Best Practices for Paving in Extreme Temperatures

Matt Fonte- Fonte & Co.

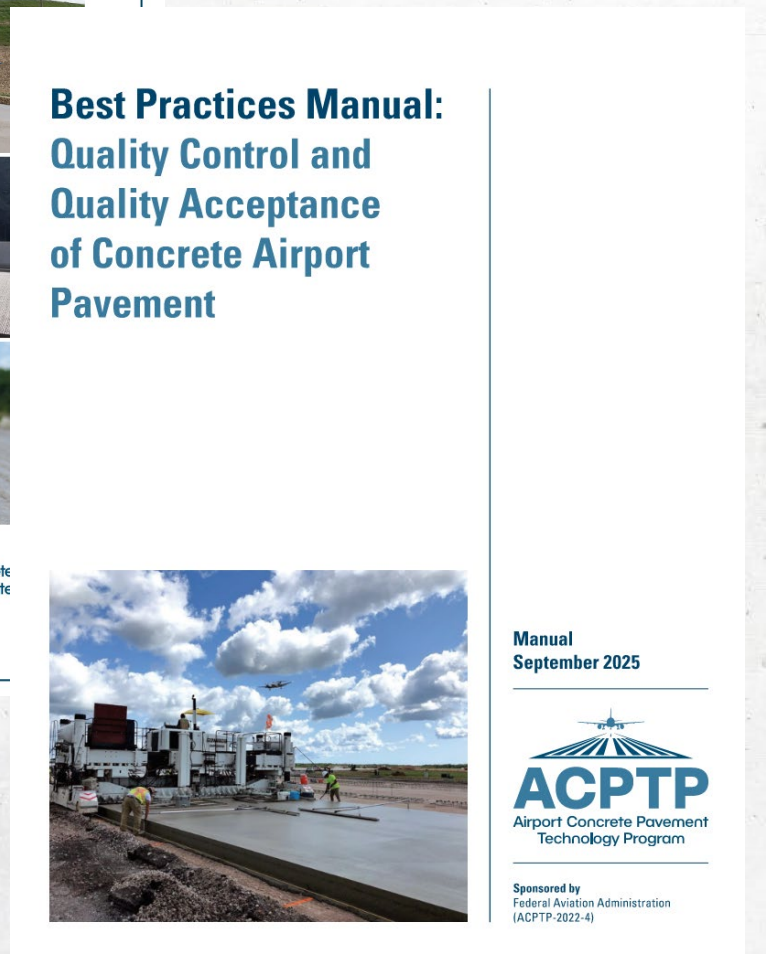
Sarah Dalton, P.E.- ACPA

Why does this matter?

- Durability issues
- Constructability challenges
- Increased risk of pay reduction and rework
- Long-term performance impacts

Quality Control Plans

- Should be project specific, not boilerplate
- Should address the conditions that will be encountered on the project
- Should include hot and cold weather paving plans
  - Includes **HOW** practices will change with weather conditions



Cold Weather Paving

What is Considered Cold Weather for Concrete Placement?

- ACI 306 Definition- Anytime ambient temperatures will drop below 40deg F during the protection period

Cold Weather Impacts

- Delayed setting and strength gain
- Increased risk of freezing and damage from ice formation internally
- The surface may cool and contract faster than the interior, causing thermal stresses and potential cracking
- Reduced rate of moisture loss but increased risk of weakened surfaces and scaling if proper protective measures are not used

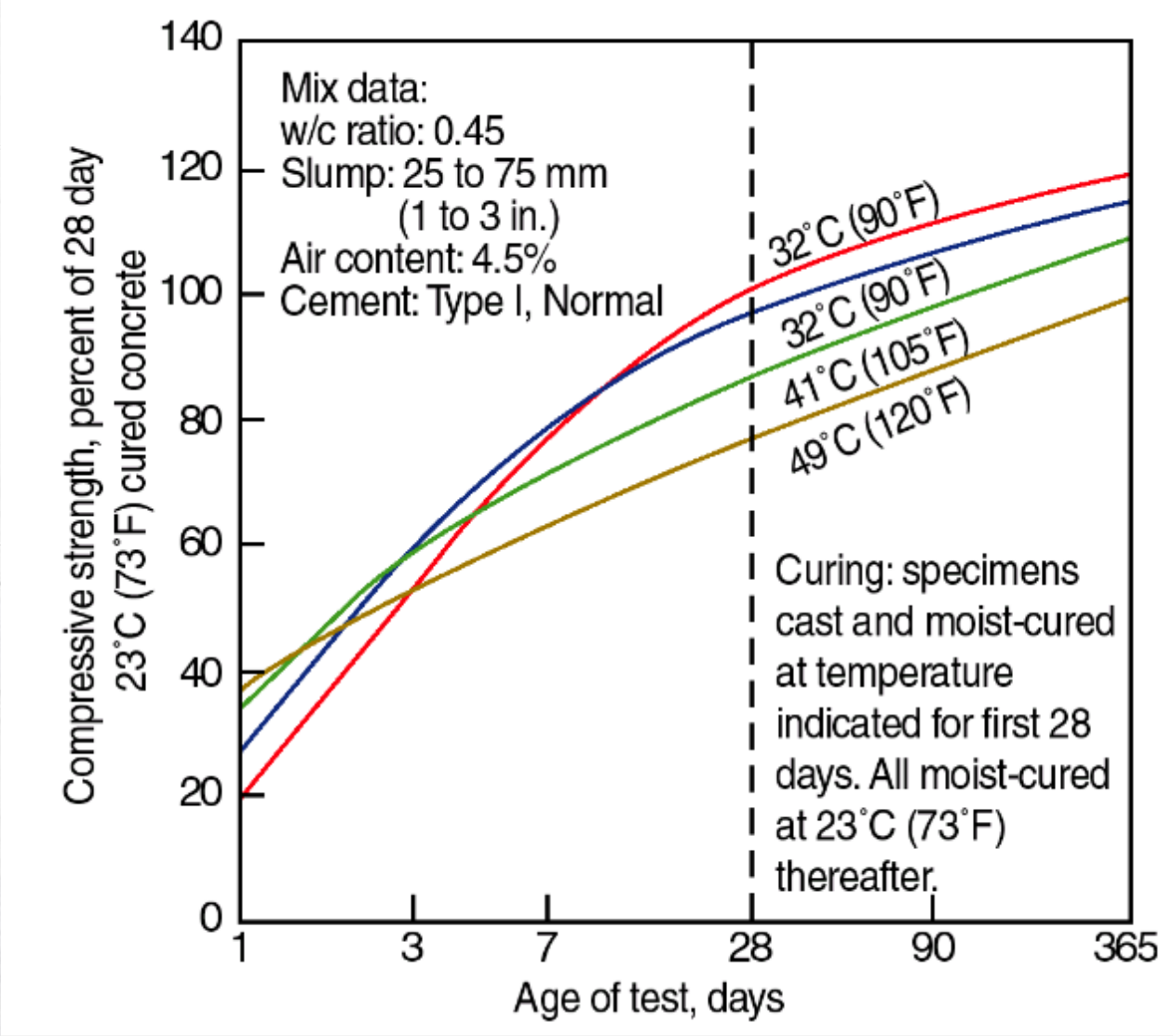
Common Specification Requirements

- Stop production if ambient temperature drops to 40°F
- Start production when ambient temperature rises to 35°F and continues to ascend
- Concrete must be at least 50°F during placement

