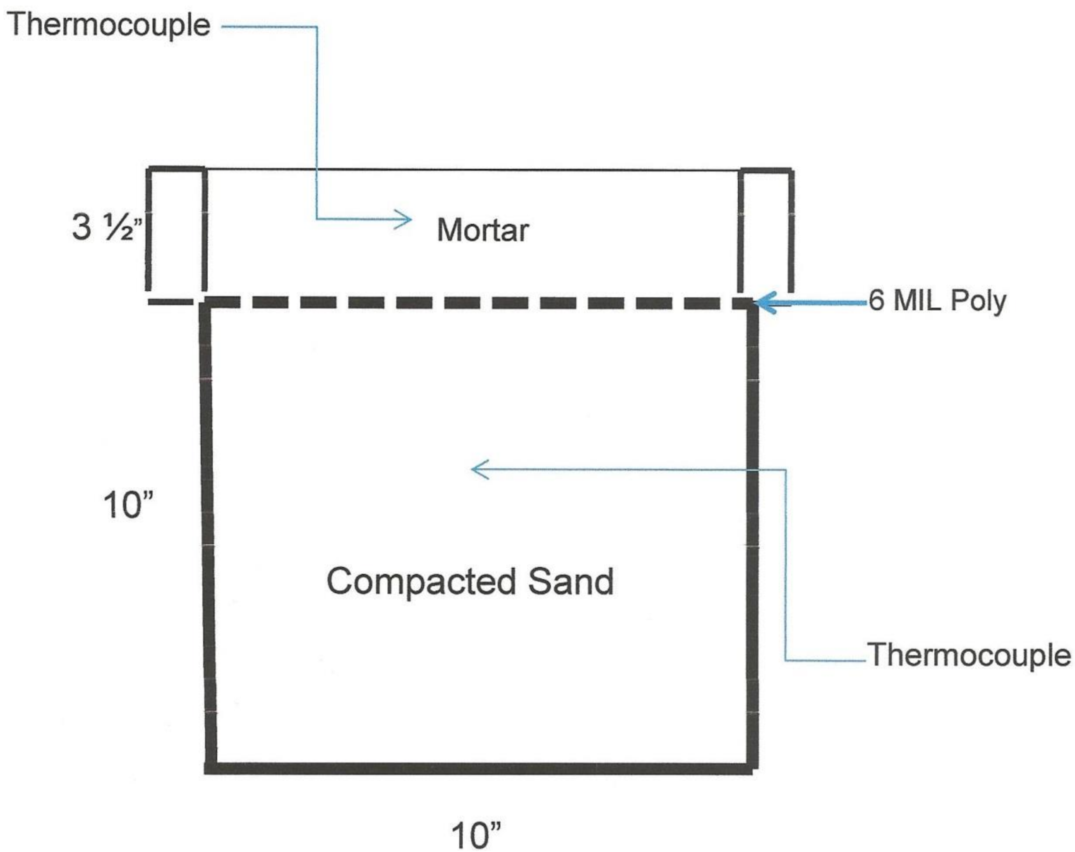
Conclusions
Computer Modeling

- Soil Condition Make a Difference
- 8 to 10 F
- 3 to 5 hour in Set Time

Experimental Comparison

Effect of Subgrade Heat Flux
on
Heat Transfer and Setting of Concrete

Experimental Setup



Subgrade Conditions

- Low Heat Flux – Dry Compacted Sand
- High Heat Flux – Damp Compacted Sand
  - (9% moisture)

