RUSSTECHNICAL NOTES

HOT WEATHER CONCRETING

DESCRIPTION:

Hot weather can lead to many problems in batching, transporting, placing, and curing of the concrete that can adversely affect the properties and service years of the concrete. Most of these difficulties arise due to the increased rate of cement hydration at higher temperatures (accelerated set times) and the increased rate of evaporation of the moisture at the surface of plastic concrete. This document has been created by **RUSSTECH ADMIXTURES** to identify the potential concrete problems associated with hot weather and to suggest preparations and procedures to reduce the undesirable effects of hot weather concreting. ACI 305R, ACI 207.IR and ACI 224R more thoroughly address topics concerning temperature, volume changes, and cracking problems with concrete.

POTENTIAL PROBLEMS:

Listed below are the potential concrete problems experienced with *freshly mixed or plastic* concrete in hot weather:

- Increased demand for water (see Figure 1)
- Faster rate of setting, increased difficulty with handling, transporting, compacting, finishing, and a greater risk of cold joints (see Figure 2)
- Rate of slump loss increased
- Increased jobsite water additions
- Increased plastic shrinkage cracking
- Entrained air content control increased difficulty

Listed below are the potential concrete problems experienced with concrete in the *hardened state* during hot weather:

- Decreased compressive strength at 28 days and later (sometimes up to 30%) resulting from higher water demand and/or higher temperature levels at time of placement
- Increased incidence of drying shrinkage and differential thermal cracking
- Decreased durability
- Variability of surface aesthetics
- Increased permeability

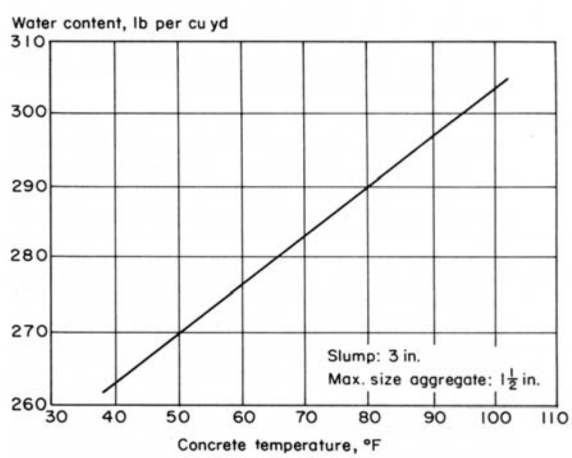

Figure 1 - Effect of concrete temperature on water requirement. Source PCA

Setting Time at Various Temperatures	
Temperatures	**Approximate Setting Times**
100F	2 hours
90F	3 hours
80F	4 hours
70F	6 hours
Source: “Concrete Construction”	

Figure 2 - Setting times at various concrete and ambient temperatures

MIX TEMPERATURE FORMULA:

If the weights, temperatures and moisture contents of the aggregates of all of the ingredients are known, the final temperature of the concrete mix is calculated using the following ACI 306 formula:

$$T = \frac{[0.22(T_sW_s+T_aW_a+T_cW_c)+T_wW_w+T_sW_{ws}+T_aW_w]}{[0.22\,(W_s + W_a + W_c) + W_w + W_{wa} + W_{ws}]}$$

T = final temperature of concrete mix (deg. F or C)
T_c = temperature of cement (deg. F or C)
T_s = temperature of fine aggregate (deg. F or C)
T_a = temperature of coarse aggregate (deg. F or C)
T_w = temperature of added mix water (deg. F or C)
W_c = weight of cement (lb or kg)
W_s = SSD weight of fine aggregate (lb or kg)
W_a = SSD weight of coarse aggregate (lb or kg)
W_w = weight of mix water (lb or kg)
W_{ws} = weight of free water on fine aggregate (lb or kg)