Objectives

- Prevent early age freezing
  - Lower temperatures slow hydration process
  - Freezing temperatures may stop hydration and cause damage to the matrix
- Ensure concrete develops proper strength for loading
- Maintain normal curing conditions
- Limit rapid temperature changes

Effect of Initial Temperature on Strength



Base Materials

- Never place concrete on frozen base/subgrade
  - May experience differential settlement as materials thaw
  - Concrete Temperatures can drop

Concrete shall not be placed on frozen ground.

- What constitutes frozen ground?
  - Temperature?
  - Frost?

Measuring Base Temperatures

- How are temperatures being measured?
  - Probe Thermometer
  - Infrared Temperature Gun
  - On the surface or slightly under?
- Who is taking measurements?
  - Quality Control
  - Quality Assurance

Base Materials

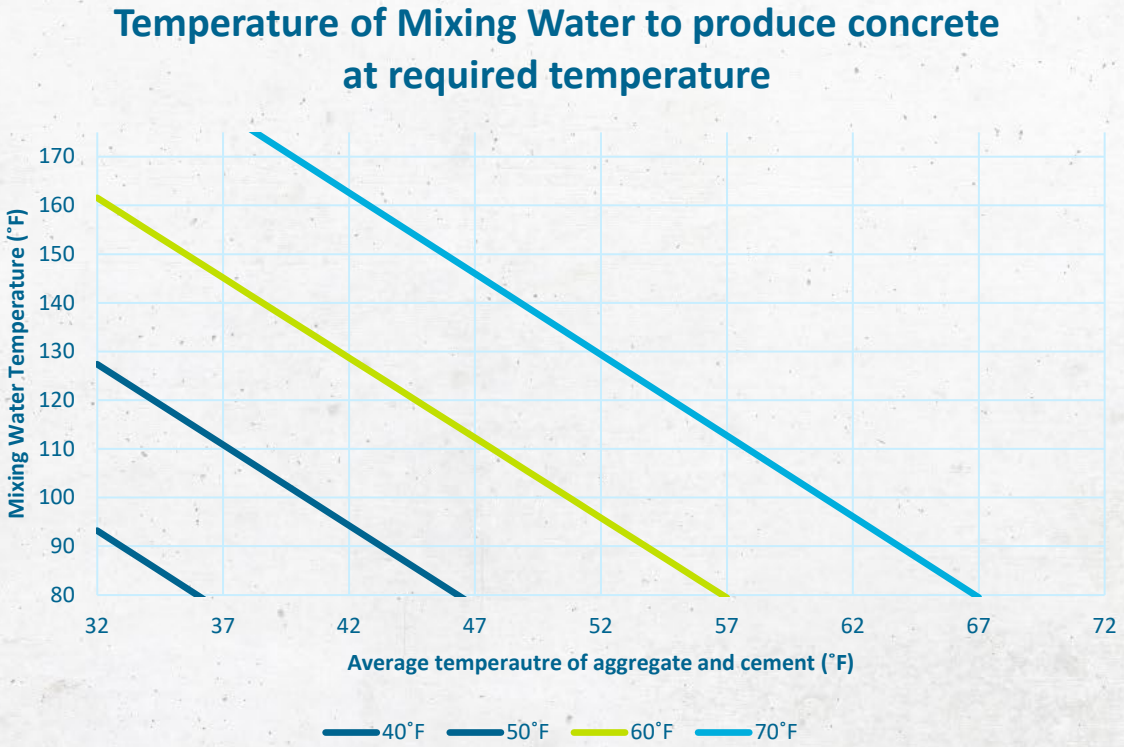
- Hydronic ground heaters and insulating Blankets
- Heated Blankets for small areas
- Base should be moist
- Spray hot water on subbase?

Batching- Aggregates

- Aggregates should be at SSD
- Stockpiles should be free from snow and ice
- Pull from sunny side of stockpile
- Can aggregates be heated?

Mixture Temperatures

- Minimum 50 deg F at time of placement
  - Boiler- Heat water at the batch plant
    - Max temp of 150 when introduced into the drum
    - May need to adjust batching sequence
      - Introduce water and aggregate before cement to even out temperatures
  - Cover loads during transport
  - Minimize haul times

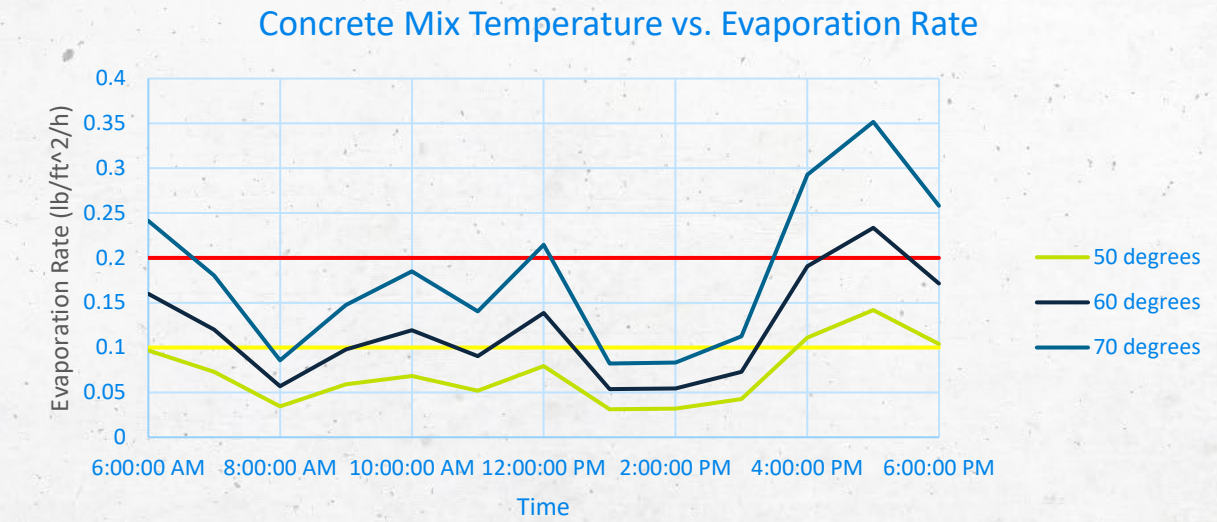


Cold Weather Mixtures

- Small doses of set accelerating admixtures conforming to ASTM C494 Type C or E may be used (should be included in original mix design)
- Not Recommended
  - Increasing cement content
  - Removing supplementary cementitious materials (SCM's)
    - SCM content may be reduced if ASR and durability testing requirements are met