Experiential Conditions

- Subgrade @ 66 F
- Mortar @ 90 F
- Differential 24 F

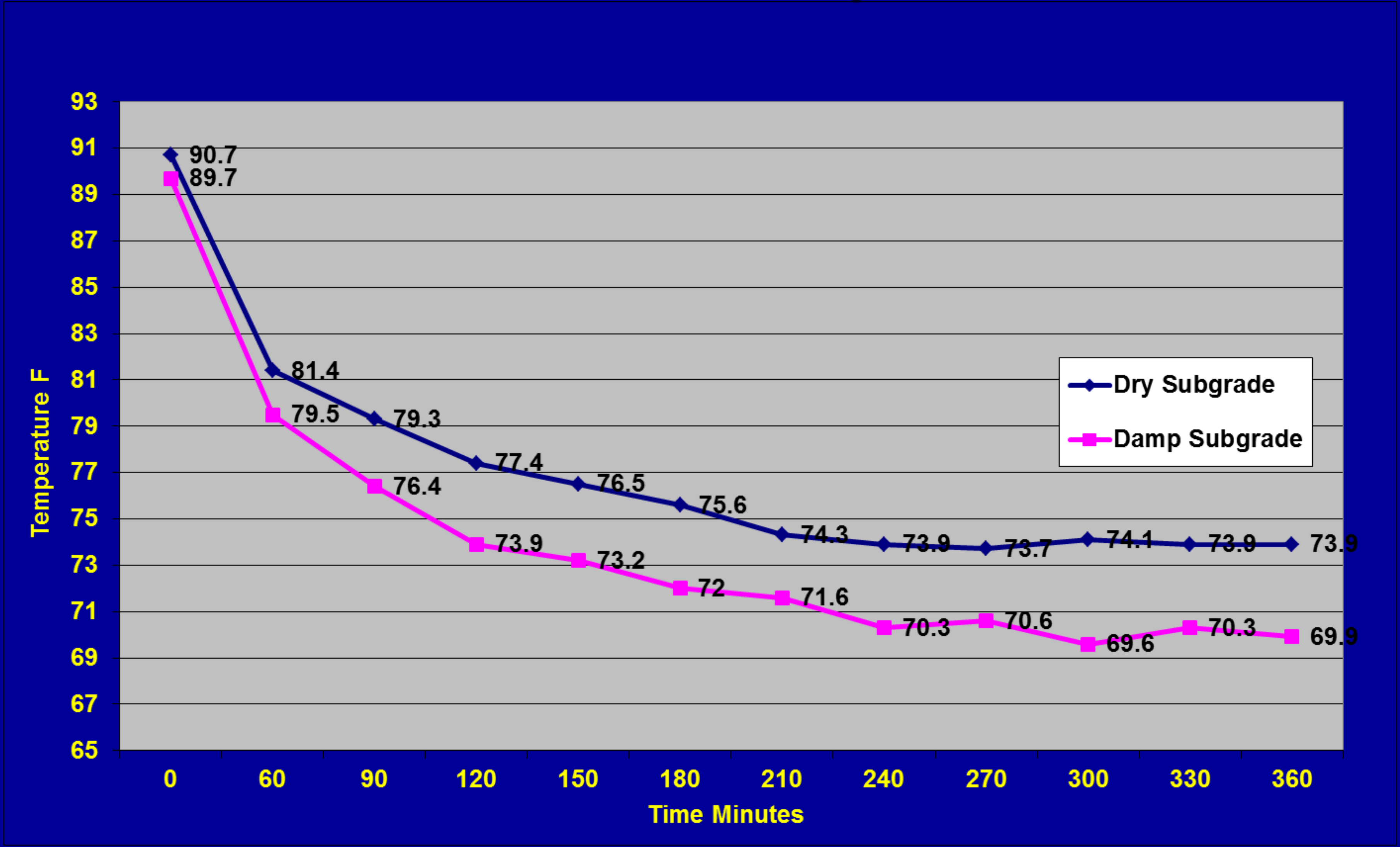
Conditions Monitored

- Ambient Temperature
- Temperature of Subgrade
- Temperature of Mortar
  - Surface
  - Internal
- Time of Set

