Hot Weather Concreting in Ohio Effects, Mixture & Placement Adjustments, and Tips

This webinar will start soon!

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Use the Question box

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How Weather Concreting in Ohio

Disclaimer

This is not a complete analysis of every material fact regarding hot weather concreting. This information contained herein is provided for use by personnel who are competent to evaluate the significance and limitations of the information provided and who will accept total responsibility for the application of this information. Others should obtain the assistance from a qualified professional before proceeding. The opinions expressed herein reflect the judgement of Ohio Concrete at this date and are subject to change. The information has been obtained from sources Ohio Concrete considers to be reliable, but we cannot guarantee that it is accurate or complete.

Overview – Hot Weather Concrete

- Impacts for the R/M Producer, Contractor, and Inspector
  - ACI Definition - when to take precautions
  - Effects of High Temperatures on Concrete
  - Cooling Concrete Methods & Mix Design Adjustments
  - Project Planning and Best Practices
  - Finishing Problems
  - Plastic Shrinkage Cracking & Drying Shrinkage Cracks
  - Curing and Protection
  - Reduced Concrete Strengths
  - Testing Procedures

Ohio Concrete – Technical Tips Series

- Technical Tips #10 – Hot Weather Concreting

  - **Contractors**: Preventing plastic shrinkage cracks and surface defects
  - **Producers**: What can be done at the batch plant to alleviate hot weather conditions
  - **Testers**: What procedures should technicians follow to properly perform tests

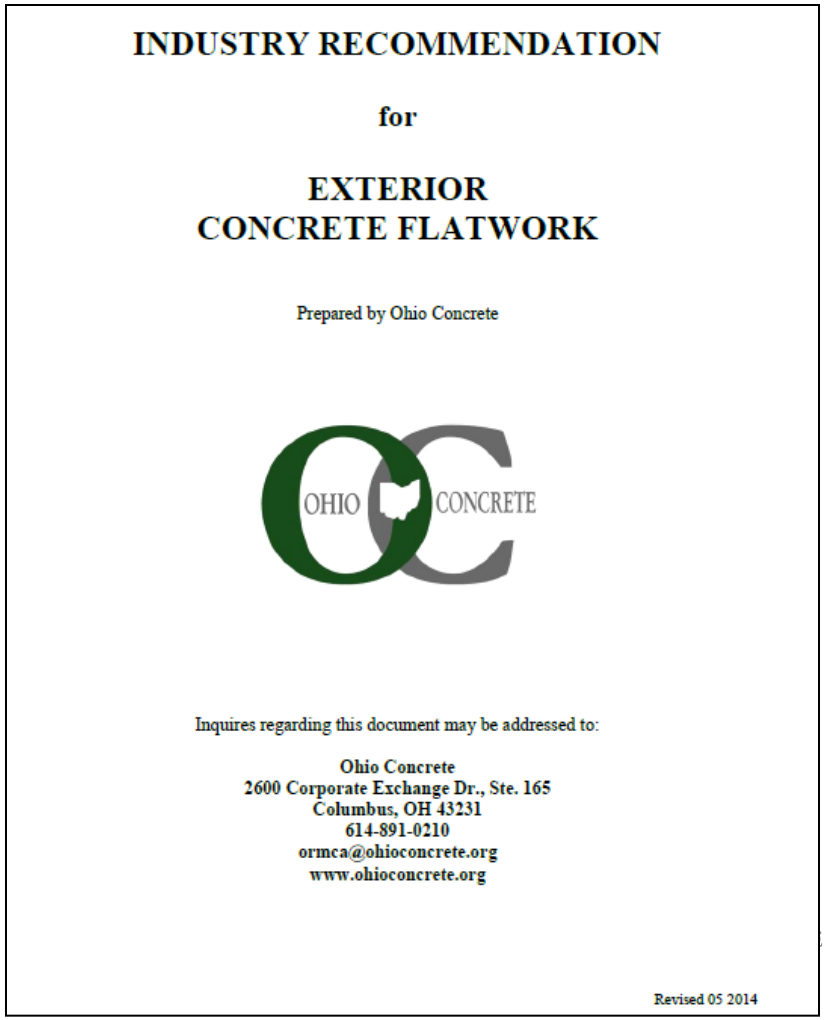
Ohio Concrete Resources – www.ohioconcrete.org

- Industry Recommendation for Exterior Concrete Flatwork

https://www.ohioconcrete.org/wp-content/uploads/2015/06/Industry-Recommendation-for-Exterior-Flatwork-Final.pdf (Free Download)

Sections On:

- Materials – Concrete Mix Design
- Consolidating and Finishing
- Jointing
- Curing
- Placing Concrete and Curing During Hot Weather



INDUSTRY RECOMMENDATION

for

EXTERIOR CONCRETE FLATWORK

Prepared by Ohio Concrete

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Specifications

CONSTRUCTION SPECIFICATION CVE-17020-CS021
CAST-IN-PLACE REINFORCED CONCRETE

1.0 SCOPE

1.1 This specification covers the requirements for cast-in-place reinforced concrete, including materials, formwork, placement of reinforcing steel and embeds, and curing.

1.2 In case of conflicting requirements between this specification and any of the referenced codes, the more stringent requirement will govern. All referenced codes shall be latest edition.

2.0 CODES AND STANDARDS

2.1 Ohio Building Code 2017

2.2 International Building Code - IBC 2015

2.3 All relevant local codes

2.4 OSHA – General Standards for Construction

2.5 ACI – American Concrete Institute

2.6 ASTM – American Society for Testing and Materials

3.0 GENERAL REQUIREMENTS

3.1 All materials and workmanship shall conform to the requirements of ACI 301 "Specifications for Structural Concrete," and to ACI 318, "Building Code Requirements for Reinforced Concrete"

3.2 All work related to concrete placement shall be closely coordinated with the other construction work. Contractor shall verify that all embedments are correctly placed before concrete is placed.

3.3 If concrete is to be placed during cold weather conditions, Contractor shall follow the guidelines of ACI 306R-88, "Cold Weather Concreting."

3.4 If concrete is to be placed during hot weather conditions, Contractor shall follow the guidelines in ACI 305R-99, "Hot Weather Concreting." Combined effects of temperature, wind speed, and relative humidity shall be considered in determining the need for additional protection of the fresh concrete.

