ATLANTIC TESTING LABORATORIES

Hot Weather Concreting

ACI 305R

ACI 305.1

CNY Engineering Expo
November 11, 2013

Topics of Discussion

- 5 Essentials of Quality Concrete
- Hot Weather – Defined by ACI
- Potential Problems in Hot Weather
- Mitigation Procedures
- Considerations During and After Placement
- Specification for Hot Weather Concreting (ACI 305.1-06)

Concrete – The Bread of the Construction Industry

5 Essentials of Quality Concrete

- Suitable Materials
- Proportioning, Mixing, and Transportation
- Placement and Consolidation
- Finishing and Jointing
- Curing

Hot Weather Concreting – Defined by ACI 305R

- High ambient temperatures
- High concrete temperatures
- Low relative humidity
- High wind speed
- Solar radiation

- Any combination that will impair the quality of the concrete due to accelerated moisture loss or cement hydration

Evaluation Question

Q. How does ACI 305 define Hot Weather?

A. Any combination of the following:

i. High ambient temperatures
ii. High concrete temperatures
iii. Low relative humidity
iv. Wind speed
v. Solar radiation

Potential Problems in Hot Weather – Fresh/Plastic State

- Increased slump loss and water demand
- Increased rate of setting
- Plastic shrinkage cracking
- Difficulty controlling entrained air content

Potential Problems in Hot Weather – Fresh/Plastic State (Cont’d)

- Set Time vs. Air Temperature
  - Approximately 30% decrease in set time for every 10°F increase in temperature

Temperature		Approximate Set Time (For a sample mix)
Degrees F	Degrees C	Hours
100	37.8	1 2/3
90	32.2	2 2/3
80	26.7	4
70	21.1	6
60	15.6	8
50	10.0	10 2/3
40	4.4	14 2/3

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Evaluation Question

Q. True or False: Air content is easier to control in hot weather?

A. False

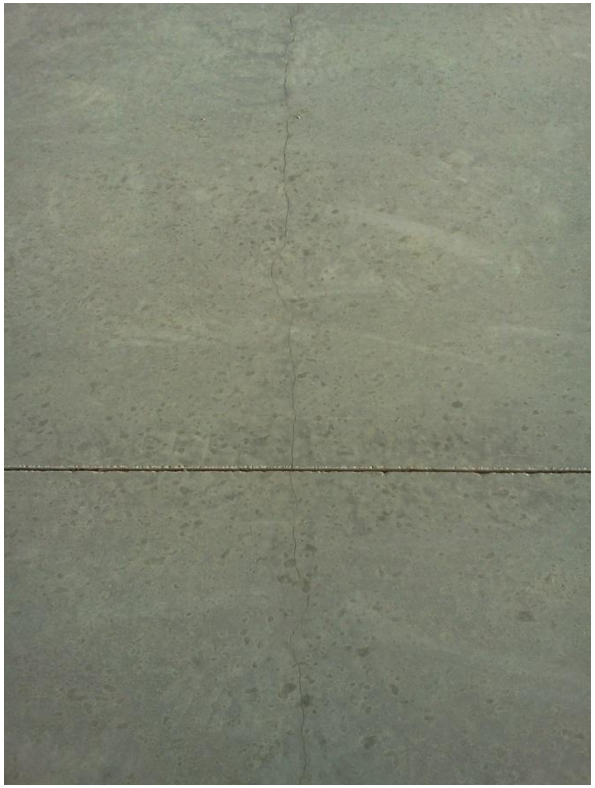
Potential Problems in Hot Weather – Fresh/Plastic State (Cont'd)