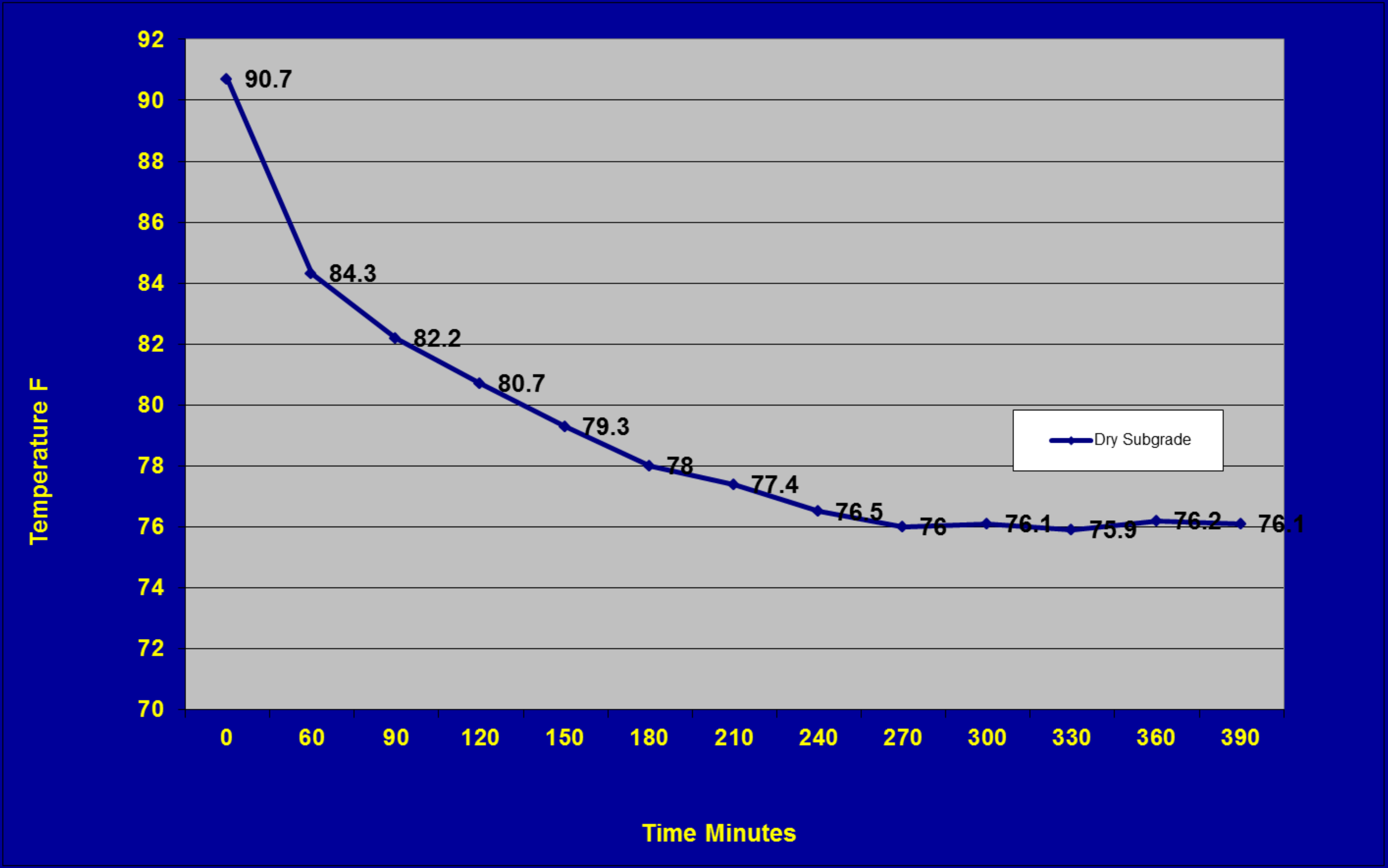
Mortar Heat Loss

Mortar Surface Temperature

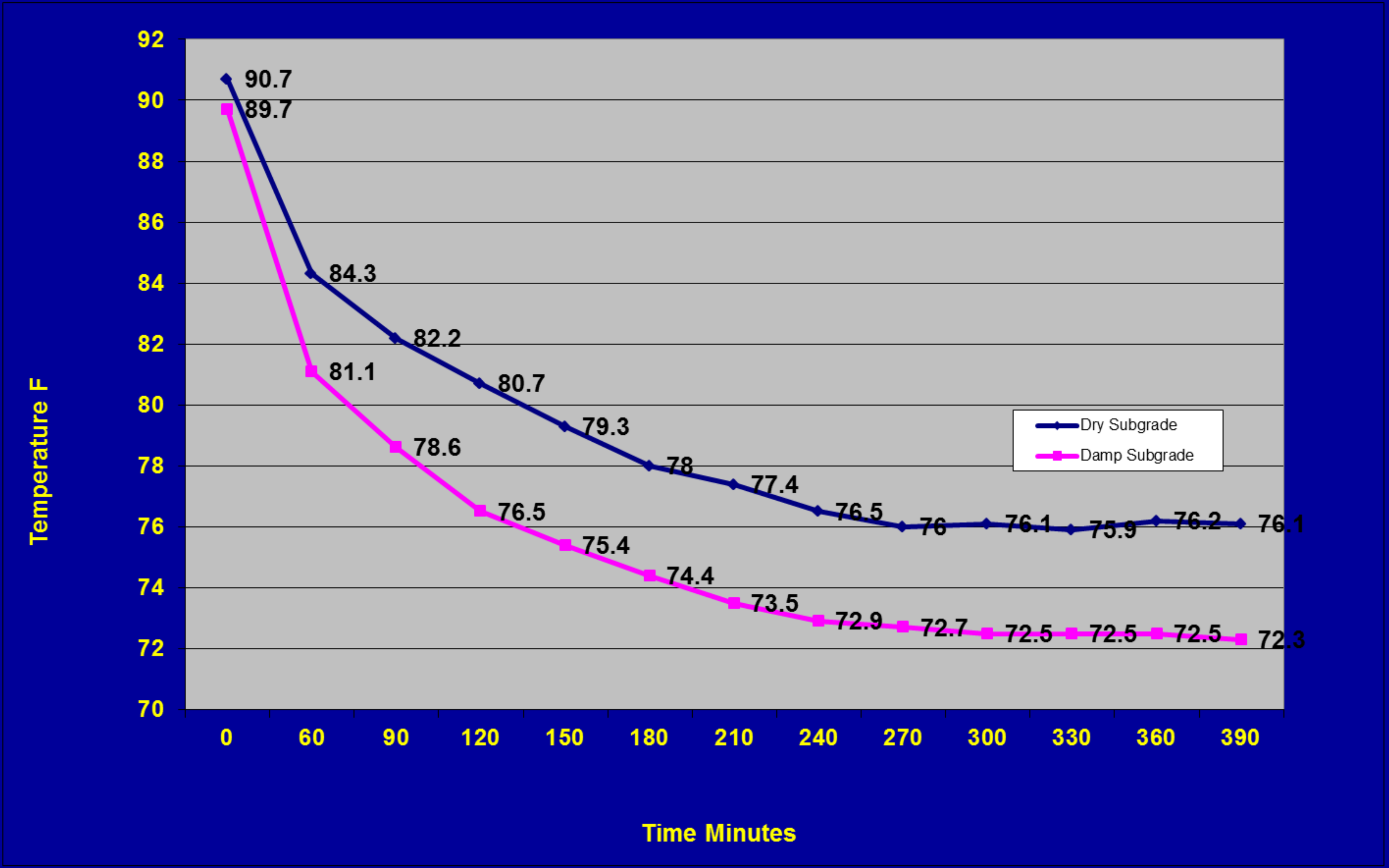
Mortar Surface Temperature