Concrete can be manufactured in hot climates *without* maximum temperature limits on the placing temperature and will perform satisfactorily if proper procedures are followed in proportioning, batching, transporting, placing, and curing. As part of these procedures, the concrete temperature should be kept as low as practical. Water has the greatest effect per unit weight on the concrete temperature. Water temperature is more easily controlled than any other ingredients and can be lowered by the following methods:

- Substituting ice for mixing water; 25 lb increments of ice will lower concrete temperature approximately 3 F (see Figure 3)
- Water chiller (see Figure 3)
- Liquid Nitrogen (see Figure 3)

Other methods which will help control mix temperature and heat are:

- Sprinkling aggregate stockpiles
- Storing aggregates in a cooler place
- Incorporation of flyash
- Incorporation of retarding admixtures such as **LC-400R, LC-400P,** or **LC-500**
- Applying evaporation retardant to the concrete surface such as **EVRT** to reduce evaporation rates at the surface

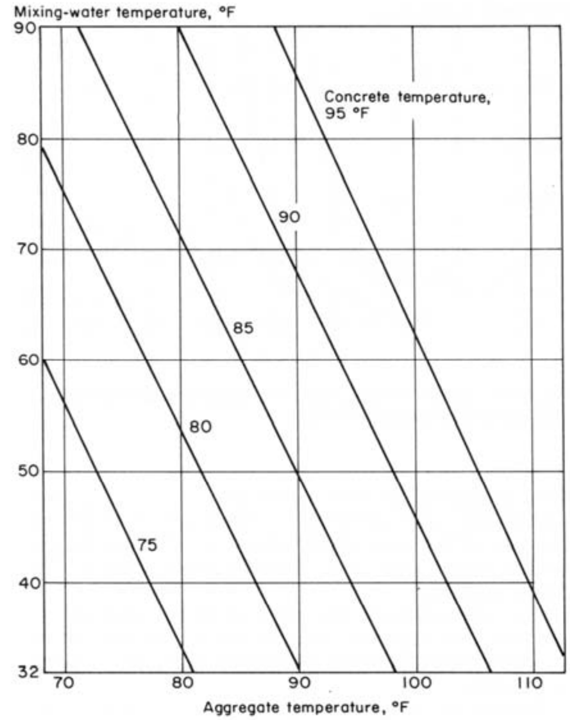

Figure 3 –Effect of ingredient temperatures on concrete temperature. Source PCA

RETARDING ADMIXTURES:

Incorporating chemical admixtures which retard the rate of set are particularly effective for offsetting some of the undesirable characteristics in hot weather. **LC-400R, LC-400P,** and **LC-500** meet the requirements of ASTM C 494, Types B and Type D, water-reducing retarder and provide the following advantages:

- Reduces water requirement
- Increases rate of set (see Figure 5)
- Improves workability
- Increases strengths both compressive and flexural
- Reduces peak heat of hydration

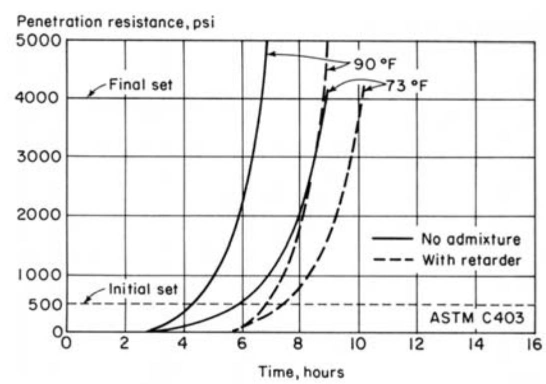

Figure 4 – Effect of retarder and concrete temperature on setting time. Source PCA

Type D Retarder	Dosage ozs./cwt.	Set Time Retardation (hr:min)
LC-400R	**3.0**	**1:00**
	4.0	**2:00**
	5.0	**3:00**
	6.0	**4:00**
LC-400P	**6.0**	**1:00**
	7.0	**2:00**
	8.0	**3:00**
LC-500	**4.0**	**1:00**
	4.5	**1:30**
	5.0	**2:00**

Figure 5 – Setting performance averages with different retarders and different brands of cement at 85 F. Source RussTech Admixtures

CURING & PROTECTION:

After placement and finishing operations are completed, procedures must continued to protect the concrete from high ambient temperatures, direct sun, low humidity, and winds. High initial curing temperatures are detrimental to the ultimate compressive strength to a greater degree than the high placement temperatures. Efforts to keep exposed surfaces from drying must be started immediately with thorough coverage of curing compound and continued without interruption.