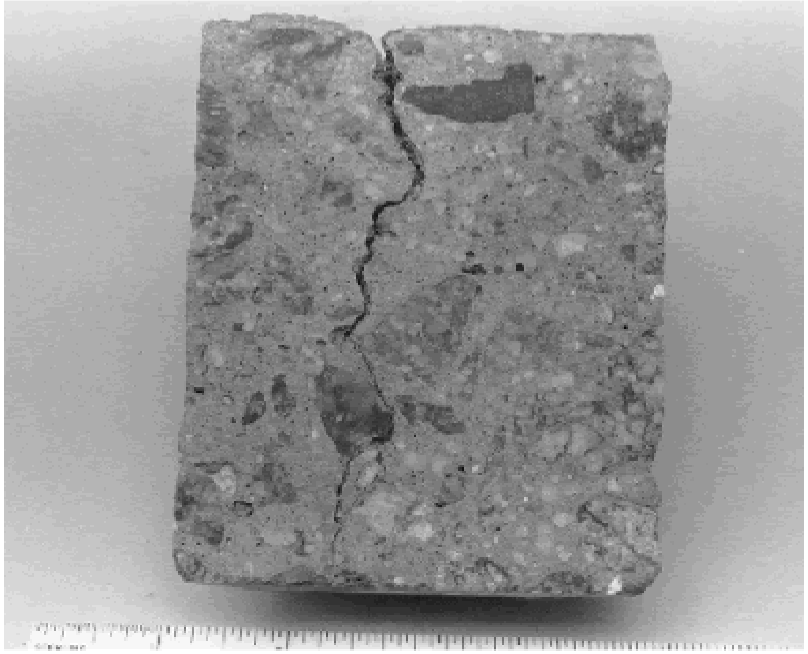
- Plastic Shrinkage Cracks
  - Occurs when rate of evaporation exceeds the rate of bleeding
  - Typically shallow, but could be considerably deep (>0.5T)
  - Parallel oriented, closely spaced (approx. 1'-3')
  - Could significantly reduce durability

Plastic Shrinkage Cracks

Picture from TxDoT

Plastic Shrinkage Cracks





Plastic Shrinkage Cracks

TxDoT

Evaluation Question

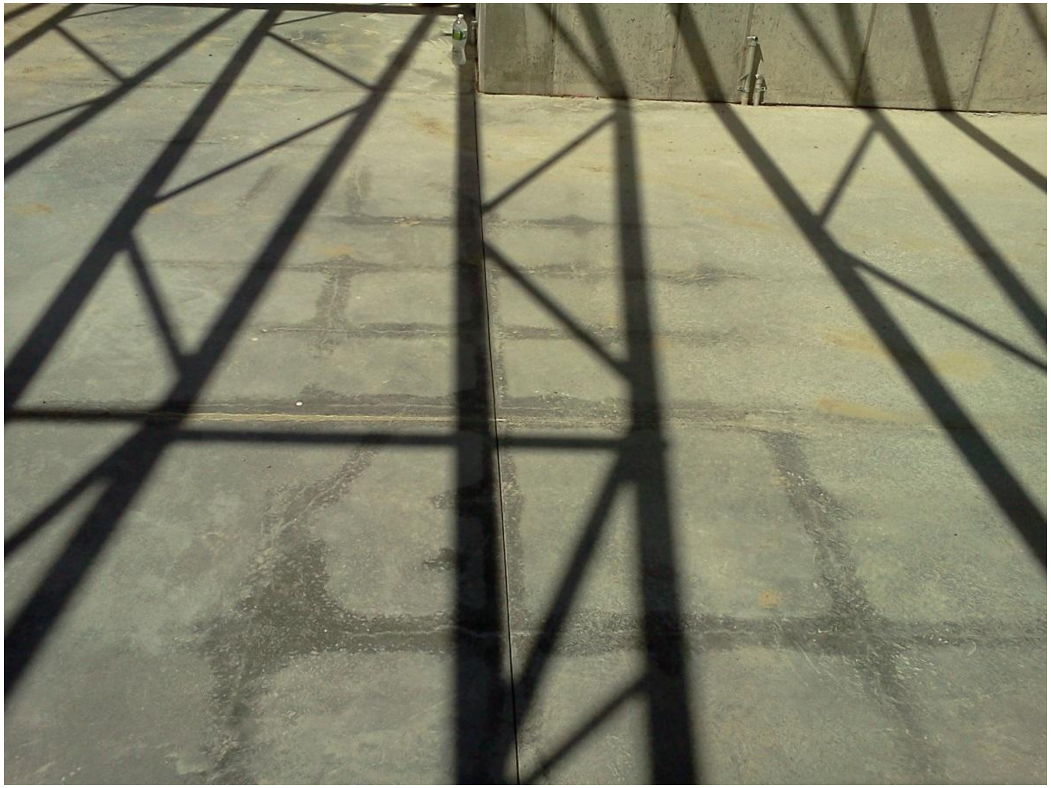
Q. Why do plastic shrinkage cracks occur?

