IN-LB	Inch-Pound Units
SI	International System of Units

Guide to Hot Weather Concreting

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Environmental factors, such as high ambient temperature, low humidity, high wind, or both low humidity and high wind, affect concrete properties and the construction operations of mixing, transporting, and placing of the concrete materials. This guide provides measures that can be taken to minimize the undesirable effects of these environmental factors and reduce the potential for serious problems.

This guide defines hot weather, discusses potential problems, and presents practices intended to minimize them. These practices include selecting materials and proportions, precooling ingredients, and batching. Other topics discussed include length of haul, consideration of concrete temperature as placed, facilities for handling concrete at the site, and, during the early curing period, placing and curing techniques, and appropriate testing and inspection procedures in hot weather conditions.

The materials, processes, quality control measures, and inspections described in this document should be tested, monitored, or performed as applicable only by individuals holding the appropriate ACI certifications or equivalent.

Keywords: air entrainment; cooling; curing; evaporation; high temperature; hot weather construction; plastic shrinkage; production methods; retempering; slump tests; water content.

CONTENTS

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

Hot weather can create problems in delivery, mixing, placing, and curing hydraulic-cement concrete that can adversely affect the properties and serviceability of the concrete. Most of these problems relate to the increased rate of cement hydration at higher temperature and increased evaporation rate of moisture from the freshly mixed concrete. The rate of cement hydration depends on ambient and concrete temperature, cement composition and fineness, amount and type of supplementary cementitious materials, and admixtures used.

A maximum as-placed concrete temperature is often specified in an effort to control rate of setting, strength, durability, plastic shrinkage cracking, thermal cracking, and drying shrinkage. The placement of concrete in hot weather, however, is too complex to be dealt with by just setting a maximum as-placed or as-delivered concrete temperature. Concrete durability is defined as the ability of concrete to resist weathering action, chemical attack, abrasion, or any other process of deterioration (ACI 201.2R). Generally, if concrete strengths are satisfactory and curing practices are sufficient to avoid undesirable drying of surfaces, the durability of hot weather concrete will not differ greatly from similar concrete placed at normal temperatures.

Where an acceptable record of field tests is not available, concrete proportions can be determined by trial batches (ACI 301 and 211.1). Trial batches should be made at temperatures anticipated in the work and mixed following one of the procedures described in 4.10. The concrete supplier is generally responsible for determining concrete proportions to produce the required quality of concrete unless specified otherwise.

If the initial 24-hour curing is at 100°F (38°C), the 28-day compressive strength of the test specimens may be 10 to 15 percent lower than if cured at the required ASTM C31/C31M curing temperature (Gaynor et al. 1985). If the cylinders are allowed to dry at early ages, strengths will be reduced even further (Cebeci 1987). Therefore, proper curing of the test specimens during hot weather is critical, and steps should be taken to ensure that the specified procedures are followed.

The effects of high air temperature and low relative humidity are more pronounced with increases in wind speed. The potential problems of hot weather concreting can occur at any time of the year, but generally occur during the summer season. Drying conditions can occur even at lower ambient temperatures, with slower set times, lower relative humidity, and wind, all of which are conducive to higher evaporation. Precautionary measures required on a windy, sunny day will be stricter than those required on a calm, humid day, even if air temperatures are identical.

1.2—Scope

This guide identifies problems associated with hot weather concreting and describes practices that alleviate these potential adverse effects. These practices include suggested preparations and procedures for use in general types of hot weather construction, such as pavements, bridges, and buildings either cast in place or precast. Temperature, volume changes, and cracking problems associated with mass concrete are treated more thoroughly in ACI 207.1R, 207.2R, and 224R.

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

E = evaporation rate, lb/ft^2/h (kg/m^2/h)

e_a = water vapor pressure in psi (mmHg) in the air surrounding the concrete obtained by multiplying the saturation vapor pressure at the temperature of the air surrounding the concrete by the relative humidity of the air. Air temperature and relative humidity are measured approximately 4 to 6 ft (1.2 to 1.8 m) above the concrete surface on the windward side and shielded from the sun's rays

e_o = saturation water vapor pressure in psi (mmHg) in the air immediately over the concrete surface, at the concrete temperature.