4.0 MATERIALS

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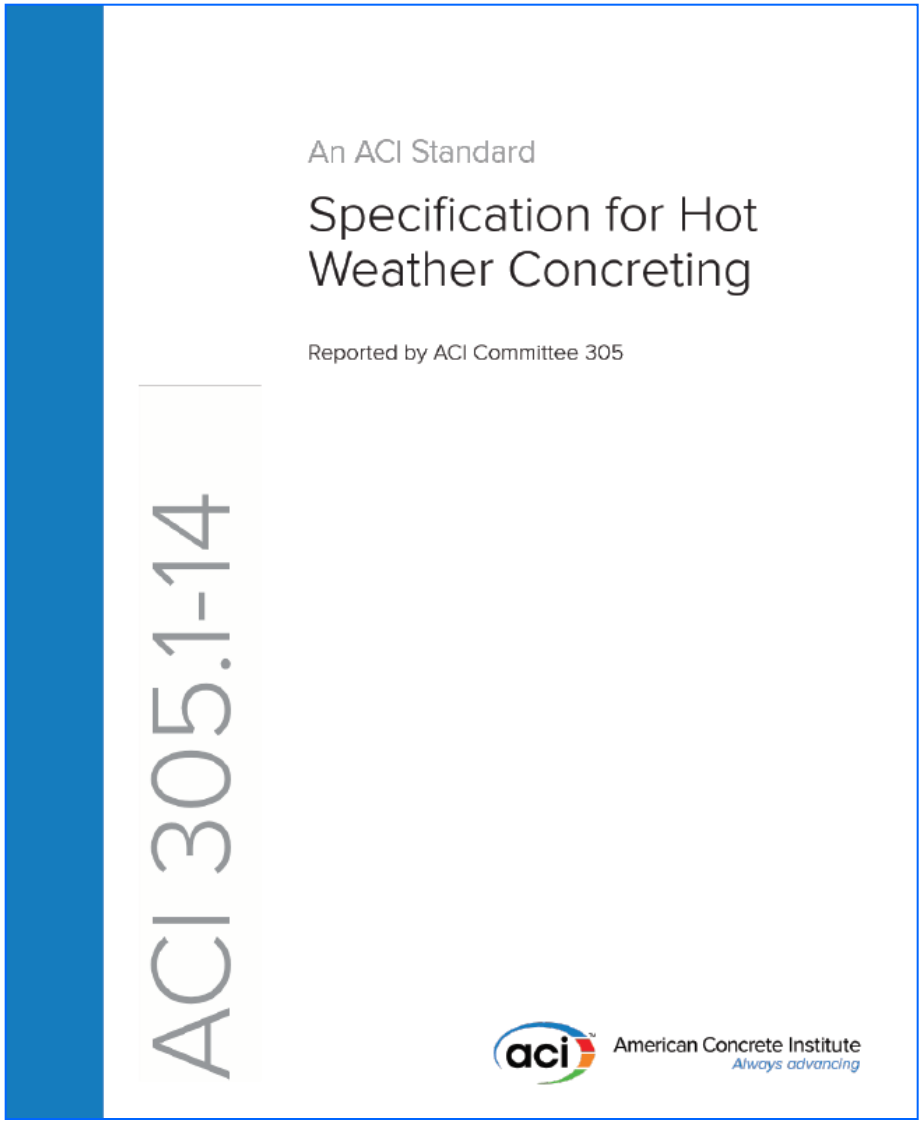
ACI 305.1-14 Specification for Hot Weather Concreting



SECTION 1 – GENERAL

SECTION 3 - EXECUTION

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ACI 305.1-14 Section 1 - General

Definition

- Conditions that tends to impair the quality of freshly mixed concrete or hardened concrete by accelerating the rate of moisture loss and rate of cement hydration.

- Or conditions that cause detrimental results:
  - high ambient temperature
  - high concrete temperature
  - low relative humidity
  - high wind speed
  - solar radiation

ACI 305.1-14 Section 3 - Execution

- **Prepare** (pre-dampen) surfaces on which concrete is placed to minimize absorption of water from the fresh concrete.

- **Prevent** rapid evaporation from the fresh concrete surface
  - Monitor site conditions, including air-temperature, relative humidity, and wind speed to assess need for evaporative control measures beginning 1 hour before beginning concrete placement operations until accepted curing procedures have been applied.
  - Measure air relative humidity at a level approximately 4 – 6 ft above the evaporating surface
  - Measure the air-temperature surrounding the concrete at a level 4 – 6 above evaporating surface
  - Measure the average wind speed at 20 inches above the evaporating surface

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ACI 305.1-14 Section 3 - Execution

Maximum Temperature of Fresh Concrete

- At time of placement shall be 95°F
- The request for a maximum concrete temperature that exceeds 95°F shall be submitted to the A/E prior to concrete placement.
  - Acceptance of a proposed maximum fresh concrete temperature that exceeds 95°F , supported by preconstruction testing,
  - Laboratory trial batch or Field trial batch

ACI 305.1-14 Concrete Production and Delivery

3.4 Production methods to reduce the concrete temperature

- Shading the aggregate stockpiles
- Sprinkling water on the coarse aggregate stockpiles
- Using chilled water for concrete production
- Substituting chipped or shaved ice for portions of the batch water
- Cooling concrete using liquid nitrogen

3.6 Concrete Bleed Water Evaporation

- Control concrete surface bleed water evaporation by using materials and methods in ACI 308.1 - Guide to External Curing of Concrete

3.7 & 3.8 Concrete Curing and Protection

- Cure concrete test specimens in accordance with requirements in ASTM C31 for acceptance testing
- Protect the concrete surface from decreases in concrete temperature > 40°F during the 24–hour period following placement.
- Timing removal of protective measures in such a way as to avoid rapid decrease in concrete surface temperatures that result in thermal shrinkage cracks

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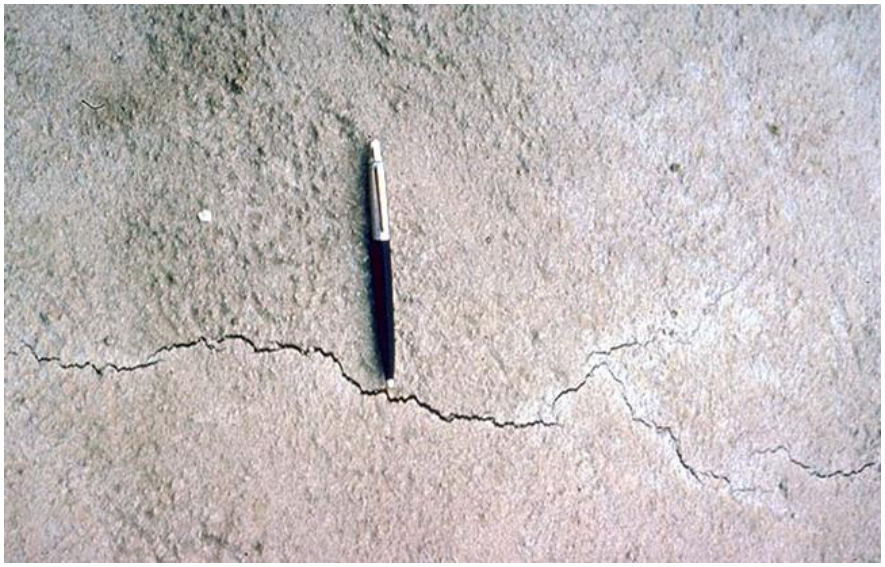
ACI 305.1-14 Appendix - Evaporation of Surface Moisture