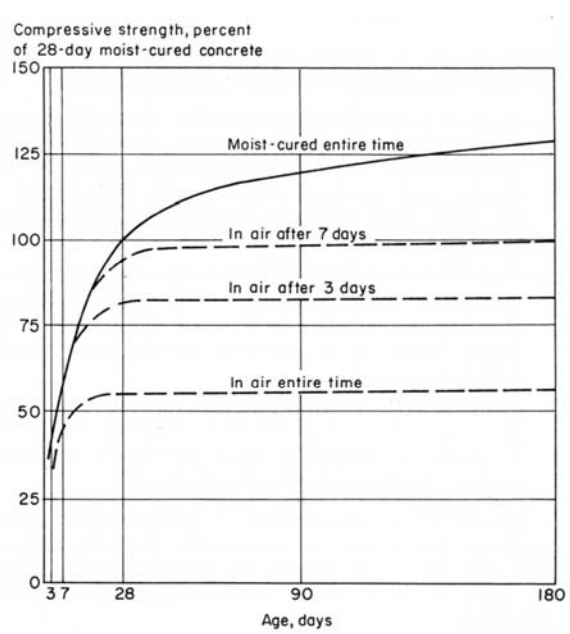

Figure 6 – Compressive strength development with different curing periods

***Failing to cure the concrete causes excessive shrinking and cracking, and will definitely impair the durability of the surface and the ultimate compressive strength of the concrete.

Liquid membrane-forming curing compounds are the most practical means of curing the concrete. These curing compounds form a membrane that restrict the loss of moisture from the concrete, thereby enhancing its strength and the surface durability.

SURFACE EVAPORATION:

Surface evaporation is associated with hot weather concreting and plastic shrinkage cracking. Generally, it occurs in concrete exposed to the environment, primarily in flatwork and may develop in other environmental conditions where the surface evaporation rate is greater than the rate at which bleed water rises to the surface of newly placed concrete. High wind velocity, low humidity, high concrete temperatures, and high air temperature, *alone or in combination*, cause rapid evaporation of surface bleed water and significantly increase the chances of plastic shrinkage cracking. A graphical method (from ACI 305R) to determine the surface evaporation rate is illustrated below:

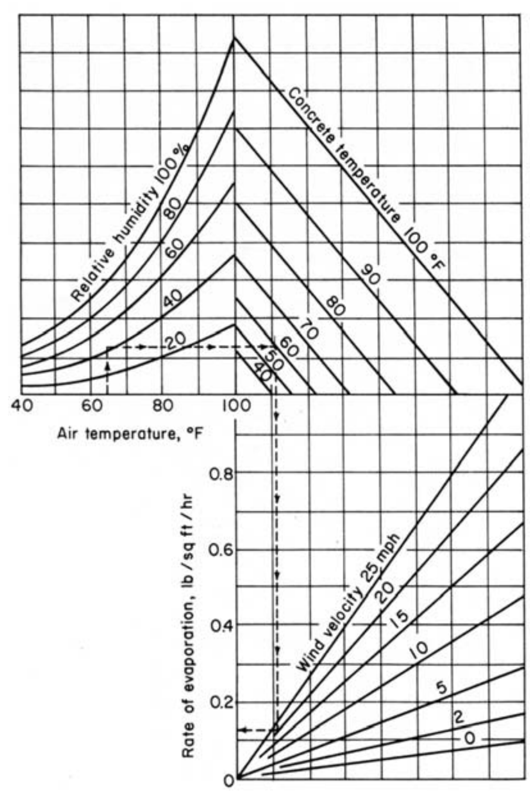

Figure 7 - Effect of concrete and air temperature, relative humidity, and wind velocity on surface evaporation. Source PCA