Internal Mortar Temperature



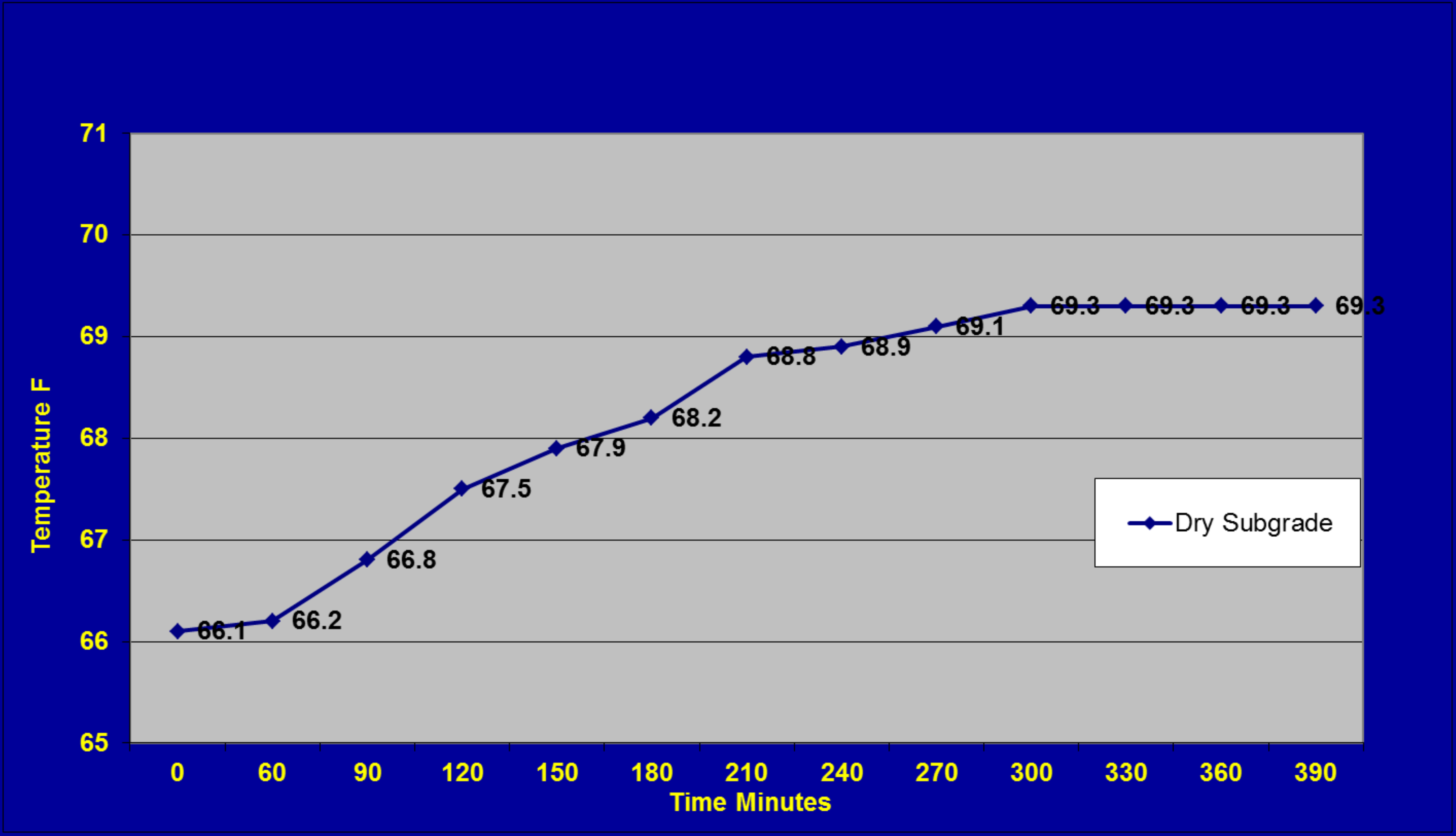
Internal Mortar Temperature



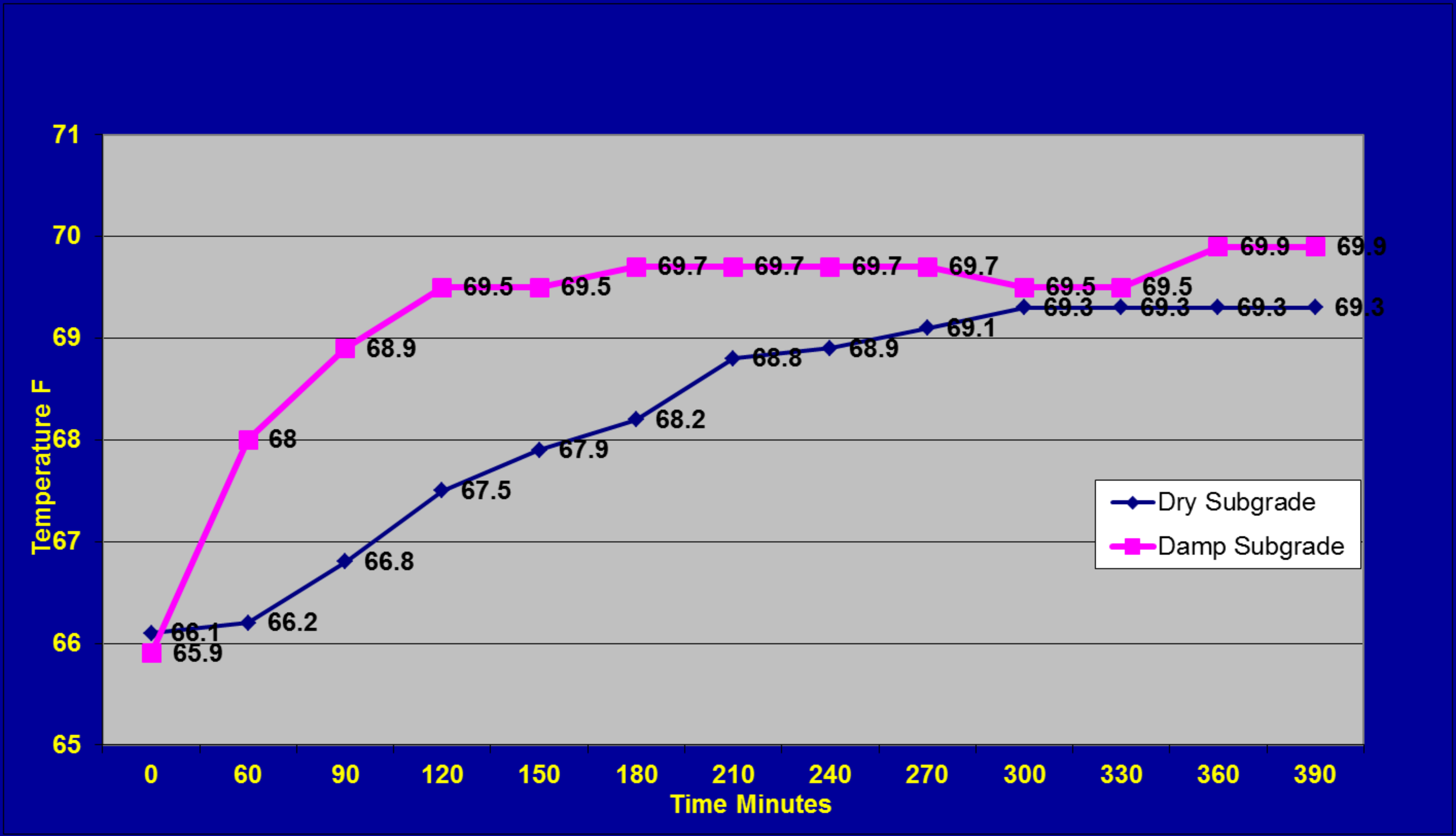
Where is the heat going?