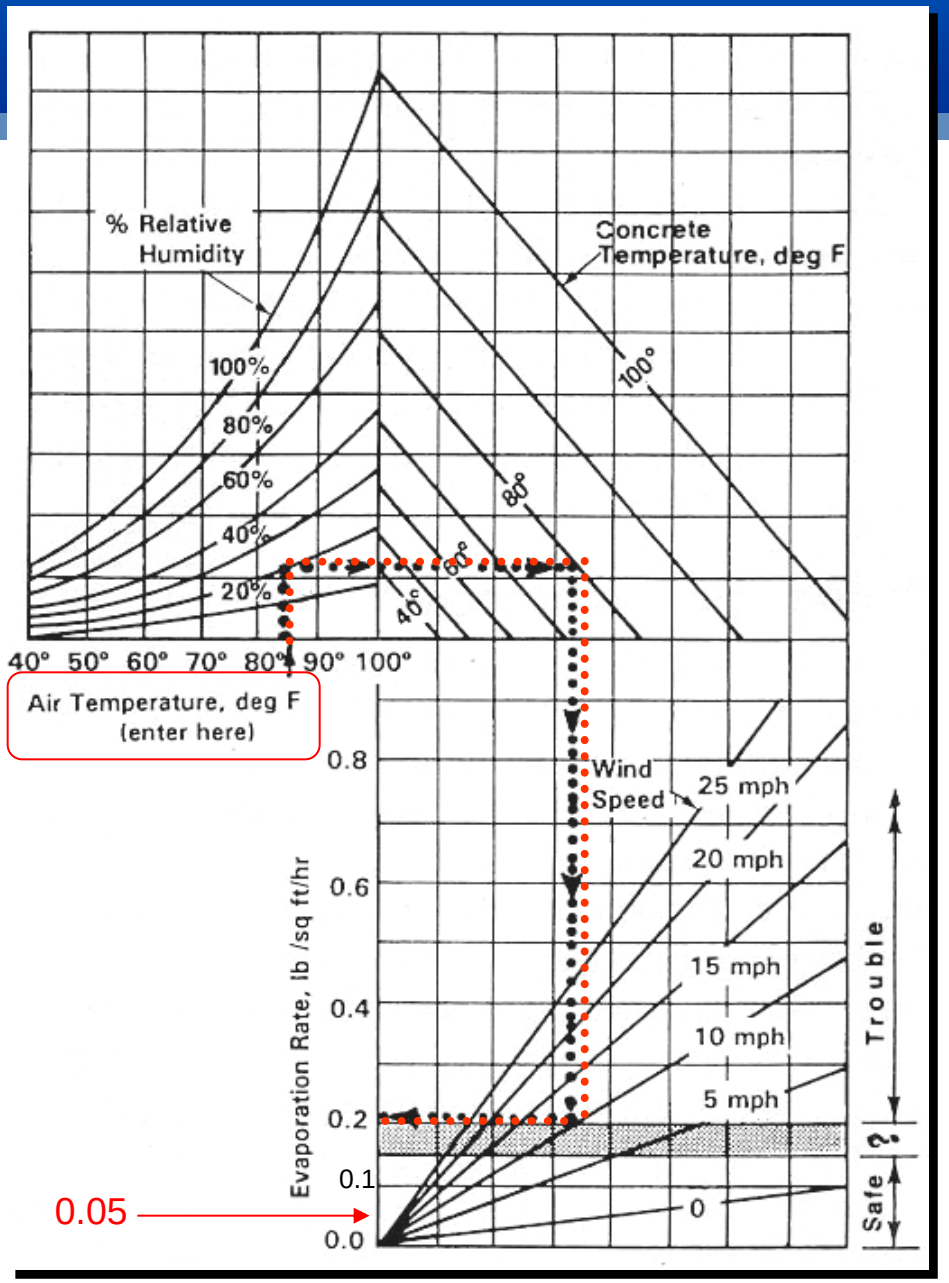
when the evaporation exceeds

0.2 lbs of water per SF/hr

Or 0.1 lbs for bridge decks and special mixtures

plastic shrinkage cracking

may occur



Evaporation Rate Handheld Device

Relative Humidity, r of air surrounding the concrete is measured at a level 4 to 6 ft above the slab

Temperature, Ta of the air surrounding the concrete in °F measured at a level 4 to 6 ft above the slab

V Average wind speed in mph, measured 20 in. above the slab

Tc temperature of the of the slab surface taken as the concrete temperature in °F

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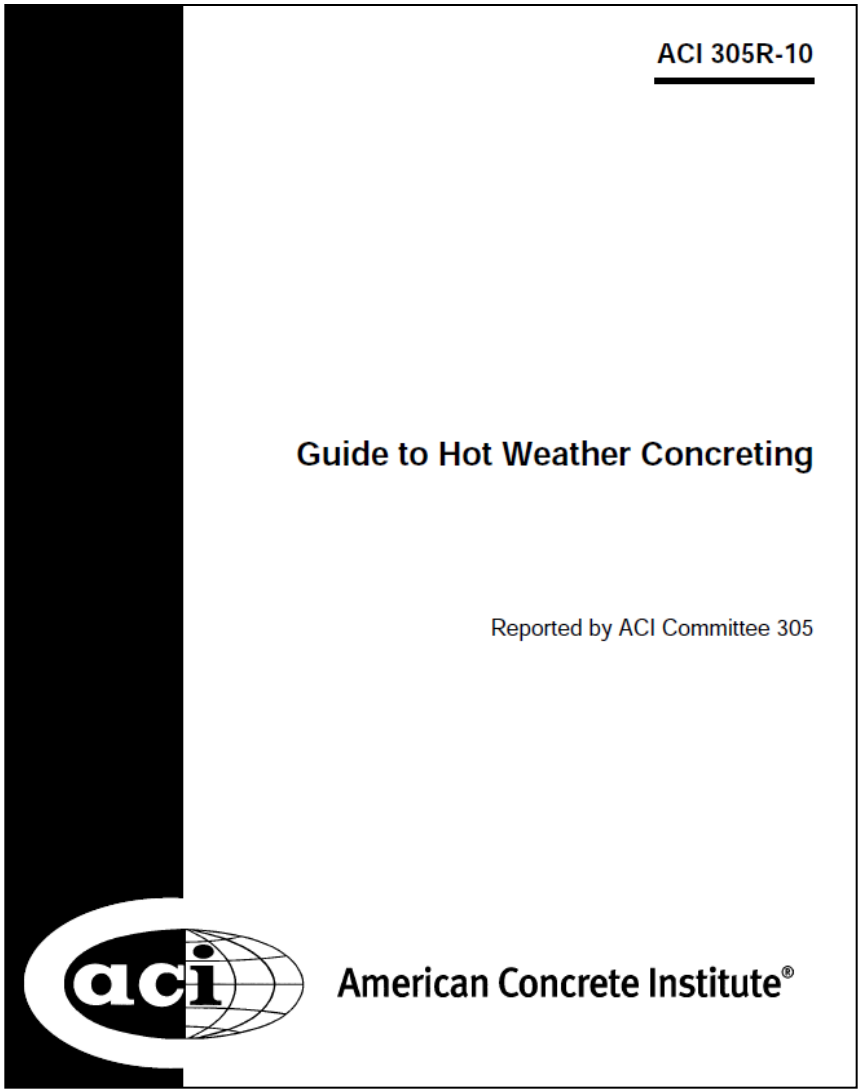
ACI 305R-10 Guide to Hot Weather Concreting



CH3 Potential problems and practices

CH4 Effects of hot weather on concrete properties

CH5 Production and Delivery

CH6 Placing and curing

CH7 Testing and inspection

Appendix – Methods for cooling fresh concrete

ACI 305R

CH 3 Potential Problems in Hot Weather

Fresh Concrete

- Increased water demand
- Increased rate of slump loss – creates tendency to add water on site
- Increased rate of setting – results in difficulty placing, finishing, and likelihood of cold joints
- Increased tendency for plastic shrinkage and thermal cracks
- Difficulty in controlling entrained air-content
- Reduced abrasion resistance

Hardened Concrete

- Decreased strength and durability resulting from adding water
- Increased permeability
- Increased tendency for drying shrinkage and differential thermal cracking
- Decreased durability from cracking
- Variable surface appearance - cold joints, color differences