Finishing

- Strength gain is slowed
- Drying is not
- Finishing may be delayed in some cases
- Avoid adding water during finishing operations



Upper Limit- .2 lb/ft^2/h

Caution Limit- .1 lb/ft^2/h

Ambient Temperature: 28-43 ˚F
Relative Humidity: 19%-50%
Wind: 3-20 mph

Texture and Curing

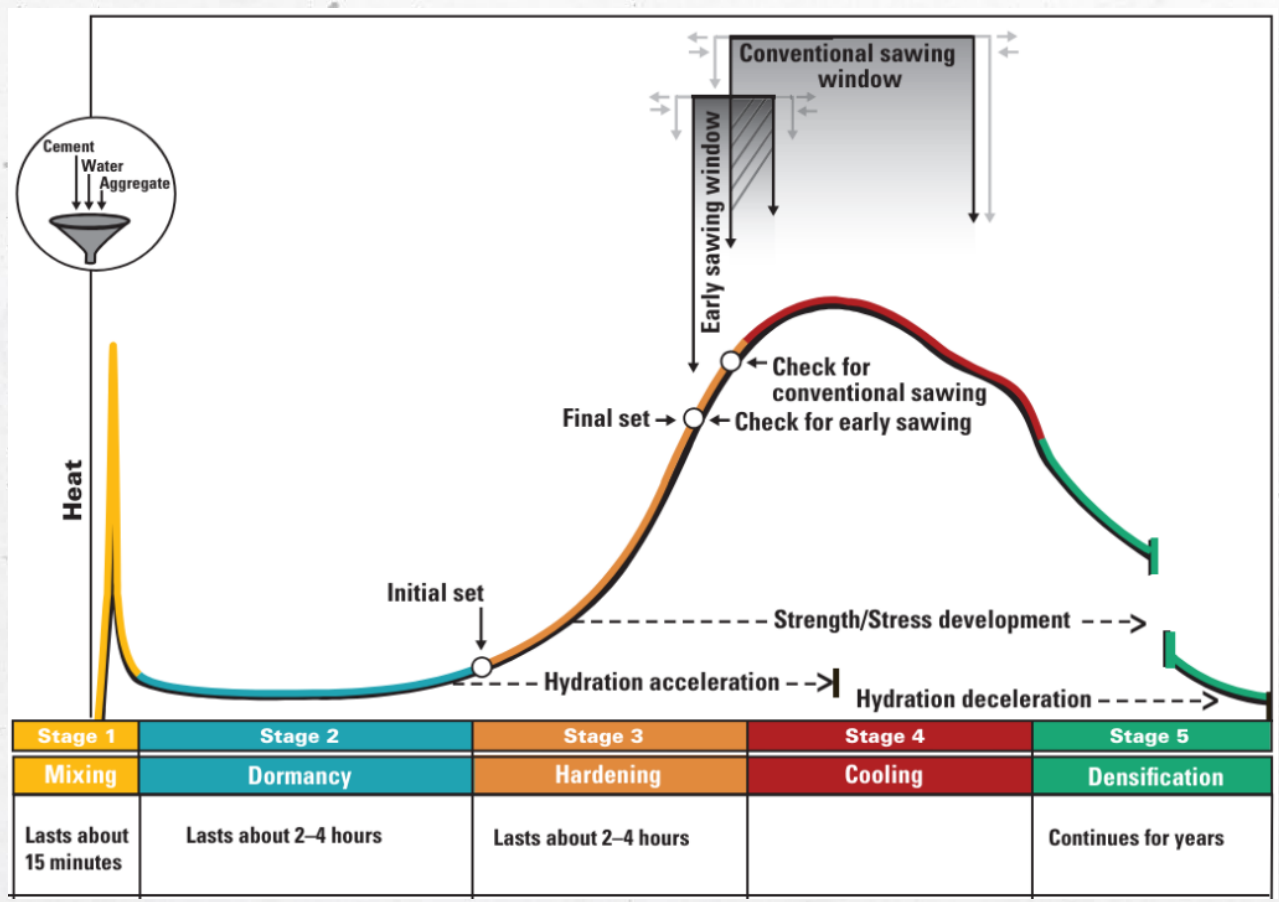
- Evaporation Retarders may be necessary if texture operation is delayed
- Proper application of curing compound is still critical

Temperature Management

- 50˚F at time of placement
- Maintain minimum 40 ˚F internal temperature behind the paver
  - Monitored with sensors and thermocouples
- Surface temperature measurements are not sufficient

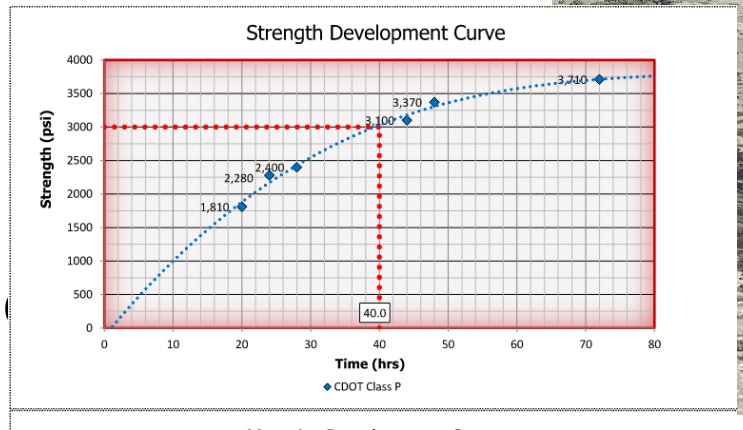
Heat Generation

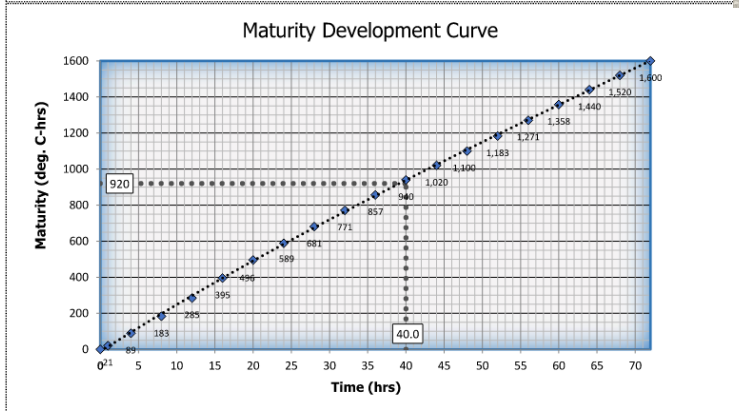
- Hydration reaction is highly exothermic



