MASTER® BUILDERS SOLUTIONS

Concrete Technology in Focus

Successful Hot Weather Concreting

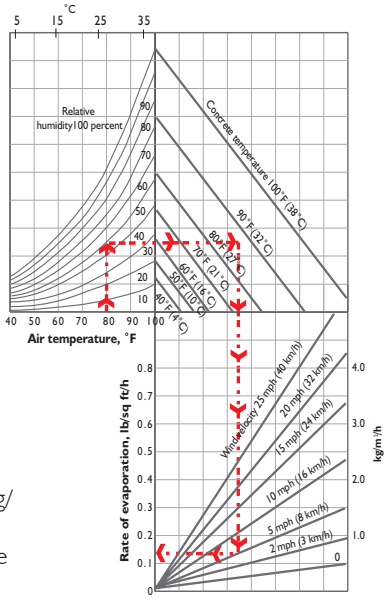
Introduction

Hot weather can lead to many problems in mixing, placing, and curing of concrete that can have an adverse effect on its properties and service life. This guide has been developed by Master Builders Solutions to assist the entire construction team (owners, specifiers, contractors, and ready-mixed concrete and precast concrete producers) in the design, production, delivery, placement and curing of quality concrete in hot weather.

ACI Committee 305 defines hot weather as any combination of high ambient temperature, high concrete temperature, low relative humidity, wind speed and solar radiation. The effects of high temperature, solar radiation and low relative humidity on concrete may be more pronounced with increases in wind velocity (see Figure 1), and can lead to rapid evaporation of moisture, which is the primary cause of plastic shrinkage cracks in concrete.

Figure 1. *Effect °C of Concrete and Air Temperatures, Relative Humidity and Wind Speed on the Rate of Surface Moisture Evaporation from Concrete*

(Source: ACI SPEC-305.1 "Specification for Hot Weather Concreting")

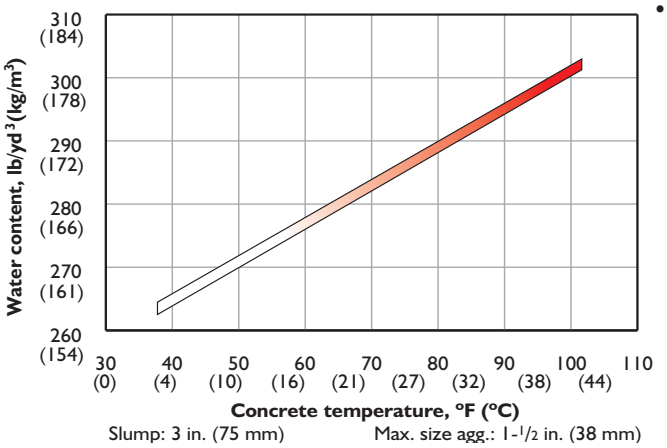


If the rate of evaporation approaches 0.2 lb/ft²/h (1 kg/m²/h), precautions against plastic shrinkage cracking are necessary.

Potential Problems

The potential problems of hot weather can occur at any time of the year in warm tropical or arid climates and generally occur during the summer season in other climates. Problems associated with freshly mixed concrete placed during hot weather conditions include increased:

- Water demand (see Figure 2)
- Rate of slump loss and tendency for retempering
- Rate of setting (see Table 1)
- Difficulty in handling, placing, consolidating and finishing
- Occurrence of plastic shrinkage cracking
- Amount of air-entraining admixture to entrain air
- Need for early curing



Risk of cold joints

Figure 2. *Effect of Concrete Mix Temperature on Water Requirement*

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

Table 1. *Setting Time of Concrete at Various Temperatures*

Temperature	Approximate Setting Time
100 °F (38 °C)	1-2/3 hours
90 °F (32 °C)	2-2/3 hours
80 °F (27 °C)	4 hours
70 °F (21 °C)	**6 hours**
60 °F (16 °C)	8 hours
50 °F (10 °C)	11 hours
40 °F (4 °C)	14 hours

In hardened concrete, hot weather can increase:

- Drying shrinkage and differential thermal cracking
- Permeability

and decrease:

- Compressive and flexural strengths
- Durability
- Watertightness
- Uniformity of surface appearance

ACI PRC-305 "Guide to Hot Weather Concreting," states that "Concrete can be produced in hot weather without maximum limits on placing temperature, and perform satisfactorily when proper precautions are observed in proportioning, production, delivery, placing, consolidating, finishing, and curing. As part of these precautions, an effort should be made to keep the temperature of the fresh concrete as low as practical."