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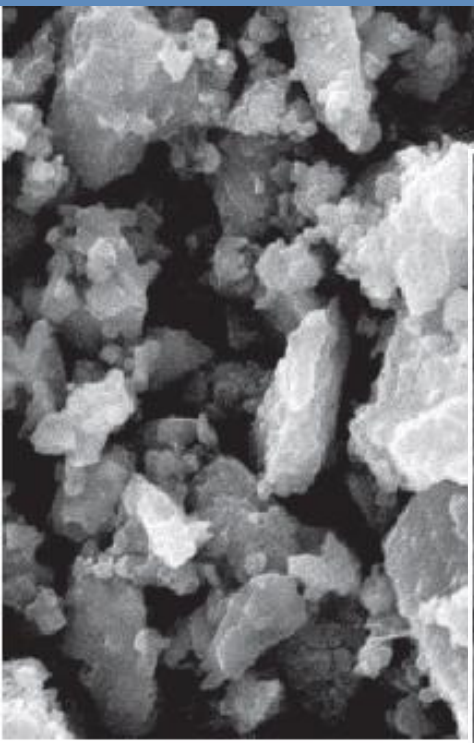
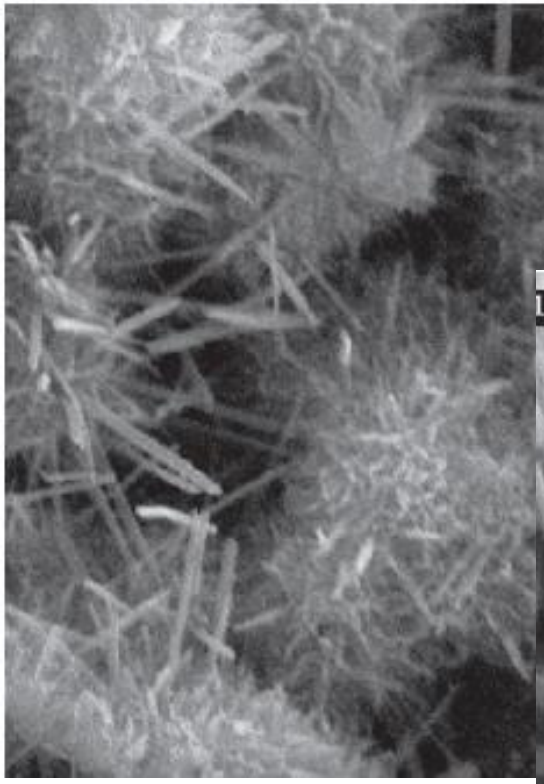
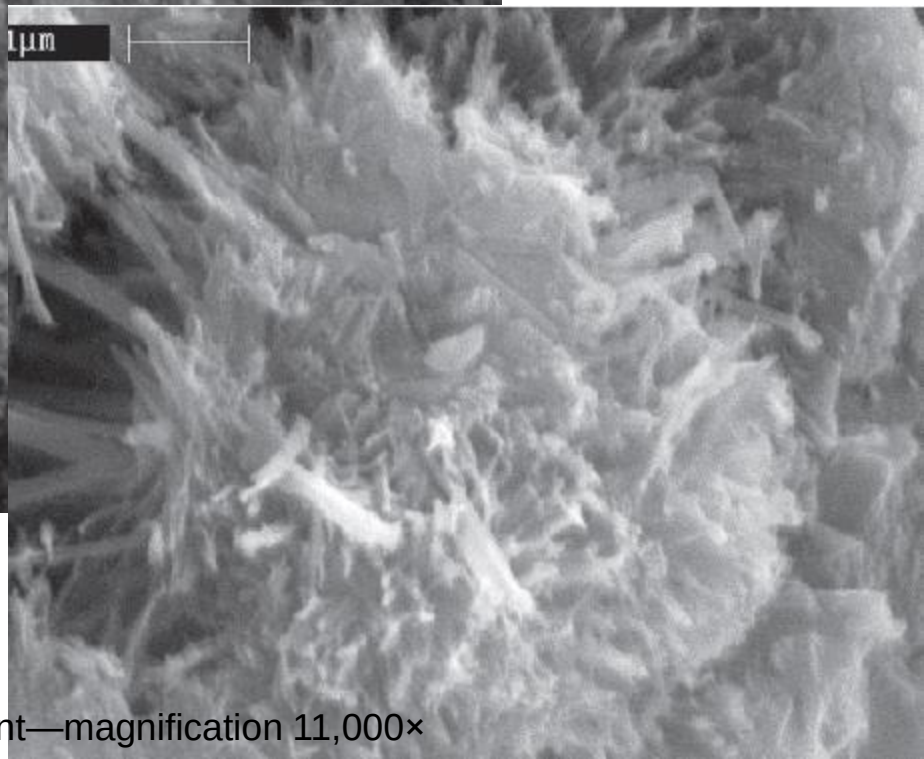
Hydration Reaction of cement particles



1-Particles of unhydrated p
through a scanning electron

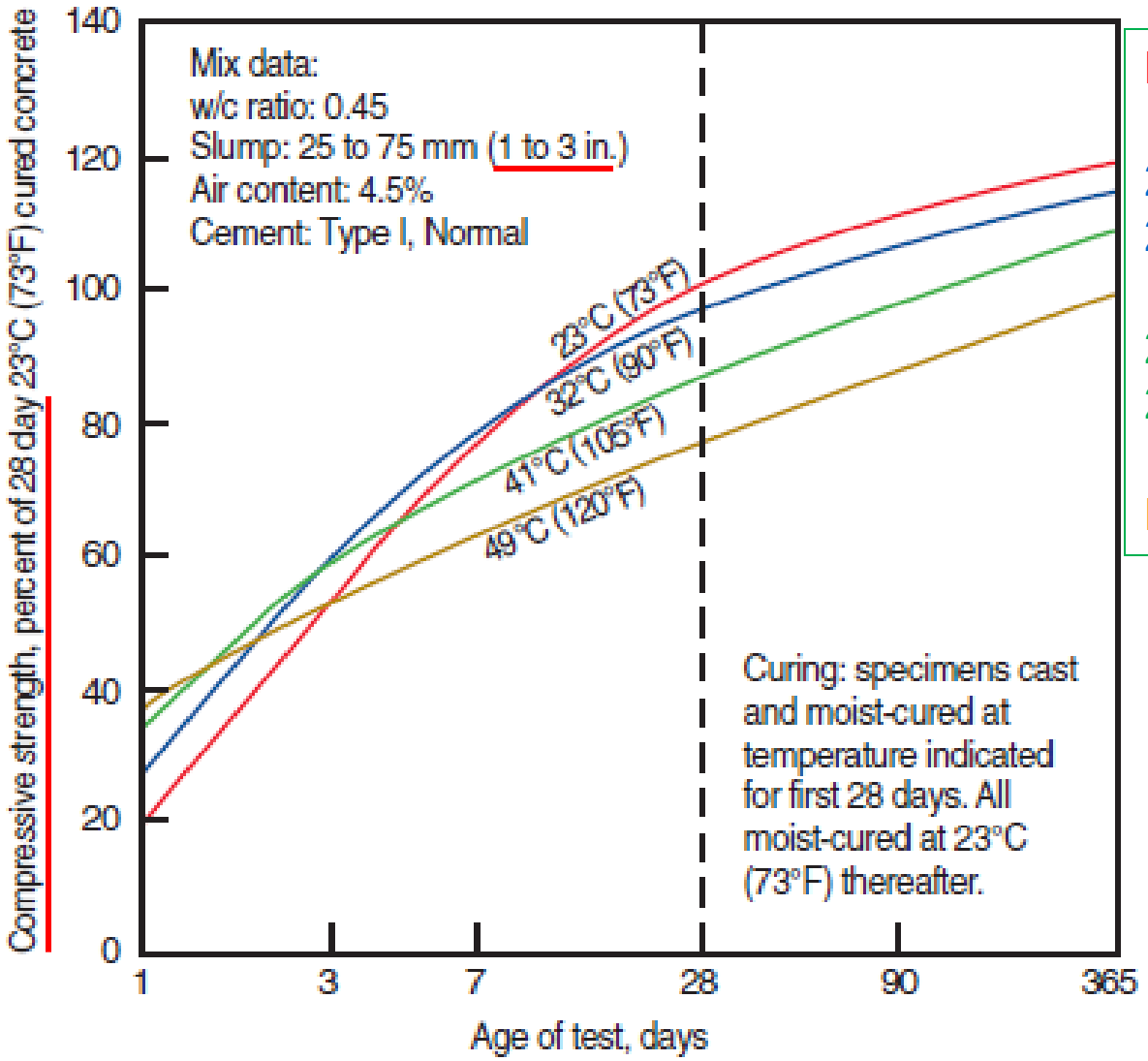


2-Partially hydrated cement.



