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01/09/2009 10:13 FAX 9784993933 COMMONWEALTH CANVAS 001

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Report on the

Apparent Thermal Resistance of Concrete Curing Blanket Systems

NETZSCH was contracted by Commonwealth Canvas to evaluate two concrete curing blanket systems for apparent thermal resistance at a nominal mean temperature of 0°C (32°F).

Two blankets were received and identified as given in Table 1. The blankets were received approximately 12 inches square. The tested systems consisted of the blanket on top of an air space of approximately 3 inches. The blanket thickness was measured and the air gap was created using 1 inch wide foam walls positioned around the perimeter of the central metering area and outer sample area. The samples were positioned horizontally with heat flow down during the tests.

The test results are given in Table 1 after a description of the procedure. This report shall not be reproduced, except in full, without the written approval of NETZSCH.

Thermal Conductivity

Thermal conductivity is the material property that determines the amount of heat that will flow through an object when a temperature difference exits across the object. Thermal conductivity is a steady state property; it can only be directly measured under conditions in which the temperature distribution is not changing and all heat flows are steady. The fundamental equation that governs steady-state heat flow in a slab geometry is:

$$Q = (\lambda \times \Delta T \times A) / \Delta x \quad (1)$$

where

Q = the rate of heat flow through the slab (W or Btu/h)

λ = the thermal conductivity of the slab material (W/m K or Btu/h ft °F)

ΔT = the temperature difference across the slab (°C or °F)

Δx = the thickness (m or ft)

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A = the cross sectional area (m^2 or ft^2)

Materials that have low values of thermal conductivity allow only a small amount of heat flow and are called thermal insulators. Materials with large values of thermal conductivity allow more heat to flow across the slab with the same temperature difference. Thermal conductivity is a material property and does not depend upon the geometry of the sample. In general, thermal conductivity is a function of the mean sample temperature. The material comprising the slab is often a mixture of materials. It could be a layered composite or a material containing gas cells in which heat can be transferred by convection and radiation as well as by conductivity through the material. In these cases the parameter, λ, defined in Equation (1) is an "effective" or "apparent" thermal conductivity for the heterogeneous material.

Experimental Procedure for Testing by ASTM C518-98

Testing was performed according to the procedure given in ASTM C518-98, *Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Meter* utilizing a Netzsch Model Lambda heat flow meter instrument. The specimen was installed horizontally between 300mm (12 inch) square aluminum surface plates treated to have a total hemispherical emittance of 0.86 at 24°C (75°F). The surface plates were smoothly finished to conform to a true plane within 0.25 percent. Above the upper (hot) and below the lower (cold) surface plates, heaters, heat sinks and insulation were installed. The two heat sink assemblies were connected to a fluid system capable of cooling the heat sink as required. Temperature control of the surface plates was accomplished by operating the fluid system continuously and reheating with the electrical heaters. The temperatures of the surface plates were controlled and monitored by temperature sensors mounted near the heaters and in the surface plates.

Between the test specimen and each surface plate, a heat flux transducer was installed. The instrument heat flux transducers utilized have sensing areas 100 mm (4 inches) square located in the center of the 300 mm (12 inch) square overall area.

Temperature measurements were performed by utilizing Type-K Chromel/Alumel thermocouples calibrated to the special limits of error specified in ASTM E230, *Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples*. All thermocouple sensors were fabricated with # 30 AWG wire. Single temperature sensors were used for measuring the hot and cold surface plate temperatures in the center of the sensing area of the instrument heat flux

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transducer. All temperature sensors were individually connected to a Lawson Labs Data Acquisition Unit having a resolution of ± 1 microvolt.

The top surface plate assembly could be adjusted to accommodate surface plate separations from 0 to 100 mm (0 to 4 inches). The opening between the surface plates was measured by using a linear motion potentiometer. The periphery of the test stack was lined with 50 mm (2 inches) of an extruded polystyrene foam insulation having a thermal resistance of about 1.8 m^2-K/W (10 hr-ft^2-°F/Btu) at 24 °C (75 °F).

In operation, the plate separation was adjusted to accommodate the test thickness of the specimen being evaluated. Typically the thickness of the specimen was measured prior to its insertion into the instrument and the plates were closed such that the thickness readout corresponded to the average thickness of the specimen. The temperatures of the top and bottom surface plates were adjusted such that the mean temperature and temperature difference test requirements were satisfied. If no temperature difference requirements were given, 28 °C (50 °F) was used.

At equilibrium, established after ensuring that during two regular sets of fifteen – one minute readings the test specimen apparent thermal conductivity changed less than 0.1 percent and not monotonically, the temperatures of both hot and cold faces were evaluated from the sensors embedded in the plates, and the heat flux through the specimen was derived from the heat flux transducer output.

The apparent thermal conductivity was calculated from

$$\frac{(S_I) \times (HFTOP)_I \times \Delta x}{\Delta T}$$

and the thermal resistance was calculated from

$$R = \Delta x / \lambda,$$

where

λ = apparent thermal conductivity
S_I = instrument heat flux transducer sensitivity
$HFTOP_I$ = instrument heat flux transducer output
Δx = test specimen thickness
ΔT = temperature difference across test specimen
R = thermal resistance

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The instrumentation was calibrated using the National Institute of Standards and Technology Standard Reference Material 1450b. The calibration specimen is a high-density fibrous glass material, 25.4 mm (1.00 inch) thick, having a thermal resistance of approximately 4.2 hr-ft^2-°F/Btu. The instrumentation was calibrated or verified within 24 hours before and after the test.

Test Results

The test results are given in Table 1. The results reported apply only to the blanket plus 3 inch air gap system with heat flow down that was tested. The results are expected to be accurate to within ±7%.

Table 1

ASTM C 518 THERMAL CONDUCTIVITY TEST RESULTS

Specimen	Test Thickness		Test Density		Mean Temperature		Apparent Thermal Conductivity		Apparent Thermal Resistance	
	mm	inch	kg/m^3	lbs/ft^3	°C	°F	SI	British	SI	British
Concrete curing blankets with with approx. 3 inch air space										
CC-2	85.8	3.38	n/a	n/a	-1	31	0.162	1.12	0.530	3.01

Thermal Conductivity SI Units: W/m-K
Thermal Conductivity British Units: Btu-in/hr-°F-ft^2
Thermal Resistance SI Units: m^2-K/W
Thermal Resistance British Units: hr-°F-ft^2/Btu