Heat Transfer to Subgrade

Subgrade Temperature
Depth 4 1/2" Below Bottom of Mortar



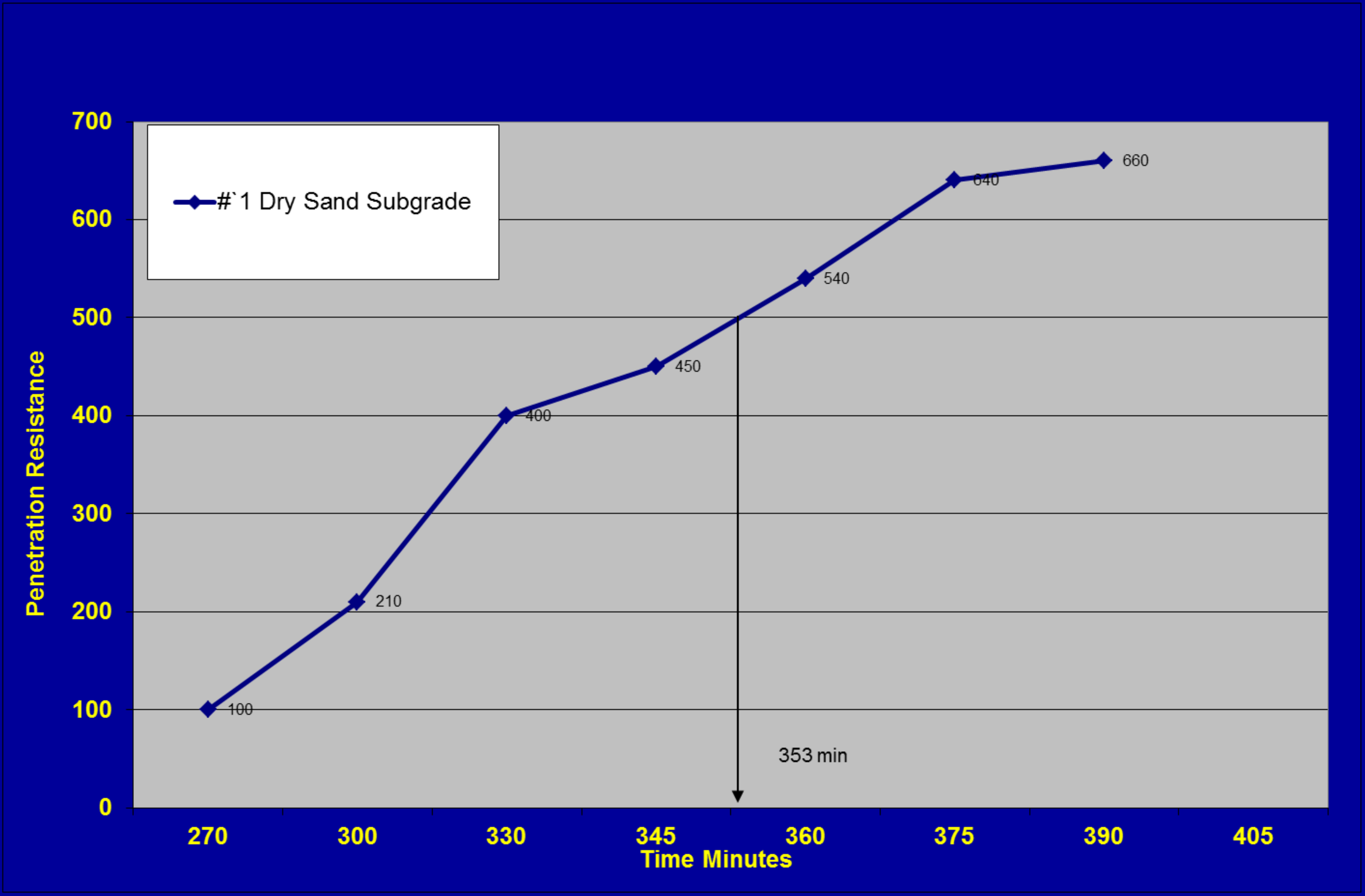
Subgrade Temperature
Depth 4 1/2" Below Bottom of Mortar