Maturity

- ASTM C1074
- AASHTO T413-24 Standard Method of Test for Estimating the Early Opening Strength of **Concrete Pavements** by Maturity Tests
- Place meters mid-depth
- Logs should be submitted to the engine daily

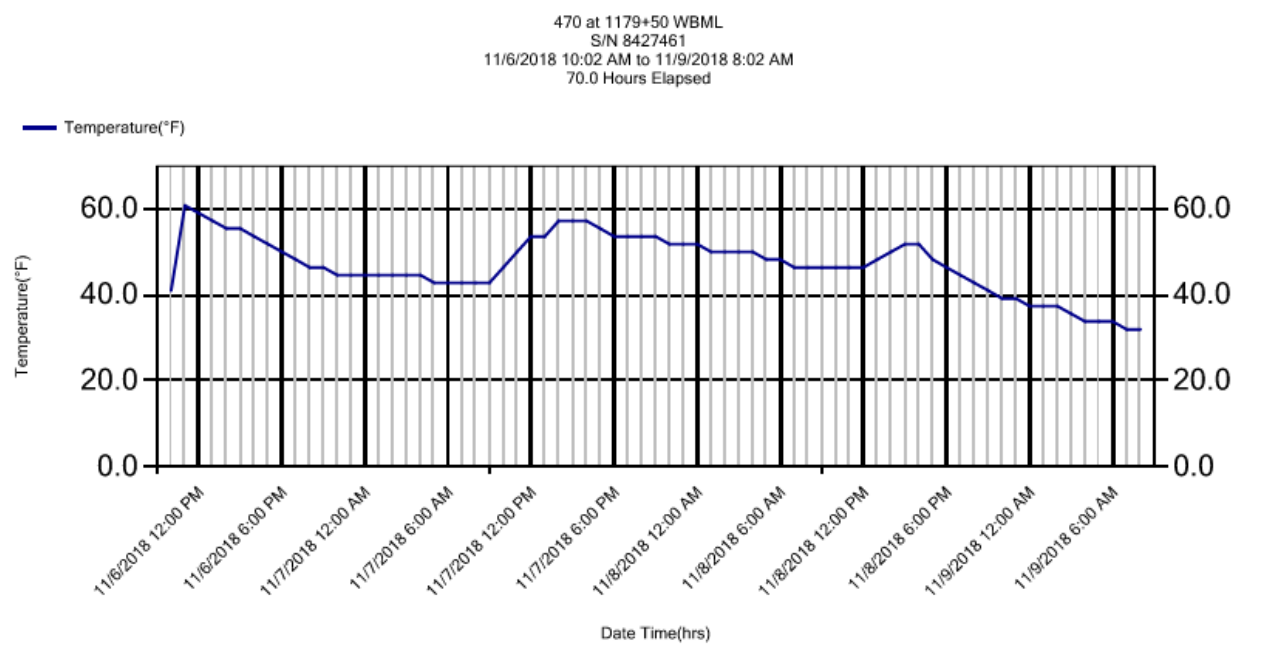




Testing was performed per ASTM C 1074 and CP 69

Cold Weather Protection

- Cover concrete to hold in heat from hydration
  - Burlap
  - Plastic
  - Insulated Blankets- small pours
- Should be contractors choice how and when to cover
  - Based on low temperature, thickness, width
- Protect slab as soon as possible
- Protection must be secured



Precautions- Green Saw

- Sawing times may be delayed based on internal temperatures
- Higher probability of joint raveling during sawing
- Consider minimizing use of water
- Protection will have to be removed for sawing- Temperature must still be

Unacceptable:

Moderate:

None:

Example Specifications

Colorado DOT

412.15 Cold Weather Concrete Paving. The Contractor is responsible for the strength and quality of the concrete placed during cold weather. Before starting paving operations, the Contractor shall be prepared to protect the concrete from freezing. Maturity meters, to monitor and record time and pavement temperature, shall be installed at the time of placement when the air temperature is expected to fall below 40 °F during the next three days or as requested by the Engineer when the air temperature is expected to fall below 45 °F during the next three days. The Contractor shall maintain the temperature of the pavement at or above 40 °F until the pavement has attained a compressive strength of at least 2000 psi. The compressive strength of the concrete shall be determined by the use of maturity meters. Maturity meters shall be placed in three locations for each day's concrete paving operations. One maturity meter shall be placed in the final 15 feet of paving, and the two other maturity meters shall be placed at locations designated by the Engineer. The maturity meter probes shall be located on the outside edge of the slab, at least 1 foot and not more than 2 feet from the edge and at mid depth of the slab. Each maturity meter shall be capable of recording the time and temperature. The maturity meters shall remain in place until the concrete has attained a compressive strength of 2000 psi.

Updated FAA Specifications*

501-4.7.1 Cold Weather.

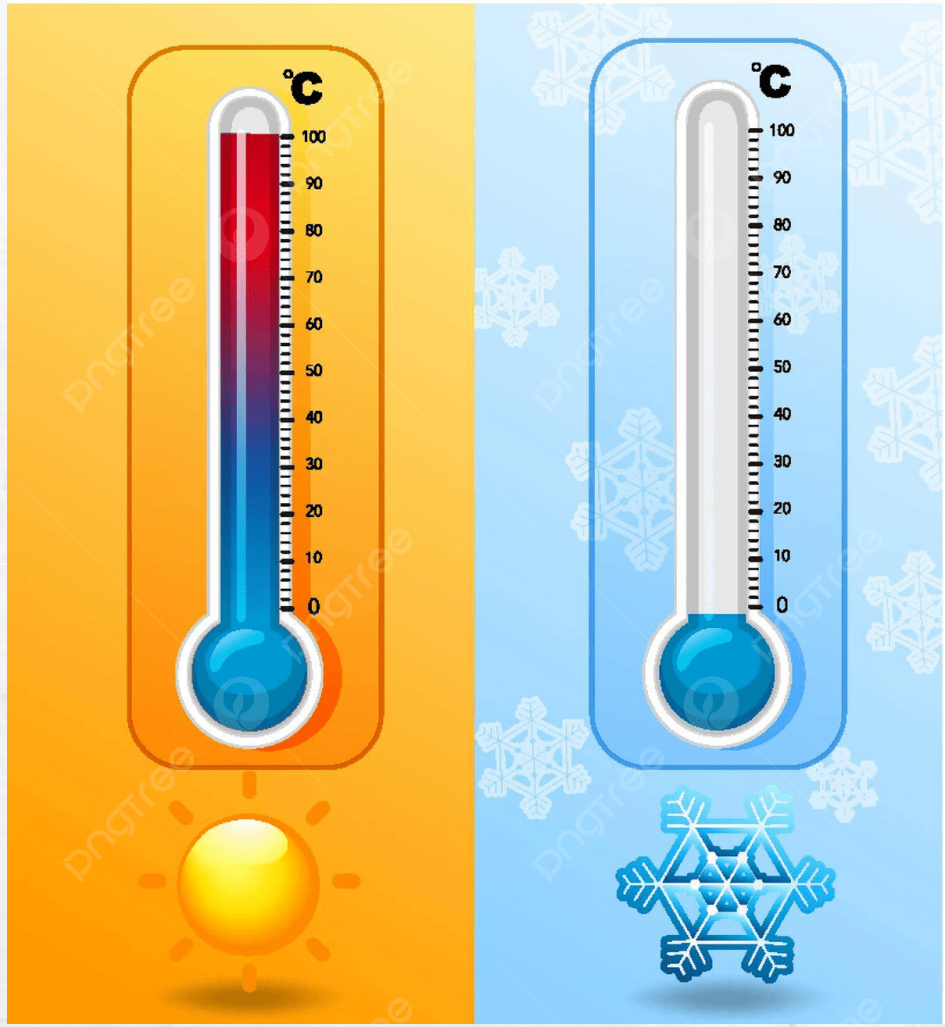
The Contractor is responsible for the strength and quality of the concrete placed during cold weather. Before starting paving operations, the Contractor must be prepared to protect the concrete from freezing.