e_s = saturation vapor pressure, psi (kPa)

r = relative humidity, percent

T = temperature, °F (°C)
T_a = air temperature, °F (°C)
T_c = concrete (water surface) temperature, °F (°C)
V = average wind speed in mph (km/h), measured at 20 in. (0.5 m) above the concrete surface
W = mass of water evaporated in lb/ft^2 (kg/m^2) of water-covered surface per hour

2.2—Definitions

Refer to the latest version of ACI Concrete Terminology for a comprehensive list of definitions. Definitions provided herein complement that resource.

hot weather—one or a combination of the following conditions that tends to impair the quality of freshly mixed or hardened concrete by accelerating the rate of moisture loss and rate of cement hydration, or otherwise causing detrimental results: high ambient temperature; high concrete temperature; low relative humidity; and high wind speed.

CHAPTER 3—POTENTIAL PROBLEMS AND PRACTICES

3.1—Potential problems in hot weather

Potential problems for concrete in the freshly mixed state include:

a) Increased water demand

b) Increased rate of slump loss and corresponding tendency to add water at the job site

c) Increased rate of setting, resulting in greater difficulty with handling, compacting, and finishing, and a greater risk of cold joints

d) Increased tendency for plastic shrinkage and thermal cracking

e) Increased difficulty in controlling entrained air content

Damage to concrete caused by hot weather can never be fully alleviated. Potential deficiencies to concrete in the hardened state can include:

a) Decreased strengths resulting from adding water to satisfy the higher water demand

b) Increased tendency for drying shrinkage if additional water was added to the concrete

c) Thermal cracking from either cooling of the overall structure, or from temperature differentials within the cross section of the member

d) Decreased durability resulting from cracking

e) Greater variability of surface appearance, such as cold joints or color differences, due to different rates of hydration or different water-cementitious materials ratios (*w/cm*)

3.2—Potential problems related to other factors

Other factors that should be considered along with climatic factors include:

a) Cements with different and increased rate of hydration

b) High-early-strength concrete, which may be proportioned with higher total cementitious content

c) Thin concrete sections with correspondingly greater percentages of steel, which may complicate placing and consolidation of concrete

d) Economic necessity to continue work in extremely hot weather

e) Use of shrinkage-compensating cement

3.3—Practices for hot weather concreting

Good judgment is necessary to select procedures that appropriately blend quality, economy, and practicability. The procedures selected will depend on type of construction, characteristics of the materials being used, and the experience of the local industry in dealing with high ambient temperature, high concrete temperatures, low relative humidity, and high wind speed.

The most serious difficulties occur when personnel placing the concrete lack experience in constructing under hot weather conditions or in doing the specific type of construction. Last-minute improvisations are rarely successful. Early preventive measures should be applied with the emphasis on materials evaluation, advanced planning and purchasing, and coordination of all phases of work. Planning in advance for hot weather involves development of an appropriate concrete mixture and a detailed plan for mixing, transporting, placing, protecting, curing, and testing of concrete. Precautions to avoid plastic shrinkage cracking are important. The potential for thermal cracking, either from overall volume changes or from internal restraint, should be anticipated, properly assessed, and mitigated.

Typical methods to minimize and to limit crack size and spacing include: proper use and timely installation of joints; increased amounts of reinforcing steel; and practical limits on concrete temperature. Some adjustments to concrete mixtures that have been successful in hot weather conditions include: using a reduced cement content; using a low-heat-of-hydration cement; the selection and dosage of appropriate chemical admixtures; the use of supplementary cementitious materials to replace cement; and the use of synthetic microfibers and macrofibers.

Developing a comprehensive plan and procedures for use in hot weather concreting conditions include the following practices and measures used to reduce or avoid the potential problems of hot weather concreting, as discussed in detail in Chapters 4 to 6:

a) Selecting concrete materials and proportions with satisfactory records in hot weather conditions or that have shown by testing to be satisfactory

b) Reducing and controlling the temperature of fresh concrete

c) Using a concrete mixture with sufficient workability that will permit rapid placement and effective consolidation

d) Minimizing the time to transport, place, consolidate, and finish the concrete

e) Scheduling of placing operations during times of the day or night when weather conditions are favorable

f) Protecting the concrete from moisture loss during placing and curing periods

g) Scheduling a preplacement conference to discuss the requirements of hot weather concreting

These suggestions are offered with the caveat that it may not be practical to implement any or all of them on a given