A. The rate of evaporation exceeds the rate of bleeding – the volume of the concrete changes

Potential Problems in Hot Weather – Hardened State

- Increased tendency for drying shrinkage
- Decreased durability from cracking
  - Increased permeability
  - Increased potential for corrosion of reinforcing steel
- Variability in surface appearance – color variations or cold joints
- Decreased 28-day compressive strength

Drying Shrinkage Cracks and Color Changes



Common Practices for Mitigation

- Cool the concrete and subgrade
- Proper concrete consistency for rapid placement and effective consolidation (use admixtures, not water)
- Minimize time to transport, place, and finish
- Proper planning!

Controlling Concrete Temperatures During Production

- Protect the ingredients from sunlight
- Cool the ingredients – Water, cement, coarse and fine aggregates
- Cooling can be achieved with water, ice ($), or nitrogen ($$)
- Cooling the aggregates will have the greatest effect
  - Cooling the coarse aggregate by 2° F will cool the concrete by approximately 1° F

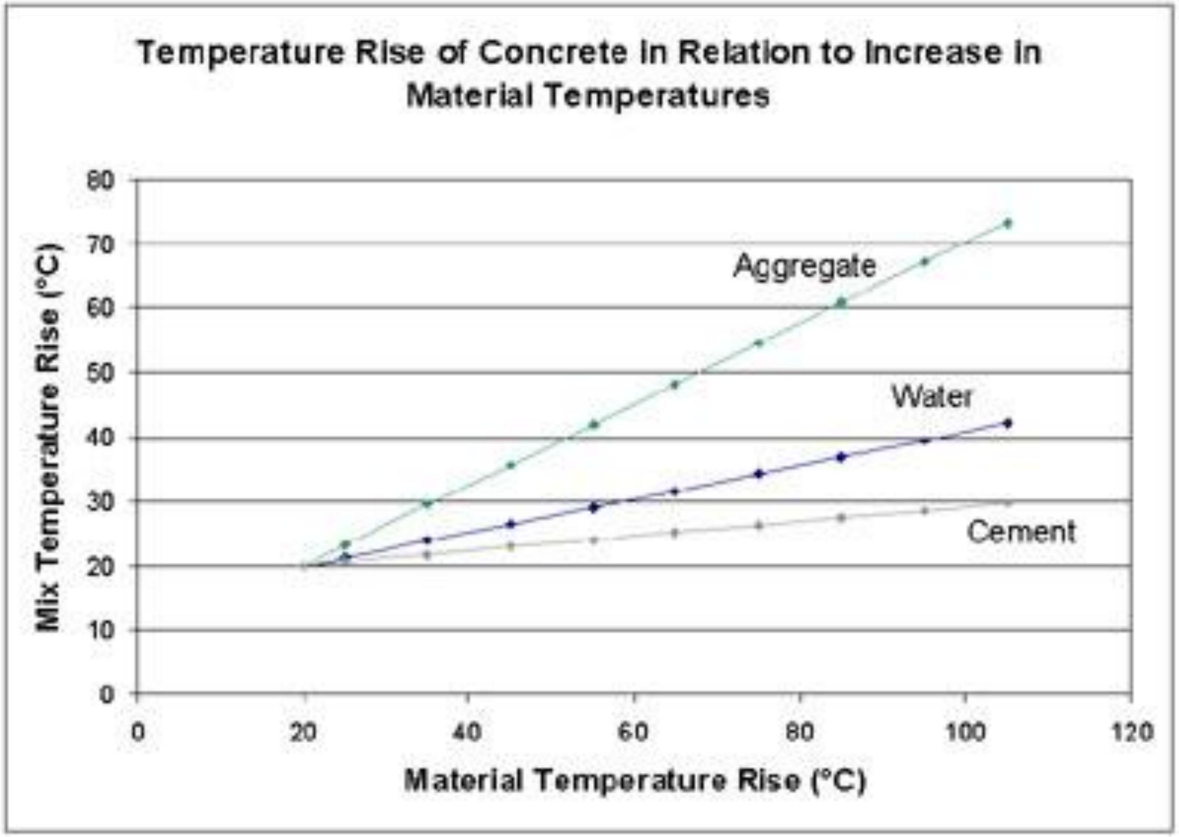
Cooling with Liquid Nitrogen (LN)

- Inert gas – Does not react chemically
- Relatively safe if used properly

Cooling with Ice - Flaked

- Increased Surface Area
- Decreased mixing time
- Calculations are relatively simple

Material Temperatures and Concrete Temperature



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Estimating Concrete Temperature (Appendix A – ACI 305R)