Concrete Temperature Control

Concrete temperature at the time of mixing is influenced by temperature, specific heat and quantity of its ingredients. The approximate temperature of freshly mixed concrete can be calculated from the following equation:

$$T = \frac{[0.22\,(TsMs + TaMa + TcMc) + TwMw + TsMws + TaMwa]}{[0.22\,(Ms + Ma + Mc) + Mw + Mws + Mwa]}$$

where:

T = final temperature of the concrete mixture

T_c, T_s, T_a and T_w = temperature of cement, fine aggregate, coarse aggregate and water, respectively

M_c, M_s, M_a, M_w, M_{ws} and M_{wa} = mass of cement, saturated surface-dry fine aggregate, saturated surface-dry coarse aggregate, mixing water, free water on fine aggregate and free water on coarse aggregate, respectively.

The temperature of concrete can be reduced by 1 °F (0.5 °C) by reducing:

- Cement temperature by 8 °F (4 °C)
- Water temperature by 4 °F (2 °C) – (see Figure 3)
- Aggregate temperature by 2 °F (1 °C)

Of all concrete-making materials, water is the easiest to cool, and using ice as part of the mixing water will help reduce the concrete temperature. The amount of ice used must be included as part of the mix water and should not be more than approximately 75% of the amount of water required to meet the specified water-cementitious materials ratio.

ACI PRC-305 has additional guidelines for the use of ice in concrete. As coarse aggregate is the ingredient with greatest mass in concrete, changes in its temperature have a considerable effect on concrete temperature. The following measures will further help to control concrete temperature at the time of batching or during the hydration process:

- Sprinkling and spraying of aggregates with water
- Shaded storage of aggregates
- Use of liquid nitrogen
- Use of fly ash/slag cement
- Use of chemical admixtures (MasterSet® R, MasterPolyheed®, MasterSet DELVO, MasterSet DELVO ESC)

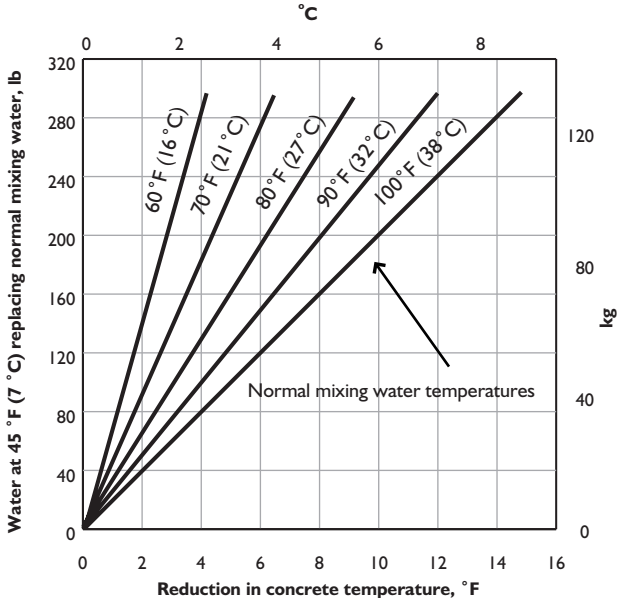


Figure 3. *Effect of Cooled Mixing Water on Concrete Temperature*

(Source: ACI PRC-305, "Guide to Hot Weather Concreting")

The use of slower setting cements may improve the handling characteristics of concrete in hot weather. A 10 to 15 °F (5 to 8 °C) temperature rise per 100 lb (45 kg) of cement occurs from cement hydration. The temperature increase from cement hydration is directly proportional to its cement content.

Fly ash, other pozzolans and slag cement are used as partial replacements for portland cement and impart a slower rate of setting and strength development to concrete, both of which are desirable in hot weather concreting.

The requirements to achieve good results in hot weather concrete placing and curing are not different from those for other seasons. Concrete should be placed where it will remain and in shallow layers to allow adequate vibration. It shall be protected using sunscreens, shades and wind breaks and protected from moisture loss. Adequate curing measures shall be undertaken.

Chemical Admixtures

Chemical admixtures conforming to ASTM C494/C494M Type B, Retarding; Type D, Water-reducing and retarding; Type F, High-range water-reducing; and Type G, High-range water-reducing and retarding, are beneficial for concrete placed during hot weather. Benefits obtained from these admixtures include:

- Reduced water demand – minimum 5%
- Improved workability during placing
- Slower rate of setting
- Lower rate of heat evolution
- Increased compressive strength
- Reduced friction among aggregates

Master Builders Solutions offers a wide range of admixtures that conform to ASTM C494/C494M for hot weather concreting, such as those listed in Table 2. Your local sales representative will help you select the admixture that best serves your needs.

Table 2. *Typical Performance Data*

Concrete and Ambient Temperatures 90 °F (32 °C)

Product	ASTM C494/ C494M Designation	Dosage fl oz/ cwt (mL/100 kg)	Setting Time Retardation vs. Plain Concrete (h:min)
MasterSet R 100 Conventional water-reducing and retarding admixture	B & D	2 (130) 5 (330)	+2:30 +8:55
MasterSet DELVO Hydration control admixture (liquid)	B & D	2 (130) 6 (390)	+0:45 +2:00
MasterSet DELVO ESC* Hydration control admixture (dry formulation)	B & D	4 (260)* (1/4 puck)	+2:15**

** One MasterSet DELVO ESC Puck = 16 fl oz of Liquid MasterSet DELVO Stabilizer*

*** Concrete and Ambient Temperatures 70 °F (21 °C)*

Miscellaneous Products

Synthetic microfibers ("MasterFiber® M or F" Series) reduce the formation of plastic shrinkage cracks.