DRYING SHRINKAGE:

The most important controllable ingredient in concrete that affects shrinkage is the *mix water*. Below are the results of shrinkage tests demonstrating the relationship between water and shrinkage. Shrinkage can be greatly minimized in concrete by keeping the water content as low as possible. Any practice which increases water demand such as, high slumps achieved with water, high concrete temperatures, and smaller top size aggregates will increase shrinkage. It has been shown that for each 1% increase in water, shrinkage increases by 2%.

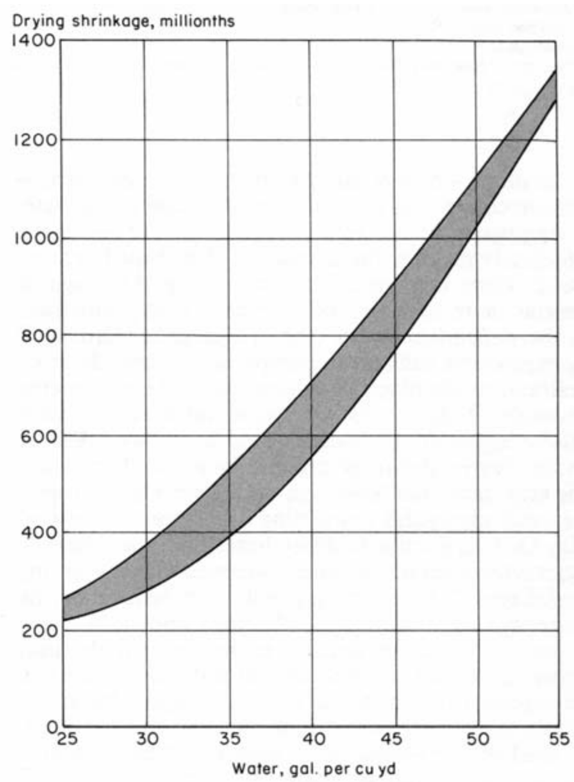

Figure 8 – Relationship between water content and drying shrinkage.

RECOMMENDATIONS:

Concrete placed in hot weather conditions, will have an increased rate of cement hydration at higher temperatures (accelerated set times) and the increased rate of evaporation of the moisture at the surface of plastic concrete (cracking). These conditions result in:

- decreased compressive strength at 28 days and later
- increased drying shrinkage and thermal cracking
- decreased durability
- more variability of surface aesthetics.

Listed below are the recommended procedures to achieve normal compressive strengths, reduced drying shrinkage, improved durability, satisfactory set times, and uniform surface aesthetics during hot weather placements:

1) Reduce mix water demand & increase the rate of set (incorporate retarder)
2) Sprinkle aggregate stockpiles to cool aggregates
3) Control the concrete temperature
4) Moisten sub-grade before placement
5) Control high surface evaporation rates by incorporating **EVRT**, an evaporation retardant that is applied to concrete flatwork surfaces during the finishing process. **EVRT** reduces surface moisture evaporation in rapid-drying conditions
6) Cure the concrete immediately and thoroughly

RussTech supplies several membrane-forming, acrylic, curing compounds such as:

- **CURE & SEAL 150**
- **CURE & SEAL 250**
- **CURE & SEAL 300**
- **CRETESEAL 30**
- **STAMPSEAL 30**

Please consult with your **RUSSTECH** technical service representative for the proper product and recommendations for your specific application.

RussTech Inc.
"We Add The Difference"

11208 Decimal Drive Louisville, KY 40299 Phone: (502) 267-7700 Fax: (502) 267-8922