3-Single particle of hydrated cement—magnification 11,000×

Effects of High Temperature on Strength



Lowest 1 day & highest 28 day

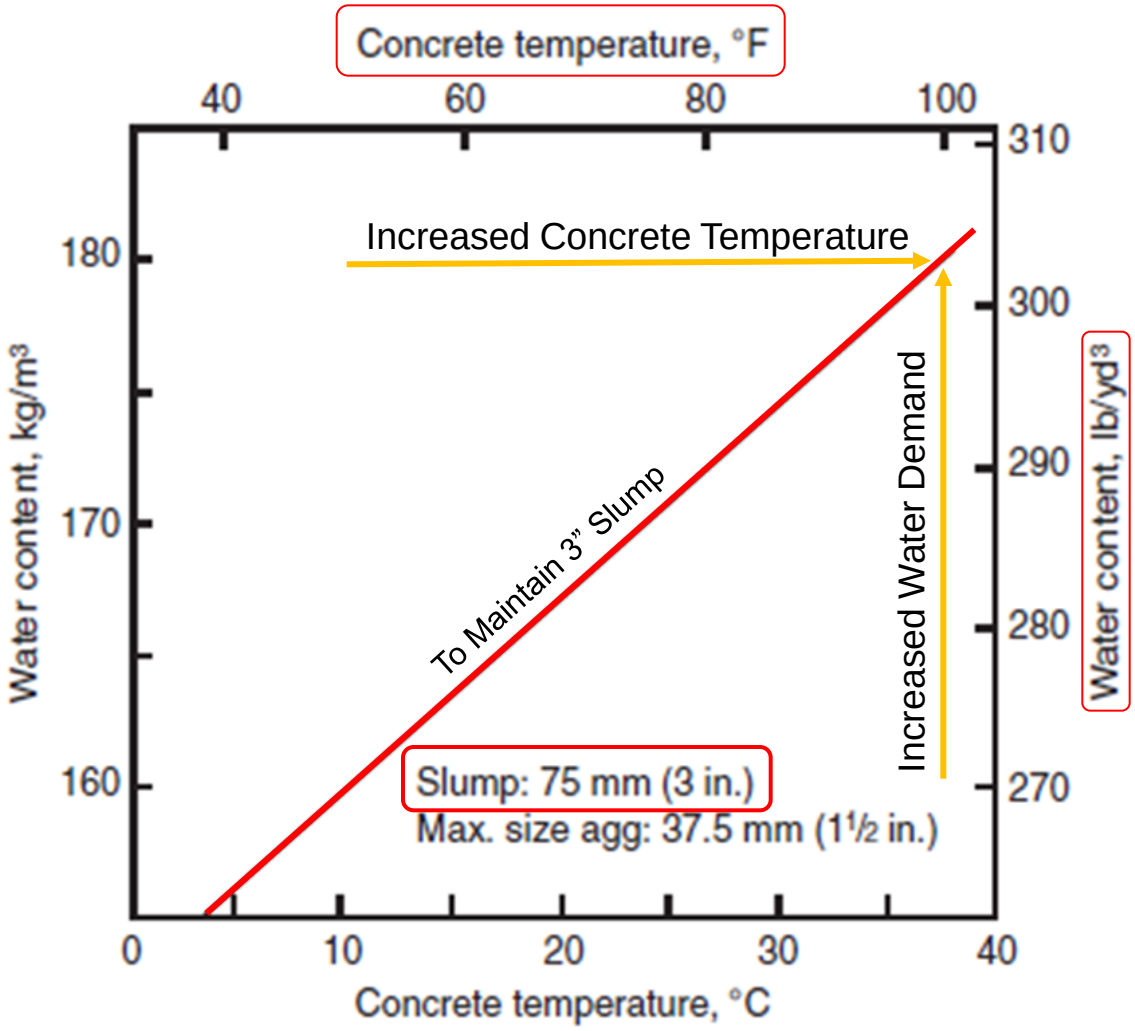
2nd lowest 1 day & 2nd highest 28 day

2nd highest 1 day & 3rd highest 28 day

Highest 1 day & lowest 28 day

Ref. PCA Fig. 16-4

Hot Weather Concreting – Effect of High Temperature



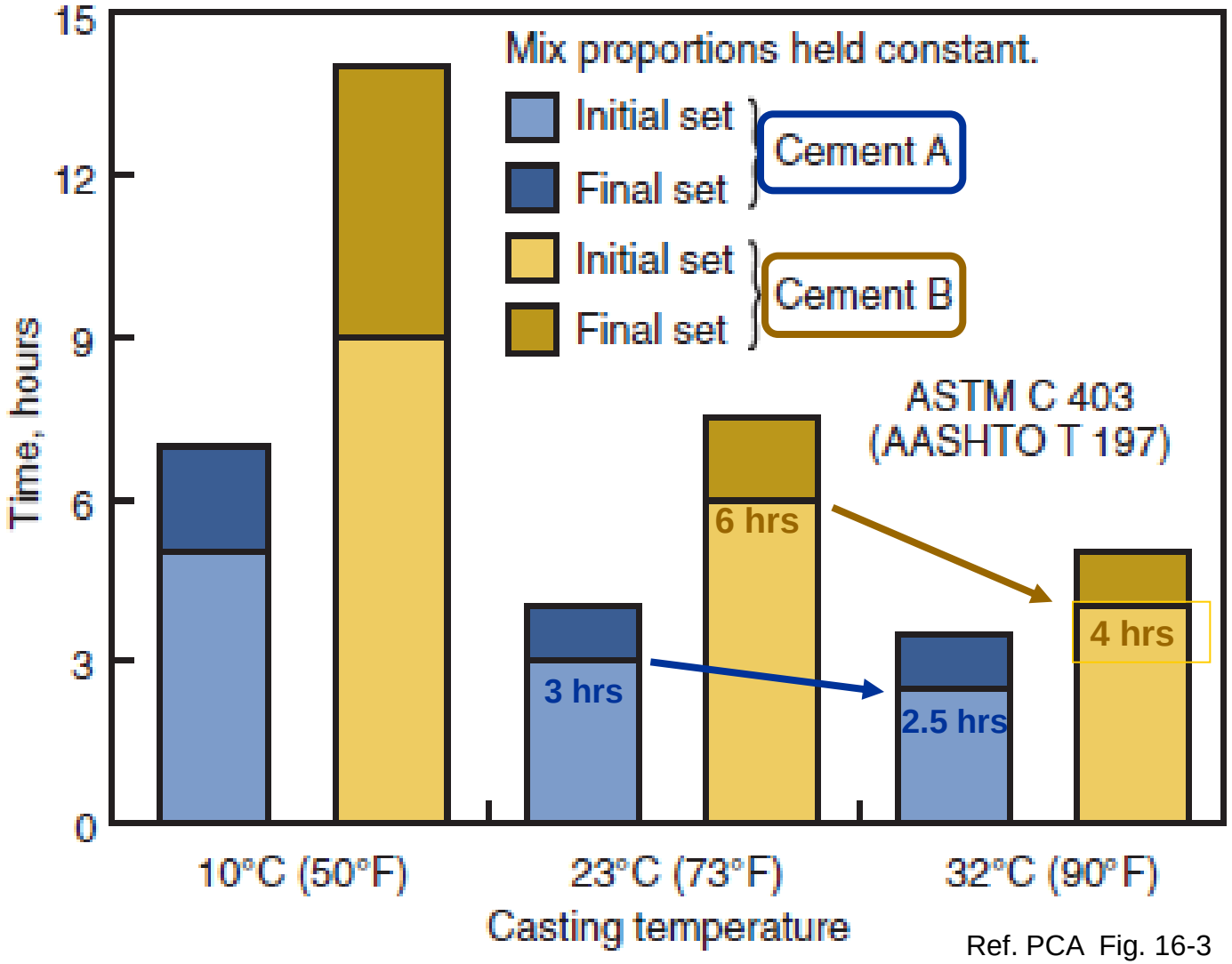
To Maintain 3" Slump

At 50°F - 270 lbs Water
At 60°F - 276 lbs Water
At 70°F - 283 lbs Water
At 80°F - 290 lbs Water
At 90°F - 297 lbs Water
At 100°F -303 lbs Water