| Maturity meters, to monitor and record time and pavement temperature, must be installed at the time of placement when the air temperature in the shade and away from artificial heat is expected to fall below 40°F during the next three days. | The Contractor must maintain the temperature of the pavement at or above 40°F until the pavement has attained a flexural strength of at least 450 psi. The flexural strength of the concrete is determined using maturity relationship according to ASTM C1074. Place maturity meters in three locations for each day's concrete paving operations. Place

* Language from Industry review draft of FAA AC 150-5370/-10J, not officially published yet

Why not use ambient temperature specifications?

- Newer technologies are available, accurate, and cost effective
- Improves schedule efficiency
- Shifts risk to contractor



Troubleshooting

- If temperatures on maturity meters/ thermocouples drop below 32 ˚F:
  - Take cores and send for petrographic examination
  - Core and test compressive strength

The following procedures shall be followed if the temperature of the concrete pavement falls below 32 °F before the concrete reaches 2,000 psi:

(1) The Contractor will take cores at locations designated by the Engineer.

(2) The Engineer will take immediate possession of the cores and submit the cores to a petrographer for examination per ASTM C856.

(3) All costs associated with coring, transmittal of cores, and petrographic examination shall be borne by the Contractor regardless of the outcome of the petrographic examination.

(4) Pavement damaged by frost as determined by the petrographic examination, shall be removed and replaced at the Contractor's expense.

Summary

- Cold weather paving can be successful and result in durable, long-life concrete pavement
- Need to control
  - Temperature
  - Moisture
  - Hydration
  - Strength Gain
- Internal concrete temperature matters more than ambient temperature
- Use available technologies for real-time monitoring
- Curing and protection are critical

Hot Weather Paving

Hot Weather Paving

- Paving at night?
- Consider the timing
- Midnight to noon?

What is Considered Hot Weather for Concrete Placement?

- High ambient temperature
- High Concrete temperature
- Low Relative Humidity
- High wind speed
- Solar Radiation

Per ACI 305R-10

Consequences of Hot Weather on Plastic Concrete

- Higher concrete temperature
- Increased water demand
- Increased difficulty in controlling air content
- Increased rate of slump loss
- Increased difficulty in placing, handling, and finishing
- Faster setting time
- Increased evaporation rate of surface water
- Increased tendency for plastic shrinkage cracking
- Importance of prompt and proper curing
- Increase chance of scaling

ACPA

Trial Batch

- Simulate weather conditions
- Simulate field conditions

Trial Batching

- Introduce Aggregates, Cementitious, and Water. (Air Entrainment on the Sand)
- Stop to ensure all materials are mixed. (Scrape the corners if needed)
- Introduce Add Mixtures and visibly look for a change in the concrete. Thoroughly Mix the concrete and test physical properties (Slump, Air, Unit Weight, and The Box Test)
- Simulate the haul. (Agitated or Non-Agitated)
- Test the physical properties again. (Slump, Air, Unit Weight, and The Box Test)
- Is your mix workable at the point of placement?

The Box Test

- This test is mandatory for slipform paving (and more)
- This test will tell you how the mix will respond to your paver.
- How well will the mix close up holes
- How well will the mix hold an edge

VKelly

- VKelly
  - Does tell about response to vibration
  - Adjust aggregate gradation and paste content to achieve desired numbers
  - Prequalification

Should we start over?

Concrete Materials Admixtures

- Air entraining admixtures (AEA)
- Water reducers
  - Normal Water Reducers
  - Mid Range
  - High Range
    - Superplasticizer
- Set modifying admixtures
  - Retarders
  - Accelerators
- Specialty Admixtures
  - Hydration Stabilizers
  - Strength Enhancing
  - Viscosity Modifiers

To make good concrete better, not to fix bad concrete

Aggregate Moisture

Aggregate Moisture

Aggregate Moisture

520 total cementitious
218 lbs. water
W/CM 0.42
3215 lbs. aggregate
1% change in aggregate moistures
218+32 lbs. water
250/520=0.48

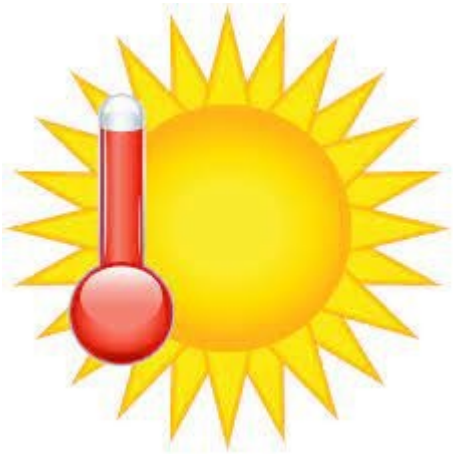
Hot Weather

Granular Materials

- Moisture is key (no standing water)

Overlays on Asphalt

- Use water to keep cool under 120 degrees
- Night paving may be necessary



Precautions- Mix

- Keep mix temperatures below 90deg F
  - Chillers and Ice can be used to cool water
  - Water aggregate
  - Covering loads during transport with non-agitating trucks
  - Sprayers on agitating trucks
  - Minimize haul times

Best Practices

Evaporation Retarders ≠ Finishing Aids

- Apply with an atomized sprayer

Finishing Aid

Evaporation Retarder

No paint brushes EVER!!!