- Without Ice, T=

$$\frac{0.22(T_aW_a+T_cW_c)+T_wW_w+T_aW_{wa}}{0.22(W_a+W_c)+W_w+W_{wa}}$$

- With Ice, T=:

$$\frac{0.22(T_aW_a+T_cW_c)+T_wW_w+T_aW_{wa}-\mathbf{112}\boldsymbol{W_i}}{0.22(W_a+W_c)+W_w+W_{wa}+\boldsymbol{W_i}}$$

Evaluation Question

Q. Prior to and during production, what has the greatest effect in cooling concrete?

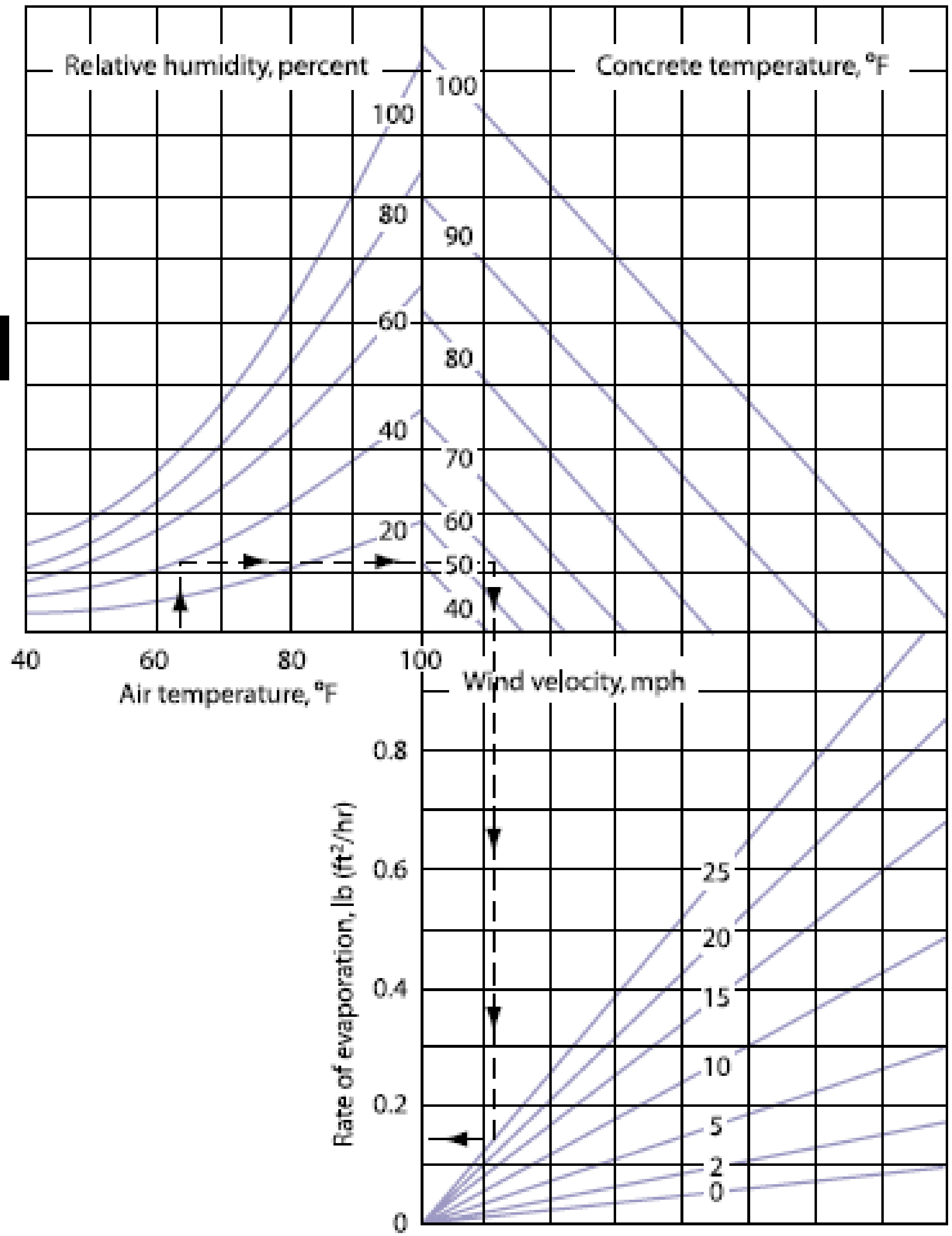
A. Cooling the aggregates, especially coarse aggregates (approximately 2:1 ratio)

Considerations During Placement

- Planning and preparation – equipment, people, water, etc.
- Time of day, or season
- Project schedule
- Formed surfaces vs. flatwork
- Weather – Wind, humidity, temperature, etc.