Requires + 33 lbs Water

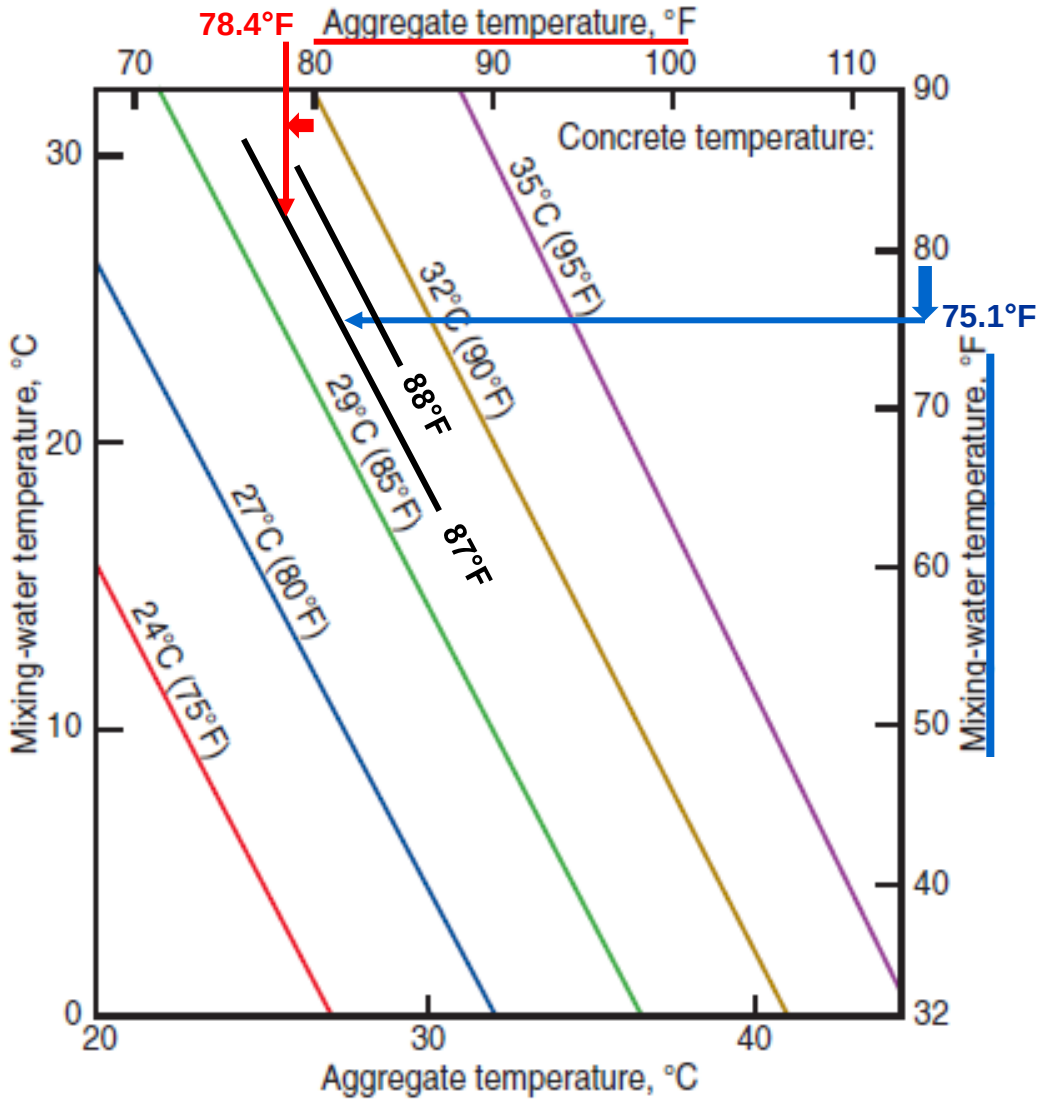
Ref. PCA Fig. 16-2

Effects of High Temperature with different Cements



Ref. PCA Fig. 16-3

Cooling the Concrete Temperature



Initial Concrete Temperature 88°F
To drop the concrete temperature 1°F

1. Lower the Aggregate Temperature1.6°F

OR

2. Lower the mix water temp. 3.9°F

Final Concrete Temperature 87°F

Ref. PCA Fig. 16-5

Cooling Concrete Methods

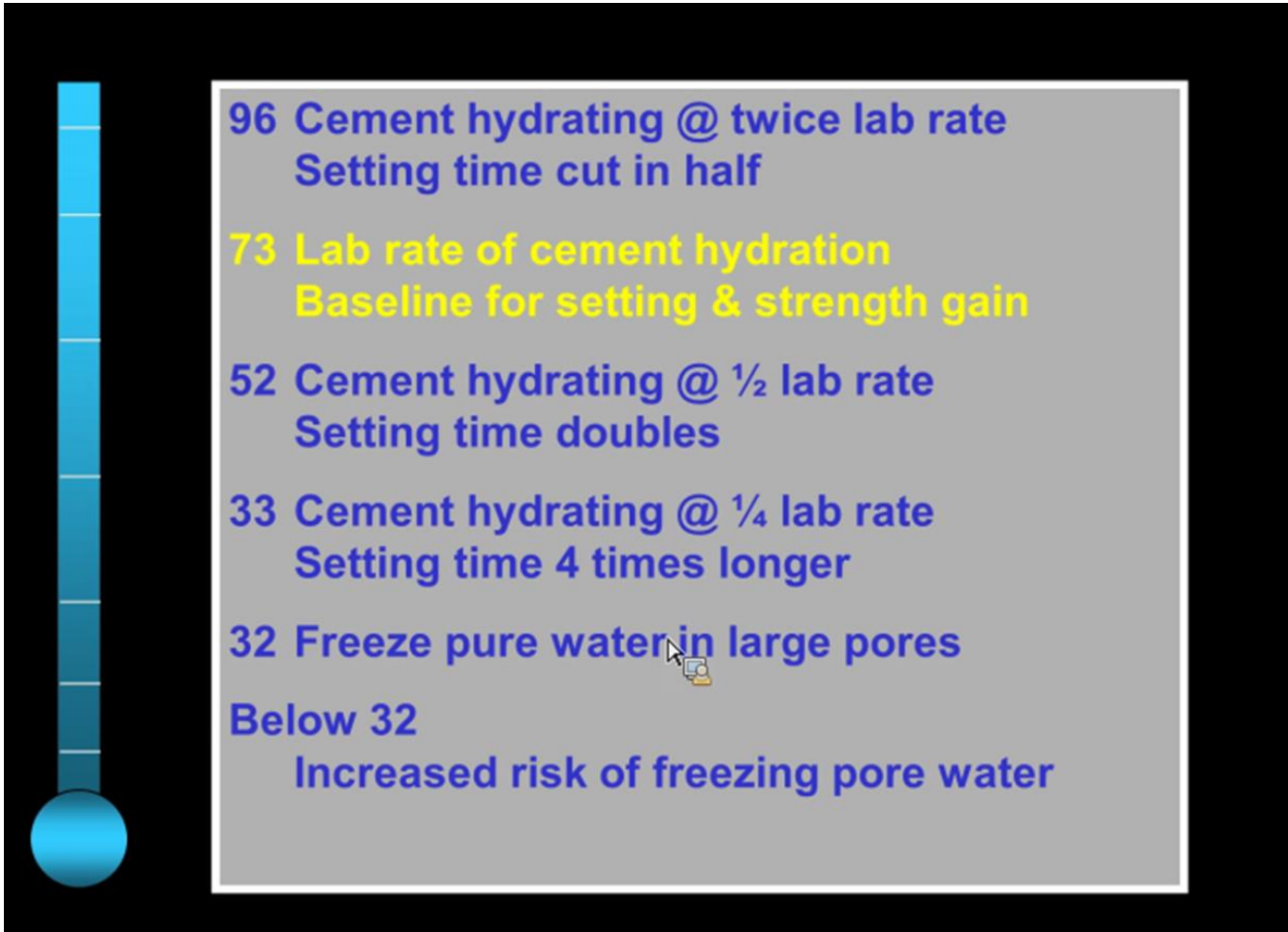
Cooling Concrete – Calculating Concrete Temperature

$$\mathbf{T} = \frac{[0.22\,(T_a M_a + T_c M_c) + T_w M_w + T_{wa} M_{wa}]}{[0.22(M_a + M_c) + M_w + M_{wa}]}$$