Spray Bar System

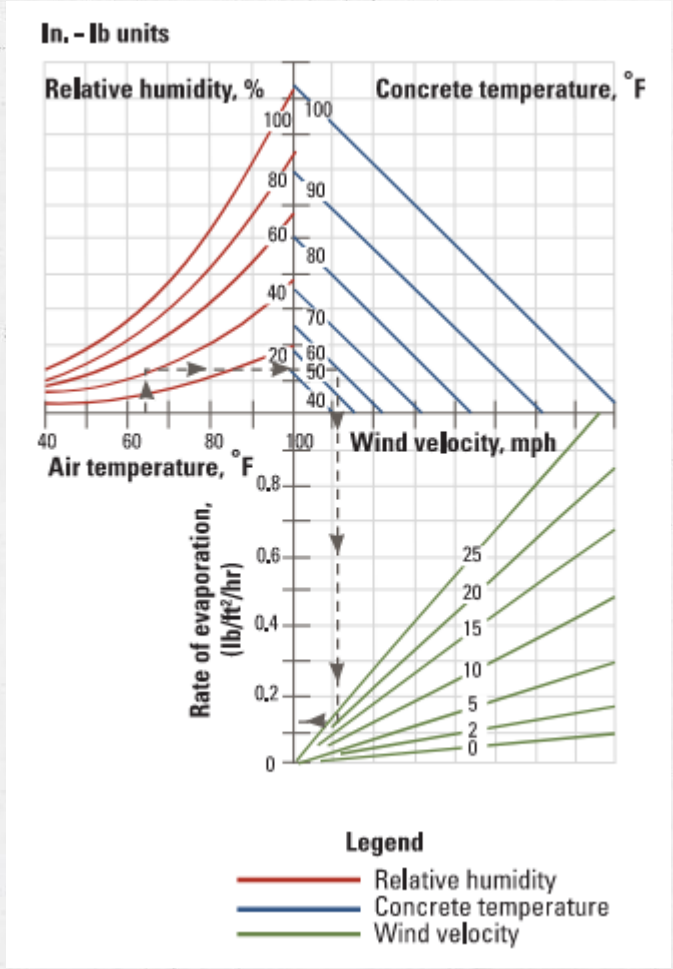
- Little water, frequently
- Timers 10 seconds on 60 seconds off

Finishing- Excessive Water

What About Handwork?

- How do I increase slump?
- What does my admixture package look like?

Evaporation Rates



/// EVAPORATION RATE CALCULATOR ///

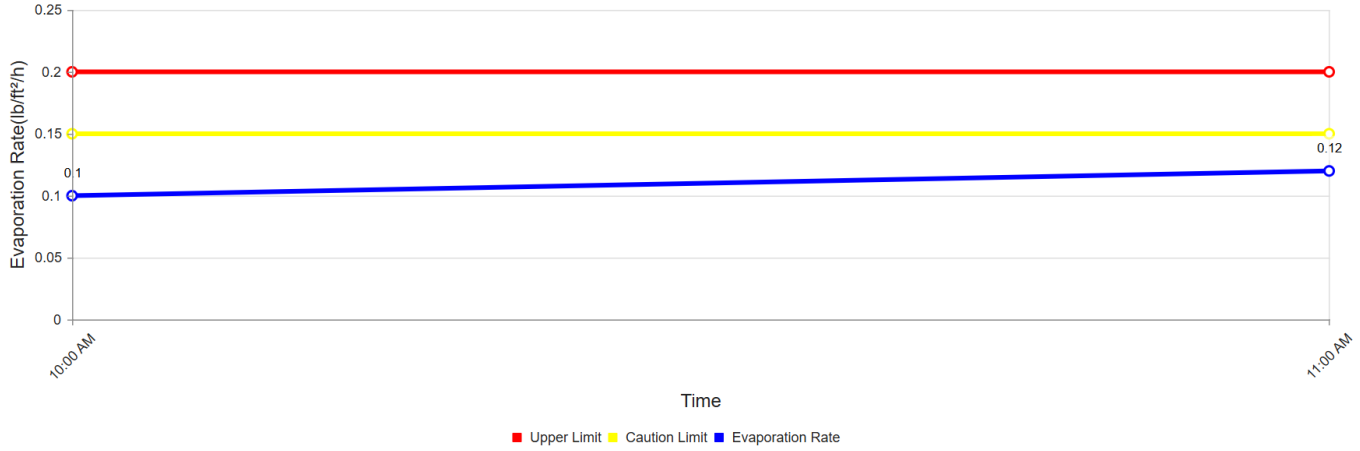
CONCRETE TEMPERATURE AND AMBIENT CONDITION

English / Metric

Time	Concrete Temp (°F)	Air Temp (°F)	Relative Humidity (%)	Wind Velocity (mph)	Evaporation Rate (lb/ft²/h)
10:00 AM	70.0	70.0	50.0 %	10.0	0.1
11:00 AM	72.0	75.0	40.0 %	10.0	0.12

Calculate | Save Inputs

EVAPORATION RATE RESULT



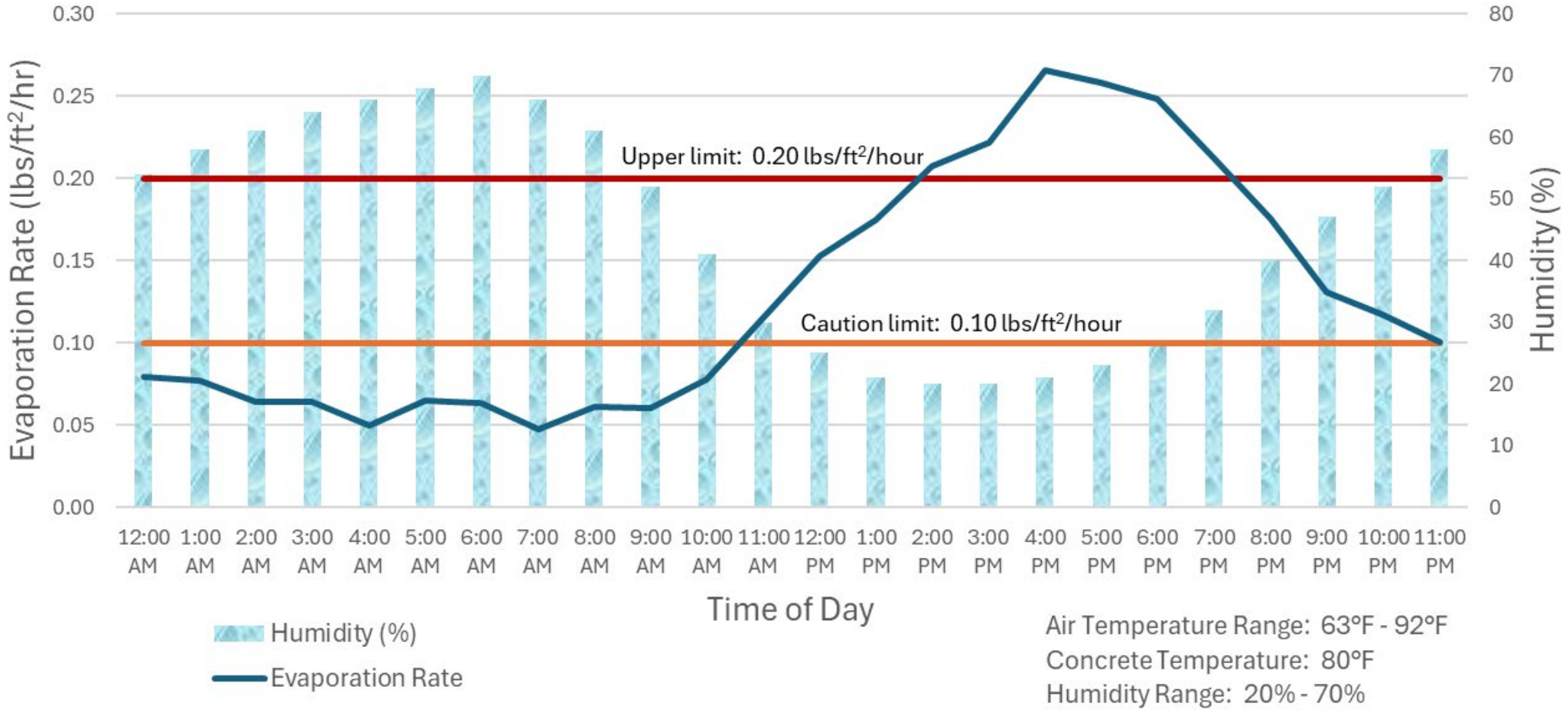
http://apps.acpa.org/applibrary/EvaporationRate/