The use of an evaporation reducer (MasterKure® ER 50)† will enhance the quality of the concrete. This monomolecular film:

- Reduces surface moisture evaporation
- Reduces crusting, plastic shrinkage cracks

† Note: MasterKure ER 50 is neither a finishing aid, nor a curing compound for concrete

Curing

Curing is the maintenance of satisfactory moisture content and temperature in concrete during its early stages so that desired properties may develop. The minimum recommended curing period is 7 days (see Figure 4). Inadequate curing can cause plastic shrinkage cracking and impair strength development and durability.

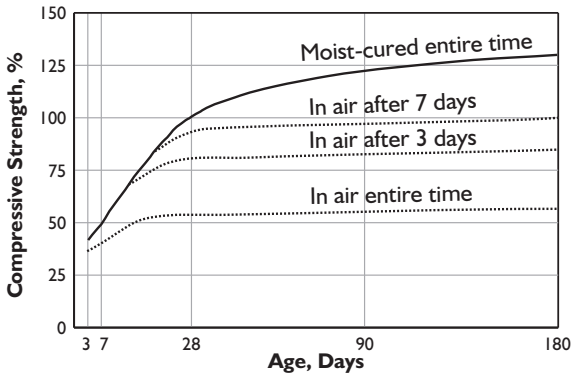


Figure 4. *Effect of Curing on Compressive Strength of Concrete*

(Source: ACI PRC-306 "Guide to Cold Weather Concreting")

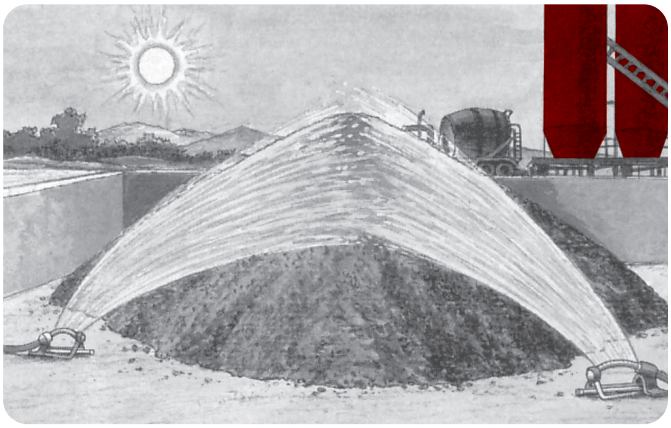
Methods of curing include:

1. Moist curing (ponding, continuous sprinkling and fogging)
2. Wet coverings (wet burlap, etc.)
3. Impervious paper and plastic sheets
4. Membrane-forming curing compounds

Solutions

Strength, durability and other desired properties of concrete can be obtained in hot weather through the use of the following techniques:

- Use of cool concrete ingredients
- Avoiding prolonged mixing of concrete materials
- Protection of materials and equipment from hot weather
- Good scheduling (plan hot weather placements at other-than-normal hours)



Summary

Hot weather difficulties are mainly caused by high concrete temperatures and rapid evaporation of water from concrete. These conditions adversely affect the quality of concrete since the rate of setting is accelerated, strength is reduced and cracks may occur in either the plastic or hardened state. Curing is more critical and air-entrainment more difficult to attain in hot weather. Field strength specimens are affected in the same manner as the concrete in place. If all precautions and recommended ACI PCR-305 guidelines are followed, successful hot weather concreting can be achieved.

Master Builders Solutions has the products and technical expertise to assist the entire construction team (owners, specifiers, contractors, and ready-mixed concrete producers) in the design, production, delivery, placement and curing of quality concrete in hot weather.

About Master Builders Solutions

Master Builders Solutions is a leading global manufacturer of concrete admixtures, as well as other sustainable solutions for the construction industry, focussed on delivering its vision: **Inspiring people to build better.** Master Builders Solutions provides value-added technology and market-leading R&D capabilities to improve the performance of construction materials and to enable the reduction of CO2 emissions in the production of concrete. Founded in 1909, Master Builders Solutions has ca. 1600 employees operating 35 production sites globally, supporting their customers in mastering their building challenges of today – for a decarbonised future.

Master Builders Solutions Admixtures US, LLC
23700 Chagrin Boulevard
Beachwood, OH 44122 USA
(800) 628-9990

Master Builders Solutions Canada, Inc
1800 Clark Boulevard
Brampton, Ontario L6T 4M7 CANADA
(289) 360-1300

master-builders-solutions.com/en-us
admixtures@masterbuilders.com