- **T** = temperature of the freshly mixed concrete
- T_a, T_c, T_w, and T_{wa} = temperature of aggregates, cement, added mixing water, and free water on aggregates
- M_a, M_c, M_w, and M_{wa} = mass, kg (lb), of aggregates, cementing materials, added mixing water, and free water on aggregates

Cement Heat of Hydration

- General guideline - temperature rises by
  - 5°F to 15°F per 100 lb of Cement



How to Reduce or Avoid Potential Problems

Batch Plant Applications:

- Select materials and mix proportions that have proven performance (lower cement contents, and add set retarding admixtures)
- Cool the concrete or one or more of its ingredients
- Coarse aggregates will have the greatest impact for cooling concrete (Because they have the largest Volume and Mass)
- Use a concrete slump to allow rapid placement and consolidation (which likely requires plasticizers)
- Add fibers to the concrete mixture (PCA)

How to Reduce or Avoid Potential Problems

Jobsite applications:

- Organize a preconstruction conference to discuss precautions
- Reduce the time of transport, placing, and finishing as much as possible to minimize waiting time

  (don’t allow trucks to set and wait on the jobsite)
- Schedule concrete placements to limit exposure to harsh conditions. (Consider nights or dates with more favorable weather conditions)
- Consider methods to limit moisture loss during placing and finishing. (sunshades, windscreens, fogging, or spraying)
- Apply temporary moisture-retaining films to control evaporation.

  (after strike-off and prior to finishing concrete)

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What is Curing?

- The maintaining of an adequate moisture content and temperature in the concrete at early age so that it can develop properties the mixture was designed to achieve
- Don’t let it dry out!!! For at least 3 days
  - Applied immediately after finishing (or sooner!)
- “The Greenhouse Effect”
  - Plastic Sheeting can cause visible discoloration streaks on the concrete surface due to moisture variations

Curing Paper / Plastic Sheets

Moisture Retaining Fabric/plastic Cover

White Membrane Cure

Curing Compound

Curing and Protection Recap

Unanticipated *Cracks . . .*

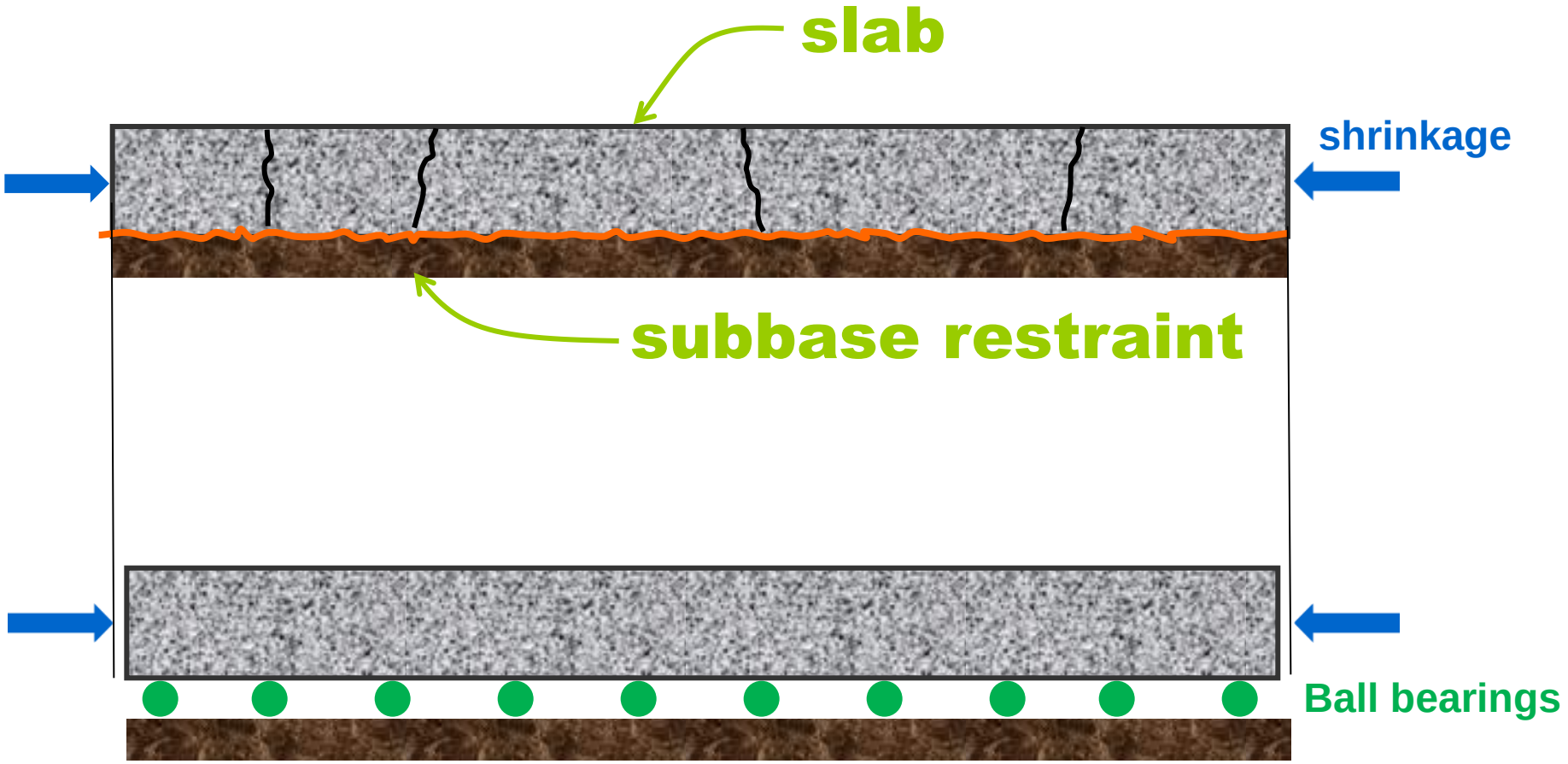
Generate
Unwanted
Discussion

shrinkage is unavoidable !