Evaporation Rates

Properties Measured

- Air Flow
- Heat Index
- Wind Chill
- Barometric Pressure
- Altitude
- Relative Air Density
- Density Altitude
- Air Density
- Dew Point
- Evaporation Rate
- Moisture Content | Humidity Ratio (Grains)
- And more

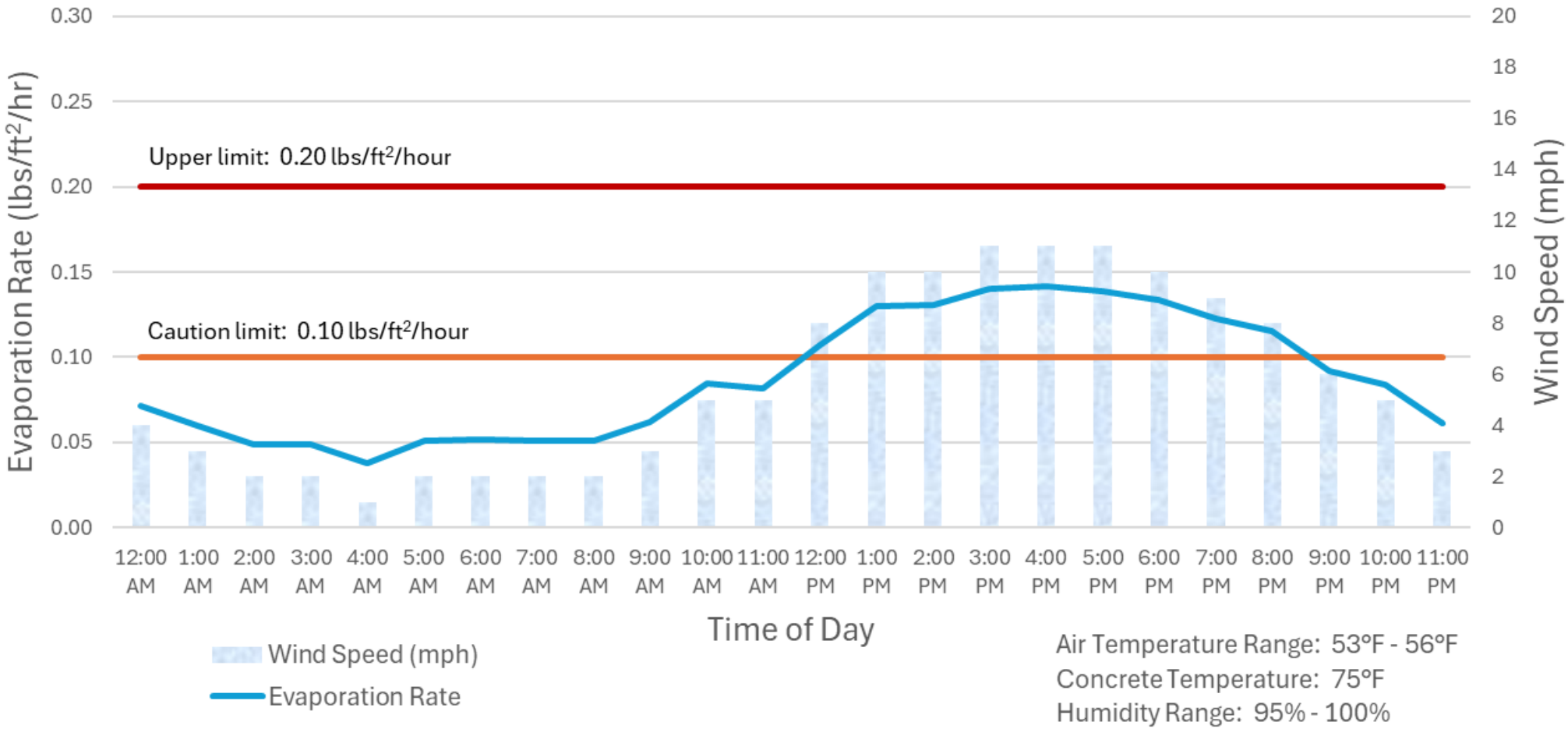
Impact of Humidity on Evaporation Rates



Evaporation rate calculations based on ACI equations and weather forecast for Riverside, CA on July 1, 2025

