CRD-C 307-91

# Method for Calculating the Amount of Ice Needed to Produce Mixed Concrete of a Specified Temperature

## 1. Scope

This method is designed to indicate a procedure that may be used as a guide for the calculation of the amount of ice required to be added to a concrete mixture in lieu of water in order to lower the temperature of the concrete as placed to a specified value. The calculations described by this method do not contemplate that heat losses due to batching, mixing, transporting, or placing will be individually measured. It is believed that the effects due to these factors are so widely variable from job to job and from time to time on any single job that they should be compensated for by the use of a temperature differential determined from field observations of the difference between calculated and actual temperatures.

## 2. Information Required

The following information is required to employ the procedures set forth herein insofar as it applies to the particular calculation contemplated.

(a) Batch Masses -The mass in pounds of each ingredient must be known or assumed. A method for selecting proportions for concrete mixtures is given in CRD-C 99.

(b) Specific Heats - The specific heat of each ingredient must be known or assumed. Specific heat of aggregates shall be determined by Method CRD-C 124. Tables of these values for ice may he found in *Handbook of Chemistry* and *Physics*, Chemical Rubber Publishing Co. The specific heat of water will be taken as 1.000 for the calculations described herein

(c) Initial Temperatures -The temperature of each ingredient as it will be added to the batch in the mixer must be known or assumed.

## 3. Procedure

(a) A heat-balance equation shall be set up of the following form:

$$W_c C_c(t_c - t_o) + W_s C_s(t_s - t_o) + W_a C_a(t_a - t_o) + W_{sm} C_{sm}(t_s - t_o) + W_{am} C_{am}(t_a - t_o) + (W_w - W_i) C_w(t_w - t_o) + W_i[(t_i - 32) C_i + (32 - t_o) C_w] - W_i F = 0$$

where:

W = mass of each ingredient in the batch, lb,
C = specific heat of each ingredient, Btu/lb - deg F,
t = initial temperature of each ingredient, deg F,
$t_o$ = temperature for use in computation, to = T - $\Delta t$,
T = specified temperature of concrete as placed, deg F, and
$\Delta t$ = temperature differential between computed and desired temperatures determined empirically, deg F (Note).

Note: This temperature differential compensates for the effects of heat transfer due to batching, mixing, transporting. and placing operations, and early heat of hydration. Since these factors are variable for any project, and also during phases of the project, mathematical computation is not feasible, the value of $\Delta t$ must be determined empirically.

F = heat of fusion of ice = 143.5 Btu/lb,

and the subscripts refer as follows:

c = cement,
s = fine aggregate,
a = coarse aggregate,
w = mixing water,
sm = free moisture in fine aggregate,
am = free moisture in coarse aggregate, and
i = ice.

Note 1: $W_w$ = mass of water added to batch at mixer.

Note 2: The specific heat of ice at 27 F approximately 0.50 Btu/lb - deg F.

(b) By substituting in this equation and solving for $W_i$ a value will be obtained for the mass of ice to be added to the mixture in lieu of an equal mass of mixing water to produce the specified temperature in the concrete as placed.

## 4. Example

The following example is presented as an illustration of the application of the above procedure.

(a) Information Available

| Ingredient | Batch mass lb | Specific heat, Btu/lb-deg F | Initial temperature, deg F |
|---|---|---|---|
| Cement | 188 | 0.28 | 110 |
| Fine agg | 700 | 0.25 | 80 |
| coarse agg | 3300 | 0.22 | 40 |
| Water | 74 | 1.00 | 35 |
| Free moisture in fine agg | 21 | 1.00 | 80 |
| Free moisture in coarse agg | 33 | 1.00 | 40 |
| Ice | - | 0.50 | 25 |

Note: The values given above for specific heat are values for the initial temperatures shown. Very slightly improved accuracy could be obtained if average values for specific heat

over the temperature range from initial temperature to specified temperature were used for each ingredient.

(b) The temperature of the concrete as placed is 55 F; the empirical differential is assumed to have been determined to be 10 F; $t_o$ therefore equals 45 F.

(c) Substituting in the equation given in Sec. 3 gives the following

$$188 \times 0.28 (110 - 45) + 700 \times 0.25 (80 - 45) +$$

$$3300 \times 0.22 (40 - 45) + 21 \times 1.00 (80 - 45) +$$

$$33 \times 1.00 (40 - 45) + (74 - W_i) (1.00) (35 - 45) +$$

$$W_i [(25 - 32) (0.50) + (32 - 45) (1.00)] -$$

$$143.5 W_i = 0$$

$$W_i = 38.3 \text{ lb.}$$

(d) Therefore, for this example, the mass of ice required to be added to the batch to replace an equal mass of mixing water in order for the concrete as placed to be at the specified temperature of 55 F is 38.3 lb.

Note: If upon solution of this equation a negative value is obtained for $W_i$, no ice will be required and the temperature of the concrete to which no ice is added will be lower than that specified.