ACI 305R-99 Figure 2.1.5

Use Figure 2.1.5 if project specifications have limits on evaporation rates during placement (i.e. ACI 305.1)

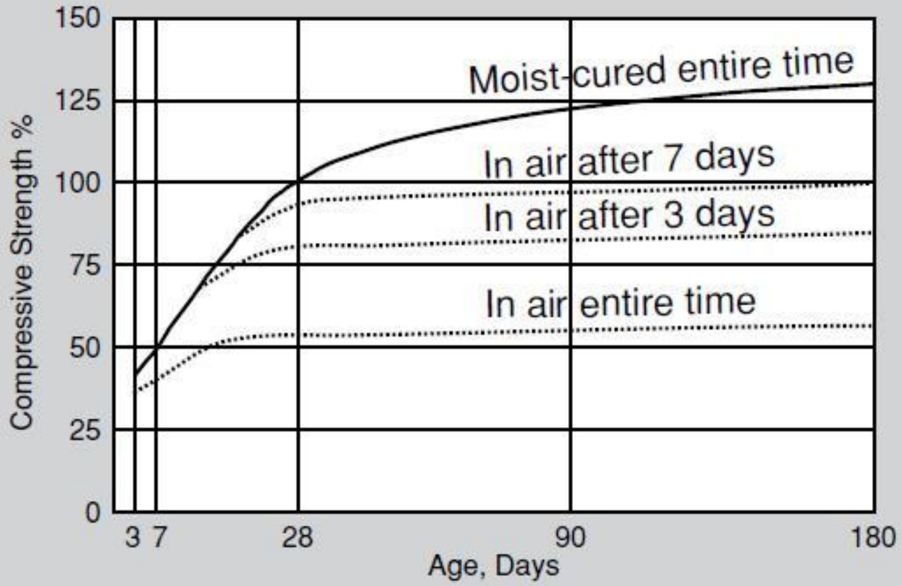


Considerations for Curing and Protection

- Concrete must be protected from moisture loss – high temperatures, direct sunlight, low humidity, high winds
- Keep exposed surfaces from drying for 7 days – moist or membrane curing (ACI 305)
- Formed surface should be loosened so curing water can be applied
- Avoid rapid heat loss/gain: 5 °F/hr. or 50 °F/24 hrs. (ACI 305)

Curing and Protection

Figure 5
Effect of Curing on
Compressive Strength of Concrete



Source: PCA, "Design and Control of Concrete Mixtures"

Curing and Protection

Evaluation Question

Q. ACI 305 recommends that concrete curing procedures continue for at least how many days?

A. 7 days. Exposed surfaces should be kept from drying, by either moist or membrane curing methods.

Testing Considerations

- Sample and test in accordance with applicable ASTM standards, perhaps more frequently
- Avoid moisture loss in composite sample used for testing
- Avoid moisture loss in strength specimens
- Maintain proper curing temperatures for strength specimens (60°F – 80°F, <6000 psi)
  - To properly evaluate, must be properly cured

Hot Weather Inspections

- Carefully read and understand project specifications
- Frequently document air and concrete temperatures, humidity, wind, evaporation rate, etc.
- Document all the test results
- Document placement and curing procedures
- Notes should be part of the permanent project records

Specification for Hot Weather Concreting (ACI 305.1-xx)

- Incorporated by reference in the Project Specifications
  - "Work on (Project Title) shall conform to all requirements of ACI 305.1-xx, Specification for Hot Weather Concreting, published by the American Concrete Institute, Farmington Hills, MI, except as modified by these documents."

Specification for Hot Weather Concreting (ACI 305.1-xx)

- Recommended to be used in entirety, not "cut and paste" as desired
- Written in the three-part section format of the Construction Specification Institute (CSI)
  - Section 1 – General
  - Section 2 – Products
  - Section 3 - Execution

Summary

- Avoid accelerated moisture loss
- Design mixes for workability and placement
- Control concrete temperatures, if possible
- Test and inspect in accordance with contract documents and specifications
- Plan for hot weather!

Question & Answer