Slide Credit: Angela Folkestad, Axios Civil Solutions

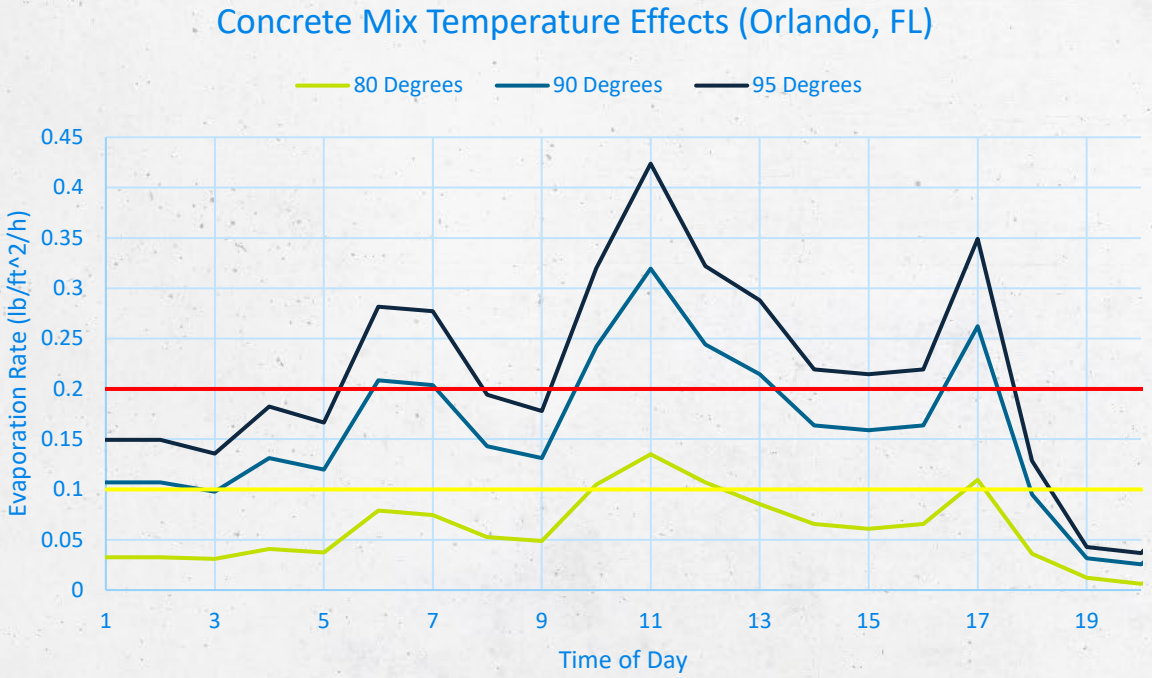
Impact of Wind Speed on Evaporation Rates in Humid Weather



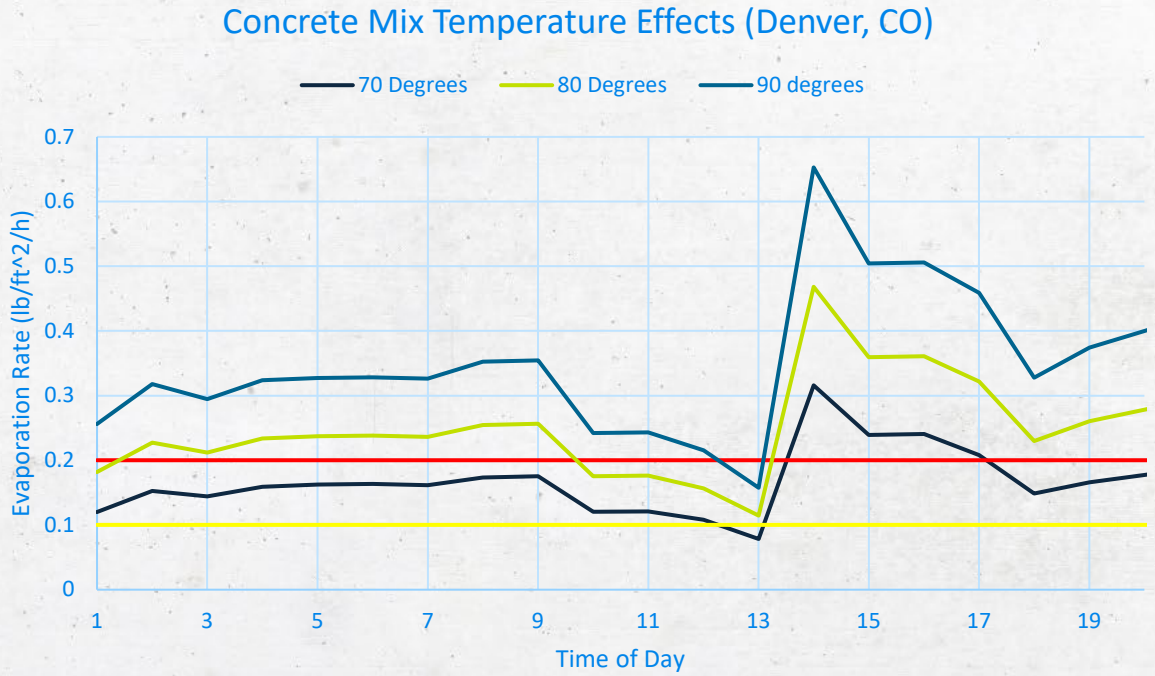
Evaporation rate calculations based on ACI equations and weather forecast for Eureka, CA on July 1, 2025

Slide Credit: Angela Folkestad, Axios Civil Solutions

Understanding your climate on an average summer day



Ambient Temperature: 75-90
Relative Humidity: 55%-85%
Wind: 0-17 mph



Upper Limit- .2 lb/ft^2/h

Caution Limit- .1 lb/ft^2/h

Ambient Temperature: 65-97
Relative Humidity: 6%-26%
Wind: 3-21 mph

ACPA

Best Practices

- Curing
  - Essential for sufficient hydration
  - Curing compounds
    - Quality matters
  - When bleed ends??
  - Enough
    - Two layers > one
    - Allow for roughness of surface

Quality Considerations with Curing

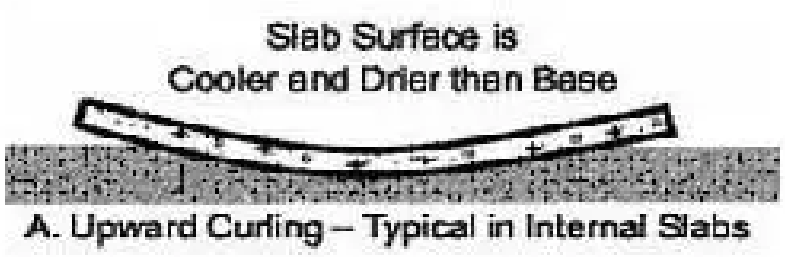
- Curing helps a concrete pavement develop its final properties evenly
  - Top
  - Middle
  - Bottom
- Differences in shrinkage, strength or other concrete properties can lead to slab curling, warping and roughness

Images Source: ACPA


Tining?
Why?
Is it delaying when you apply your cure?

Curling & Warping

- Wet the subgrade
- Cure quickly and thoroughly
- White as a sheet of paper



Precautions- Green Sawing

- Early Entry Saws
- Skip joints if necessary
  - Cut every 3rd or 4th until caught up and then fall back
- Extra saws onsite

Weather Considerations

- Hot weather concreting
  - Hydration is faster
  - Evening cold fronts can set up thermal stresses - need cover?

Thank You

Matt Fonte

303-478-1529

matt@fonteandco.com

www.fonteandco.com

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Sarah Dalton, P.E.

303-718-7297

sdalton@acpa.org

www.acpa.org

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