RUSSTECHNICAL NOTES

COLD WEATHER CONCRETING

DISCUSSION:

ACI 306R-88, "Cold Weather Concreting" states, "that concrete placed in cold weather can result in sufficient strength and durability to satisfy intended service requirements. Concrete will develop these qualities only if it is properly produced, placed, and protected. The necessary degree of protection increases as the ambient temperature decreases." Cold weather significantly affects concrete setting time and early strength-gain characteristics. This bulletin has been developed by RussTech Admixtures to assist the construction team with suggestions on cold weather concreting.

CONCRETE SETTING TIME:

Concrete setting times vary with changes in ambient and concrete temperatures. In the table shown below, the setting time of the concrete increases by approximately one-third for each 10 F decrease in temperature.

Setting Time at Various Temperatures

Temperatures	Approximate Setting Times
70 F	6 Hours
60 F	8 Hours
50 F	11 Hours
40 F	14 Hours
30 F	19 Hours
20 F	No set (concrete will freeze)

Source: "Concrete Construction", 1990

Reduced temperatures cause the rate of hydration and strength-gain to slow down dramatically and below freezing it's nearly nil. Through concrete temperature control, accelerating admixtures and ambient temperature control it is possible to speed up the rate of hydration and strength-gain to achieve successful cold weather concreting.

TEMPERATURE CONTROL:

Temperature control of concrete and ambient temperatures makes a big difference in early concrete strength performance. In the table below, all specimens were made from the same concrete taken at the same slump from the same project. Note the different compressive strength test results after three days of exposure at the ambient temperatures shown.

3 Day Compressive Strength-Gain at Various Ambient Temperatures

Temperature	Compressive Strength, psi
70 F	2700
60 F	2150
50 F	1600
40 F	1200
30 F	850
20 F	400

Source: RussTech Admixtures

In cold weather, concrete temperatures should be controlled so that the temperature of the concrete does not go below the concrete temperatures recommended in ACI 306R-88.

ACI 306R-88 Concrete Temperature Recommendations

	Section size, minimum dimension, in.	
Air Temperature	<12 in.	12-36 in.
Minimum concrete temperature as placed and maintained		
****	55F (13C)	50F (10C)
Minimum concrete temperature as mixed for indicated air temperature		
Above 30F (-1C)	60F (16C)	55F (13C)
0 to 30F (-18 to –1C)	65F(18C)	60F(16C)
Below 30F (-18C)	70F(21C)	65F(18C)
Maximum allowable gradual temperature drop in first 24 hr after end of protection		
****	50F(28C)	40F(22C)

The easiest and most practical ingredient to heat in concrete to increase the concrete temperature is the mixing water. If the mix water temperature is increased 4 F the temperature of the concrete will be increased 1 F. In the table below are listed approximate water temperatures needed for a certain concrete temperatures based on various material temperatures.

Concrete Mix Water Temperature Requirements

Cement/Aggregates Temperature	Concrete Temperature	Water Temperature
20F	55F	210F
30F	65F	210F
40F	70F	210F
50F	80F	210F
20F	50F	190F
30F	60F	190F
40F	70F	190F
50F	78F	190F
20F	49F	170F
30F	55F	170F
40F	68F	170F
50F	74F	170F
20F	45F	150F
30F	52F	150F
40F	60F	150F
50F	70F	150F

Source: RussTech Admixtures

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 may be calculated using the following ACI 306 formula:

$$T = \frac{[0.22(T_s W_s + T_a W_a + T_c W_c) + T_w W_w + T_s W_{ws} + T_a W_w]}{[0.22\,(W_s + W_a + W_c) + W_w + W_{wa} + W_{ws}]}$$

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)
W_{wa} = weight of free water on coarse aggregate (lb or kg)

CHEMICAL ACCELERATORS:

Accelerating admixtures meeting the requirements of ASTM C 494, Type C, accelerating; and Type E, water reducing and accelerating; can be particularly effective tools for cold weather concreting. These are some of the advantages theses accelerating admixtures will provide:

- Accelerates set time
- Reduces mixing water
- Increases rate at which heat is generated during hydration – promoting earlier setting and finishing
- Aid in prevention of concrete from freezing when used at higher doses
- Increases early and ultimate strengths
- Earlier use of structural concrete
- Earlier stripping and reuse of forms
- Superior finishability on slabs and Precast

RUSSTECH ADMIXTURES supplies a full line of both non-chloride and chloride-bearing accelerators that will accelerate set times and increase early, as well as, ultimate compressive strengths. Listed in the table below are typical acceleration performance characteristics for both types of accelerators.

ACCELERATION PERFORMANCE AT 50F (AMBIENT & CONCRETE)

	Dosage (ozs/cwt)	Acceleration (hrs:mins)
LCNC-166	10	3:05
(non-chloride-based)	20	4:08
FASTSET 100HE	16	2:55
(chloride-based)	32	4:20

Source: RussTech Admixtures

SUB-FREEZING PLACEMENTS:

In below freezing ambient temperatures (down to 20F), **LCNC-166 and RUSSTECH RCI** non-chloride accelerating admixtures can be incorporated at elevated dosages to provide freeze-resistant concrete with normal setting characteristics that reduce the amount of protection normally required to prevent freezing in the plastic state. For assistance with determining specific recommended freeze-resistant dosages of **LCNC-166 or RUSSTECH RCI**, consult with your local RussTech technical service representative.

CONCRETE CURING:

Concrete must have an adequate amount of moisture around it to have proper compressive strength development and durability. Inadequate curing will cause:

- Weak surface layer
- Plastic shrinkage cracks
- Reduced compressive strength
- Reduced concrete durability

In cold weather, concrete needs to be protected from drying out too quickly. Concrete contractors should plan ahead to prevent surface evaporation by incorporating the use of a surface evaporation retardant, such as **EVRT**, to prevent moisture from escaping from the concrete faster than the concrete is setting up.

ACI 306 recommends membrane forming curing compounds or plastic sheeting for curing in cold weather. Water curing is *not* recommended during cold weather concrete placements.

RECOMMENDATIONS:

Cold weather presents difficulties with concrete usually relating to set time and strength development. ACI 306 cold weather concreting guidelines, if followed, will assure successful and satisfactory results. Listed below are the basic recommendations to be employed during cold weather placements.

1. Use a heated or warm concrete mix
2. Do not allow the concrete to freeze
3. Do not place concrete on a frozen sub-grade
4. Protect concrete from excessive drying
5. Incorporate accelerators to maintain strength and normal set time
6. Avoid rapid changes in concrete temperatures
7. Cure the concrete

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