It’s normal to experience drying shrinkage cracking on every concrete slab

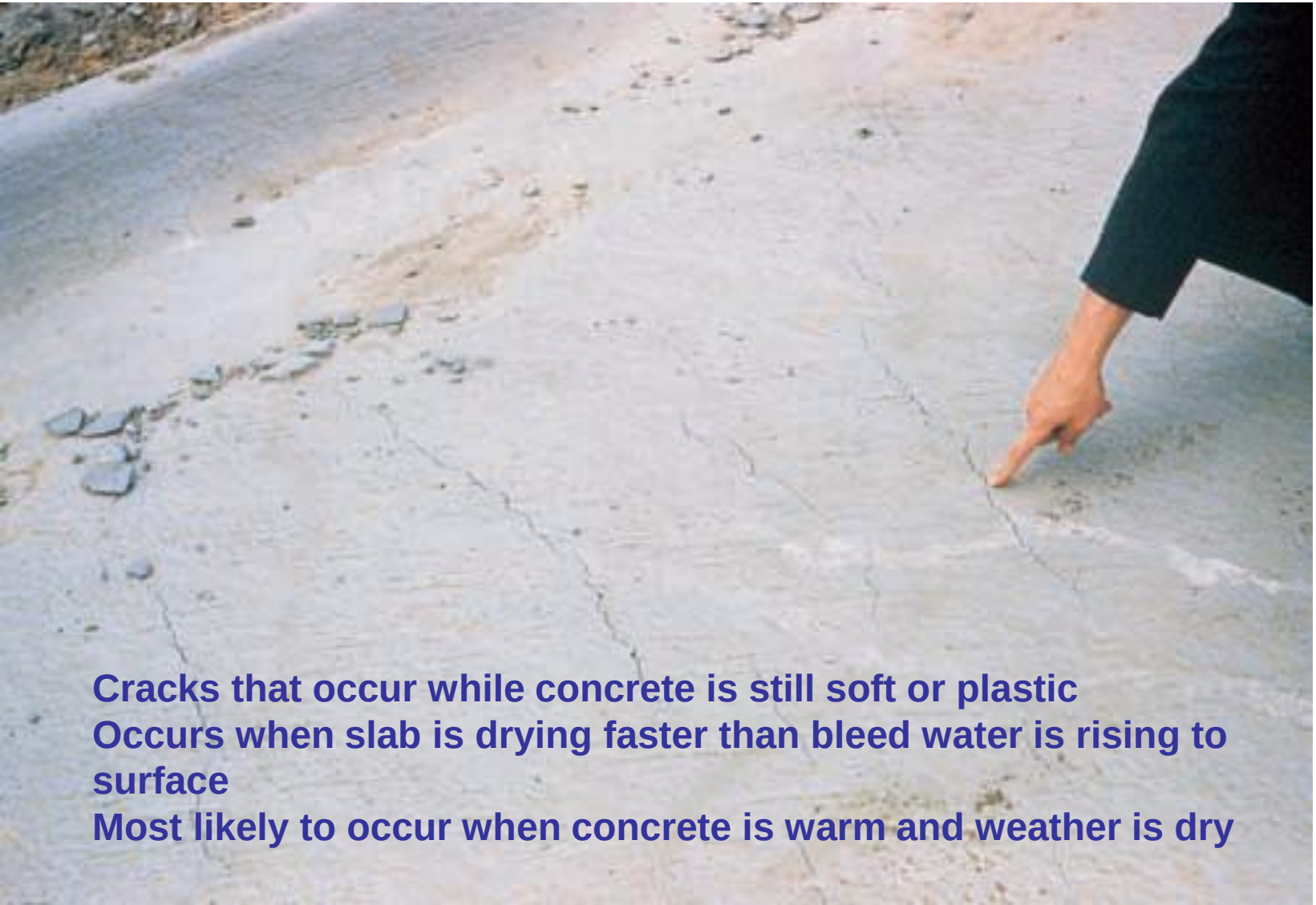
concrete shrinks about 1/8” for every 20’

SHRINKAGE & CRACKS



shrinkage + no restraint = <u>no cracks</u>

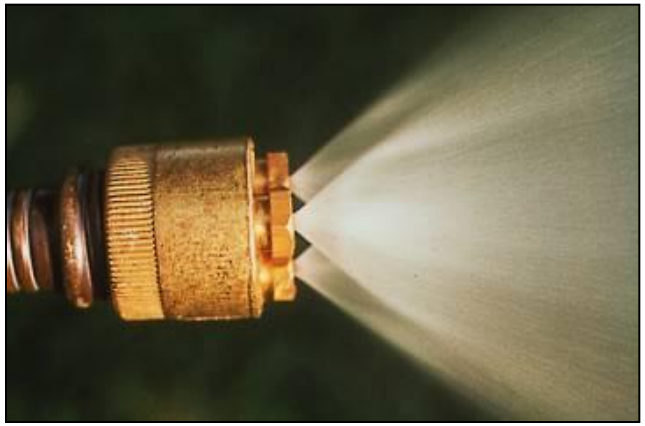
Plastic Shrinkage Cracking



Cracks that occur while concrete is still soft or plastic
Occurs when slab is drying faster than bleed water is rising to surface
Most likely to occur when concrete is warm and weather is dry

How to Minimize Plastic Shrinkage Cracking

- Provide proper equipment and man power
- Fogging and Misting or evaporation retardants
- Dampen sub-grade
- Set up wind barriers
- Use synthetic fibers
- Adjust set time to minimize plastic shrinkage



Hot Weather Effects on Concrete Strength

- High initial concrete temperatures has significant effect on compressive strength in a negative manner

- ASTM C31 requires 60-80 degrees F curing temperature up to 48 hours for concrete specified under 6000 psi. Concrete greater than 6000 psi is to be 68-78 degrees F up to the first 48 hours.

Initial Curing on Site

Concrete Cylinders (ASTM C31)

- There are two different purposes for field concrete cylinder testing.
  - One test is for determining the strength potential for the concrete as delivered to the job.
  - The other is for determining the strength of the concrete in place at a given time.
- Both tests are covered by ASTM C31 “Standard Practice for Making and Curing Concrete Test Specimens in the Field”
  - One very important difference between the two test procedures is the method of curing required for the cylinders.
  - Because correct cylinder curing is commonly neglected, invalid test results are often misinterpreted as test failures.

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Standard Cure Cylinders

- The first purpose of cylinder testing is to confirm that the strength of the concrete, as delivered to the job, meets the specified design strength, typically at 28 days.

- This procedure requires that:
  - During the first 24 hours all cylinders will be stored in a surrounding temperature of 60-80 degrees F for less than 6000psi concrete and 68-78 degrees F for concrete with a strength greater or equal to 6000 psi.
  - Within 16 to 24 hours all cylinders will be removed from the molds and stored in a moist condition until time of test at a temperature of 73.5 degrees F.

Field Cure Cylinders

- The second purpose of cylinder testing is to confirm the time at which concrete in place is strong enough for forms to be removed or for the structure to be put into service.
  - This procedure directs that:
    - Cylinders are stored as near as possible to the concrete in place.
    - Cylinder molds are removed at the time forms are removed.
    - Cylinders are cured to duplicate, as nearly as possible, the curing of the concrete in place until the time of test.

Hot Weather Concreting Recap

- Warm, moist conditions ideal for durable, strong concrete
- Hot, dry and windy conditions cause problems
- Solutions
  - Use cooler concrete ingredients
  - Consider mixtures adapted for high temp – SCMs, retarders
  - Consistency that allows for rapid placement and consolidation
  - Transport, place, consolidate and finish with least possible delay
  - Plan job to reduce exposure (ie, place at night)
  - Protect from moisture loss at all times during placing and curing
    - Fog spray
    - Evaporation retardants

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Conclusions

- The placing, finishing and curing of concrete is not an exact science – adjustments for the placement
- The Contractor is at the mercy of the weather
  - Every day is different
- Concrete mixture as well as placement procedures will need to be modified
- Curing essential to quality concrete
  - Intermediate (during placement)
  - Final
  - Specimens per ASTM C31

Conclusions cont.

- The perfect day to place concrete:
  - 70ºF
  - 100 % humidity
  - no wind

- If you are hot and sticky with perspiration then its good for the concrete.

- However, if you're working outside, got your sun glasses on and there's a nice breeze, then that might be clue that rapid surface evaporation is taking place.

Resources

- American Concrete Institute, *ACI 305.1-14 Specifications for Hot Weather Concreting*
- American Concrete Institute, *ACI 305R-10* Guide to Hot Weather Concreting
- American Concrete Institute, *ACI 308R Guide to Curing Concrete*; *;*
- National Ready Mixed Concrete Association, *Concrete in Practice* (www.nrmca.org);
  - *CIP 3 Crazing Cracks*
  - *CIP 4 Cracking*
  - *CIP 5 Plastic Shrinkage Cracks*
  - *CIP 11 Curing*
  - *CIP 12, What, Why, and How – Hot Weather Concreting*
- Ohio Concrete, *Industry Recommendation for Exterior Concrete Flatwork,* 2014
- Ohio Concrete, *Technical Tips 10 - Hot Weather Concreting*
- *Design and Control of Concrete Mixtures*, Portland Cement Association, Skokie, IL, 15th Edition, 2016
- Ken Hover; “Keeping Concrete Cool in Heat of Summer”

Thanks For Attending! …. Questions??

Upcoming Future Webinars

- Stay tuned for future webinars by Ohio Concrete
  - We welcome suggested topics

Your opinion matters!

Please take a moment to complete the brief survey following today's presentation to help us improve future webinars.

THANK YOU!