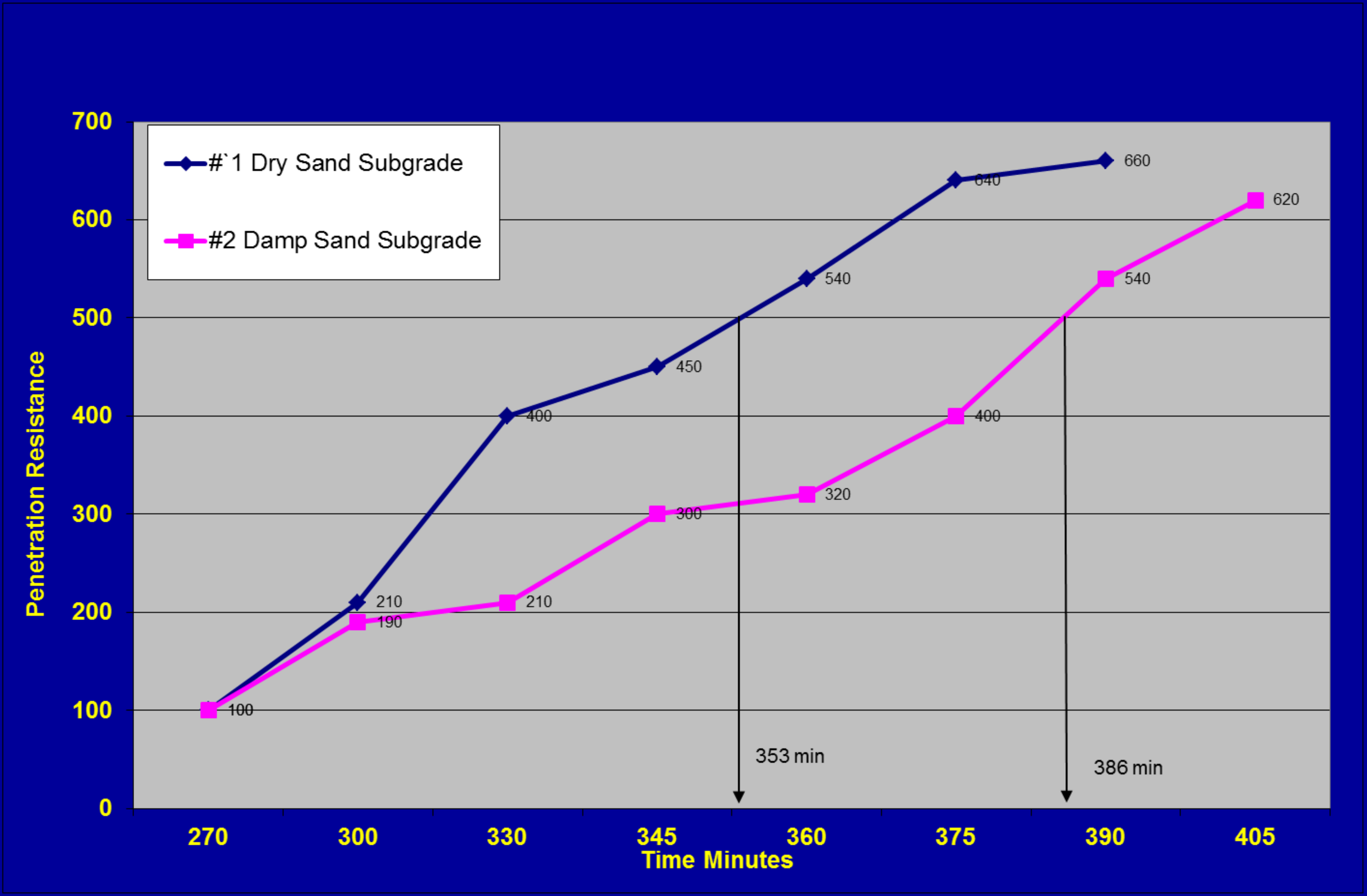
Time of Set

The Final Test

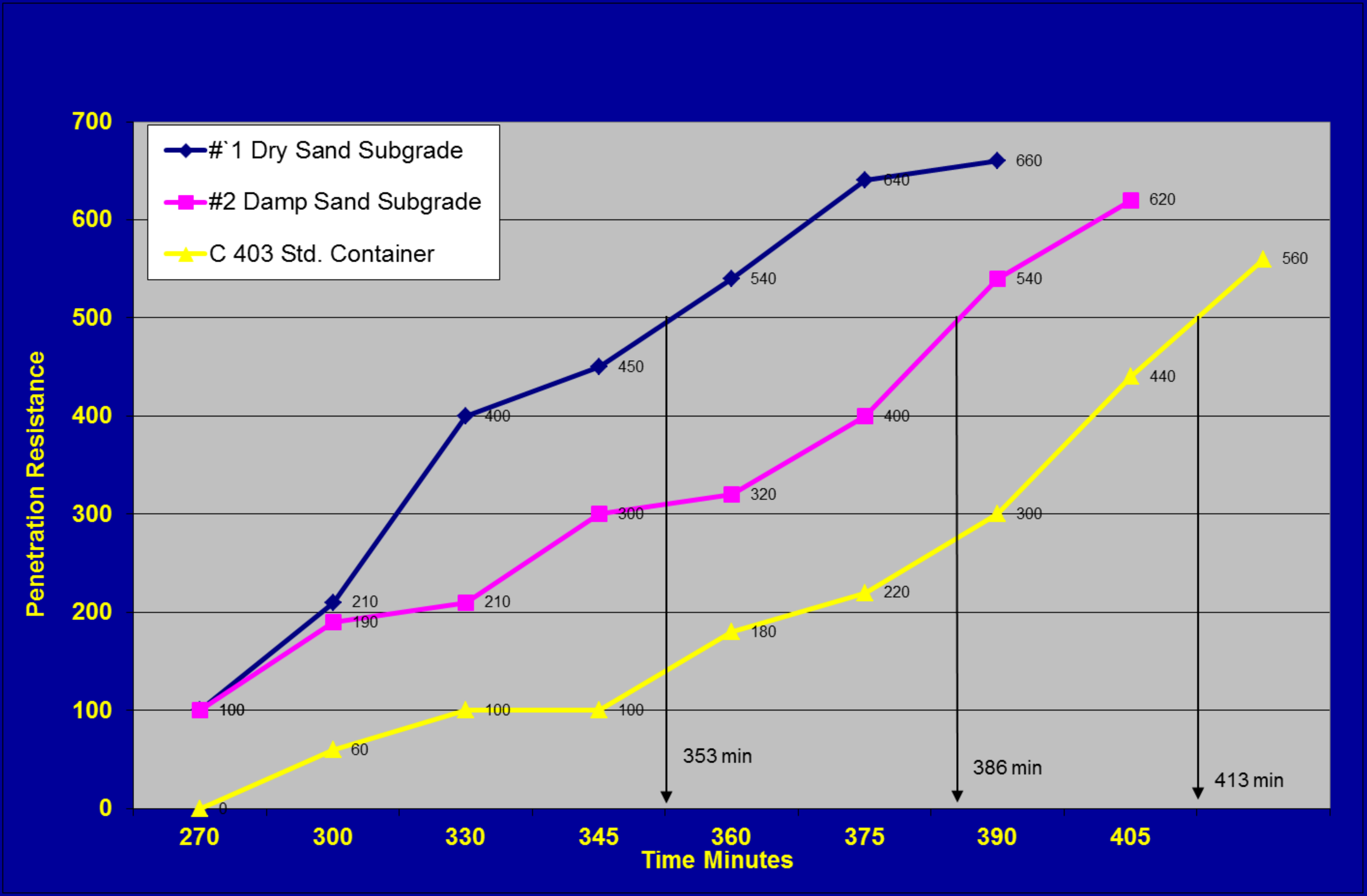
ASTM C 403 Time of Set



ASTM C 403 Time of Set



ASTM C 403 Time of Set



Subgrade Characteristics
Heat Loss Effects

- Can Affect Heat Loss
- Slower/Faster Setting
- Variable Setting ?

