CRD-C 124-73

METHOD OF TEST FOR SPECIFIC HEAT OF AGGREGATES, CONCRETE, AND OTHER MATERIALS (Method of Mixtures)

1. Scope

1.1 This method of test covers a procedure for determining the mean specific heat (c, heat capacity) of aggregates, concrete, and other materials by the method of mixtures using particles smaller than 1 in. (or 25 mm) in size (Notes 1 and 2).

Note 1.- When more precise values are desired and the specimen may be pulverized or ground to pass a No. 20 sieve the method given in CRD-C 242 should be used.

Note 2.- The term "specific heat" has been used to refer to the dimensionless ratio of the amount of heat required to raise a unit weight of a material 1 deg to the amount of heat required to raise the same unit weight of water 1 deg. However, the quantity referred to as "specific heat" in this method is that also known as heat capacity (c), which is the amount of heat required to raise the temperature of a unit mass of the material 1 deg. When the units of heat used are those for which the heat capacity of water is 1.0, as Btu (International Table)/lb mass-deg F or cal/g-deg C then the numerical values for heat capacity and specific heat are equal. In the metric (SI) system the unit for heat capacity is the joule/kilogram-kelvin (J/kg K) which is numerically equal to the J/kg C. The conversion factor from either Btu/lb mass-deg F or from cal/g-deg C to J/kg C is 4.1868E + 03.

2. Apparatus

2.1 The apparatus used in this test shall consist of:

2.2 Calorimeter.- A calorimeter of the vacuum-flask type with external insulation, large enough to accommodate samples of approximately 2 lb (or 1 kg) in weight placed in a wire basket, and provided with an insulated cover in which are openings for thermometer and stirrer.

2.3 Thermometer.- A thermometer graduated to 0.1 F (0.06 C), in the range 32-150 F (0-65.6 C).

2.4 Constant-Temperature Bath, Hot.- An electrically heated constant temperature bath with thermostat set at 125 ± 1 F (51.7 ± 0.56 C).

2.5 Constant-Temperature Bath, Cold.- A refrigerated bath, with refrigeration thermostatically controlled at 35 ± 1 F (1.67 ± 0.56 C).

2.6 Basket.- A wire-mesh basket, of material of known specific heat, approximately 4 in. (or 100 mm) in diameter by 4 in. (or 100 mm) high.

2.7 Balance.- A balance capable of weighing 5 lb (2.27 kg) with an accuracy of ±0.005 lb (2.3 g).

2.8 Standard Specimen.- A specimen of material of known specific heat, approximately 0.20 Btu/lb-deg F (837.4 J/kg-deg C).

2.9 Timer.- A timer reading in minutes and seconds.

3. Specimen

3.1 For determinations of mean specific heat of aggregates, concrete, and other materials according to the method outlined herein the specimen to be used shall consist of approximately 2 lb (or 1 kg) of the material to be tested. The specimen shall contain no particles larger than 1 in. (or 25 mm) in size. When the material to be tested includes larger particles they shall be crushed before testing.

Note.- If a larger calorimeter is used the weight of the specimen may be increased proportionally.

4. Procedure

4.1 Determination of the Water-Equivalent of the Calorimeter.- Approximately 2 lb (or 1 kg) of water, weighed to the nearest 0.01 lb (4.6 g), shall be placed in the calorimeter. The calorimeter shall be placed in the constant temperature room until temperature equilibrium is attained. A weighed standard specimen of known specific heat shall be placed in the wire basket, the basket shall then be suspended by a fine wire in either the hot or the cold constant-temperature bath until equilibrium is reached (about 15 min). The specimen shall have been weighed previously both dry, and in a dripping condition after immersion. The water carry-over shall be treated as described in Paragraph 5 below. The temperature of the constant-temperature bath and of the water in the calorimeter shall be recorded to 0.05 F (0.03 C), and the standard sample shall be placed

inside the calorimeter. The water in the calorimeter shall be stirred by manually raising and lowering the wire attached to the specimen. This supporting wire shall pass through a minute hole in the cover. Temperatures shall be recorded each minute during the temperature change, and for several minutes after the maximum change has occurred. The time-temperature curve shall then be plotted as indicated by the example given in Fig. 1 and the curve shall be extrapolated as described below to correct for the heat lost during the time the measurements were being taken. The line EGF shall be so drawn that the area BFG is equal to the area EGC. The approximate position of line EGF shall be determined by inspection. The line between points E and F gives the maximum temperature change which the specimen would have attained had there been no heat loss from the calorimeter. This temperature change shall be used in the calculations described in Paragraph 5 below.

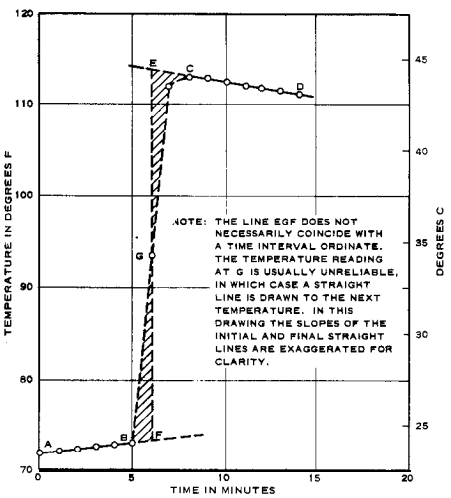

Fig. 1. Time-temperature history, specific heat determination

4.2 Determination of the Mean Specific Heat of Aggregates, Concrete, and Other Materials.- The mean specific heat of an aggregate shall be determined by placing a weighed sample, approximately 2 lb (or 1 kg), in either the hot or the cold water bath, and proceeding as in subparagraph 4.1. The sample shall have been weighed previously both dry, and in a dripping condition immediately after removal from the bath, and the water carry-over shall be treated in accordance with the calculations described in Paragraph 5 below. At least seven determinations shall be made. Hot and cold specimens shall be tested alternately in order to prevent the temperature of the water in the calorimeter from becoming greatly different from the room temperature, so that heat losses will be small or negligible.

5. Calculations

5.1 The water equivalent of the calorimeter and the mean specific heat of the sample of aggregate shall be calculated from the following formulas:

5.2 Water Equivalent.-

$$M_e = \left[\frac{(c_s M_s T + c_1 M_o T + c_b m_b T)}{c_1 T_1} \right] - M_1$$

where

M_e = water equivalent of calorimeter, lb (kg),

c_s = mean specific heat of standard, B/lb-deg F (J/kg-deg C),

M_1 = weight of water placed in calorimeter, lb (kg),

c_1 = mean specific heat of water, B/lb-deg F (J/kg-deg C),

Note.- The specific heat of water may be assumed to be 1.000 Btu/lb-deg F (4186.8 J/kg-deg C) without significant error.

T_1 = temperature change of water, corrected for heat loss, deg F (C),

M_s = weight of samples, lb (kg),

M_o = weight of water carry-over, lb (kg),

T = temperature change of sample, corrected for heat loss, deg F (C),

c_b = specific heat of basket, B/lb-deg F (J/kg-deg C),

M_b = weight of basket, lb (kg).

5.3 Mean Specific Heat.-

$$c_s = \frac{(M_l + M_e)\, c_l T_1 - (M_o c_l + M_b c_b)\, T}{M_s T}$$

where:

c_s = mean specific heat of specimen, B/lb-deg F (J/kg-deg C), and the remaining symbols have the same meaning as above.