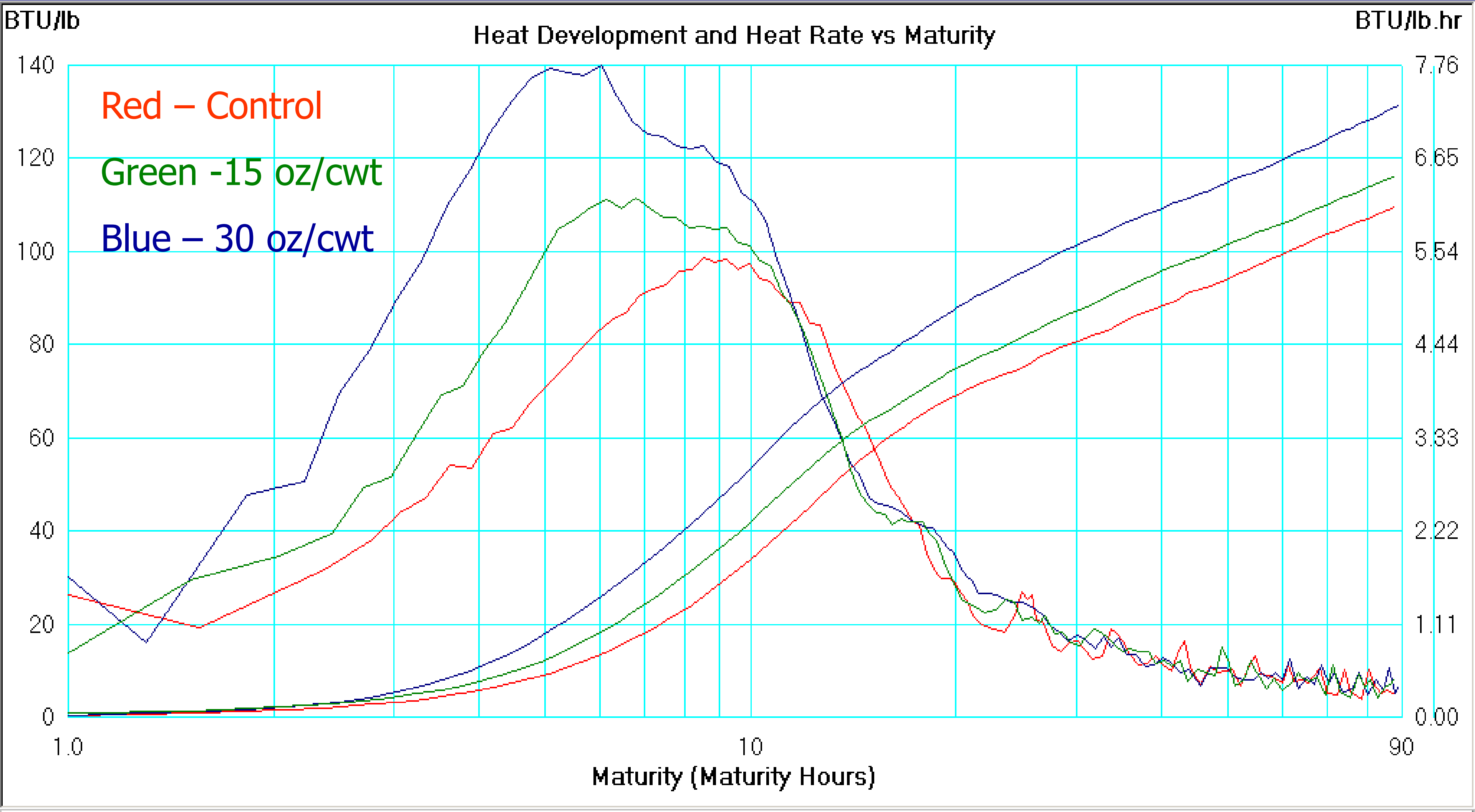
Cold Weather Protective Measures

Unintended Consequences

Chemical Accelerators

- Accelerate Hydration Reactions
- Increase Early Heat Liberation
- Not an Antifreeze Agent

Heat Rate Development
Effect of Non-Chloride Accelerator



Calcium Chloride – Most Effective But Lots of Side-Effects

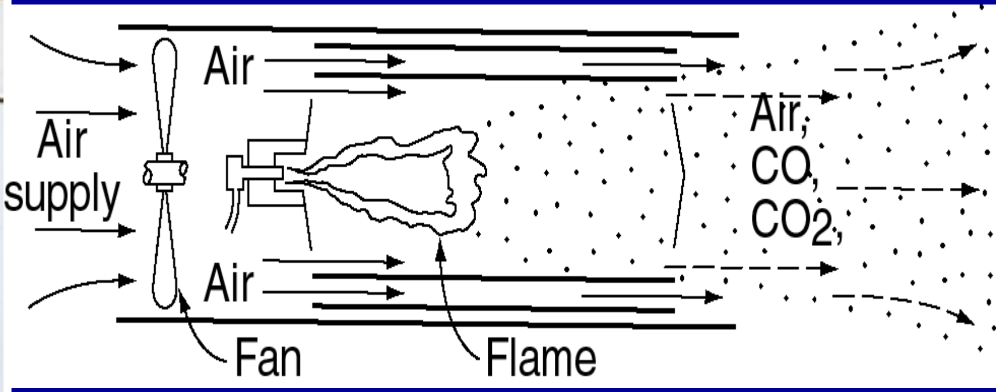
Typical Discoloration from Calcium Chloride

Corrosion of Metals – Limiting Chloride Content

Never Use CaCl in Concrete Containing Aluminum

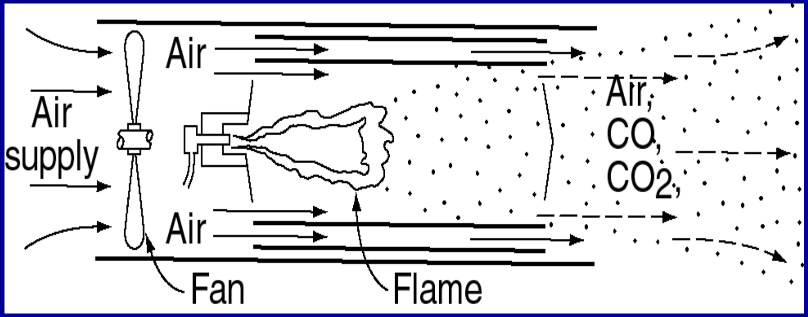
Heated Enclosures

- Carbon Dioxide Exposure!



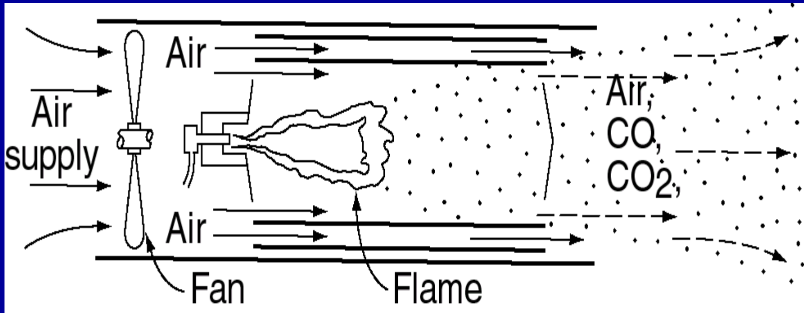
Carbon Dioxide

- Odorless
- Heavier Than Air
- Solubility Inversely Related to Temp.



Carbonation

- Carbon Dioxide Levels
  - Normal 0.03% to 0.08%
  - At 3% your sick
  - At 6% your dead
  - We’re tougher than concrete:
    - 0.15% causes damage

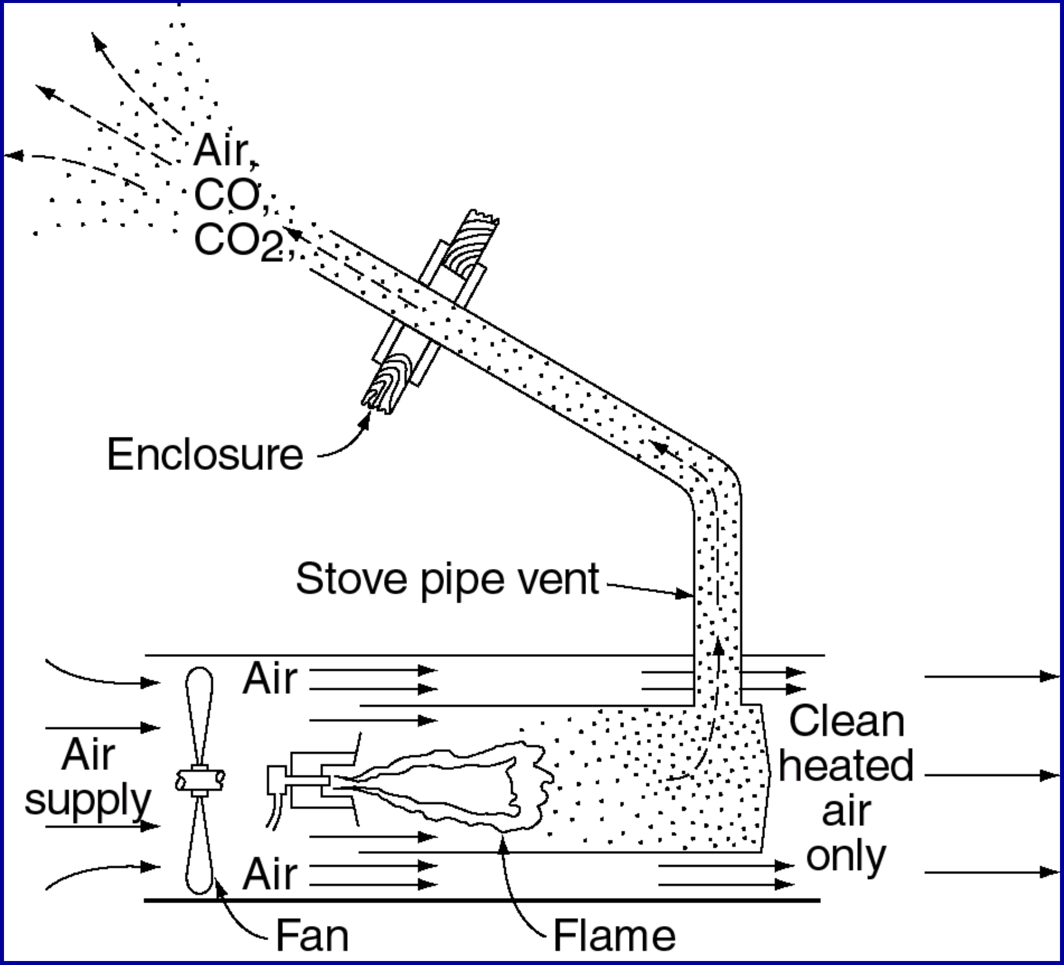


Carbonation
Plastic Concrete

- **CO_2 + Water = Carbonic Acid**
- **Carbonic Acid reacts**
  - **1st: Free CaOH in paste**
    - **Converts to $CaCO_3$ (calcium carbonate)**
  - **2nd: Attacks newly formed CSH Compounds**
    - **Again, more $CaCO_3$**
- **Affects? 1/16 to ½ inch**

Dusting Concrete Surfaces

Indirect-Fired Heater



The Best Thing Cold Weather is Good For!