Estimating Fresh Concrete Temperatures

Infrared thermometers provide rapid check

BY LUKE M. SNELL AND MARK A. CHEEK

Because the temperature of concrete can affect workability, air content, time of set, and rate of strength development, as well as placement and curing procedures, accurate on-site temperature measurement is an important element in any quality control program. This is especially true when concrete temperatures approach limiting values. For example, in hot weather, ready mixed concrete producers can use chilled water, ice, or retarders when concrete temperatures approach 90 °F (32 °C). Conversely, in cold weather, the producer can add heated water or accelerators when the concrete temperatures approach 40 °F (4 °C). To make sure these changes to the mixture are achieving the desired results, the producer needs to determine the job-site temperature of each load of concrete.

Concrete temperatures for quality assurance are obtained using procedures specified in ASTM C 1064, "Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete."[1] This method requires the use of a temperature-measuring device capable of measuring temperatures ranging from 30 to 120 °F (0 to 50 °C), with an accuracy of ±1 °F (±0.5 °C), when submerged at least 3 in. (75 mm) in a fresh concrete sample for at least 2 minutes (or until the reading stabilizes). The temperature-measuring device can be an armored, glass thermometer or an electronic temperature meter. Testing is to be completed within 5 minutes after acquiring the sample. Normally, because acquiring a sample and measuring the temperature can interfere with placement procedures, this test is run only when specified in the contract documents.

INFRARED THERMOMETERS

Because infrared (IR) thermometers measure infrared radiation emitted by an object, the surface temperature can be measured without any physical contact. IR thermometers are therefore useful as simple, fast tools for measuring the temperature of objects that are hard to physically access. As shown in Fig. 1, the user simply points the IR thermometer at the object and "shoots." In less than a second, the temperature is displayed on a digital display on the thermometer. Thus, the temperature can be determined without interfering with the progress of the work at hand.

Although no special training is required to use the instrument, manufacturers have a few recommendations[2] that help keep the measurements as accurate as possible. First, users should note that IR thermometers measure temperature over an area, not at a point (the small dot from the laser provided on many units is only to help aim the instrument). An optical system in the thermometer collects the infrared energy from a circular measurement area and focuses it on the detector—the diameter of the measurement area is therefore a function of the resolution of the optical system, normally characterized by the manufacturer as a ratio. This ratio, multiplied by

Fig. 1: Taking temperature measurements with an infrared thermometer is as easy as pointing at the object and pulling the trigger

the distance to the object being measured, provides the diameter of the measurement area.

The object being measured should be at least twice as big as the measured area.

Users should keep in mind that steam or dust in the air can obstruct the thermometer's field of vision, decreasing its accuracy. Also, if the thermometer is exposed to a rapid change in temperature, it should be given time to adjust to the new conditions before use. Finally, the thermometer should be checked regularly by testing it on an object with a known temperature.

As mentioned previously, the instrument only measures surface temperature. Therefore, it's necessary to determine where in the placement process it should be used to provide the best estimate of job-site concrete temperature.

TEST PROGRAM

To compare the standard concrete temperatures measured in accordance with ASTM C 1064 with those measured using IR thermometers, four sets of temperature measurements were collected. Data Sets 1 and 3 were obtained at construction projects in the St. Louis, MO, metropolitan area, and Data Sets 2 and 4 were obtained in New Orleans, LA, and Gallup, NM, respectively. For each data set, the standard temperature was measured during the process of performing routine quality assurance tests. For each batch of concrete on which quality assurance tests were performed, temperatures were also measured using an IR thermometer at the following three locations:

TABLE 1:
Results of statistical analyses of differences between standard and IR temperature readings

	Temperature difference*		
	$T_W - T_S$	$T_C - T_S$	$T_D - T_S$
Number of data points:			
Data Set 1	29	29	29
Data Set 2	30	30	30
Data Set 3	5	6	0
Data Set 4	23	23	23
Total	87	88	82
Maximum, °F (°C)	5 (2.8)	8 (4.4)	12 (6.7)
Minimum, °F (°C)	−16 (−8.9)	−16 (−8.9)	−17 (−9.4)
Average, °F (°C)	−1.9 (−1.1)	−1.7 (−0.9)	−0.4 (−0.2)
Standard deviation, °F (°C)	3.5 (1.9)	3.7 (2.1)	5.7 (3.2)

* T_S = Standard concrete temperature measured per ASTM C 1064; T_W = IR temperature measurement for the concrete in the wheelbarrow or forms; T_C = IR temperature measurement for the concrete in the chute; and T_D = IR temperature measurement for the surface of the mixing truck drum.

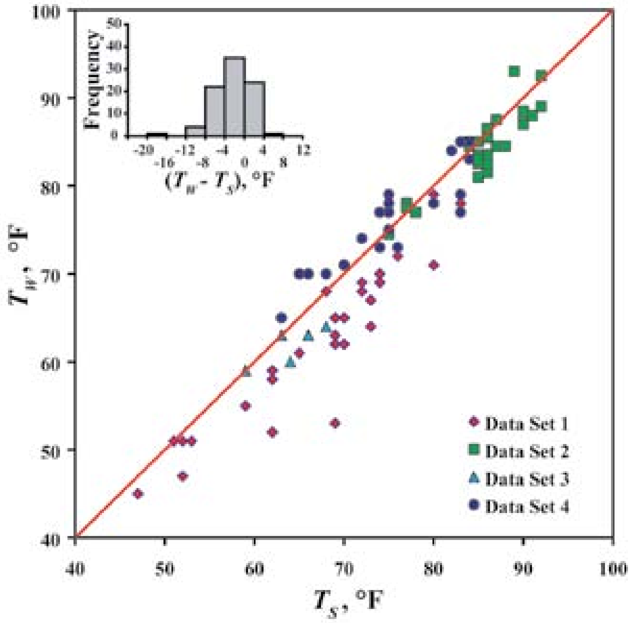

Fig. 2: Comparison of standard temperatures measured per ASTM C 1064 versus temperatures measured with an IR thermometer on the concrete in a wheelbarrow or the forms. Red line indicates equal temperatures measured using the two methods (°C = 5/9 × [°F – 32])

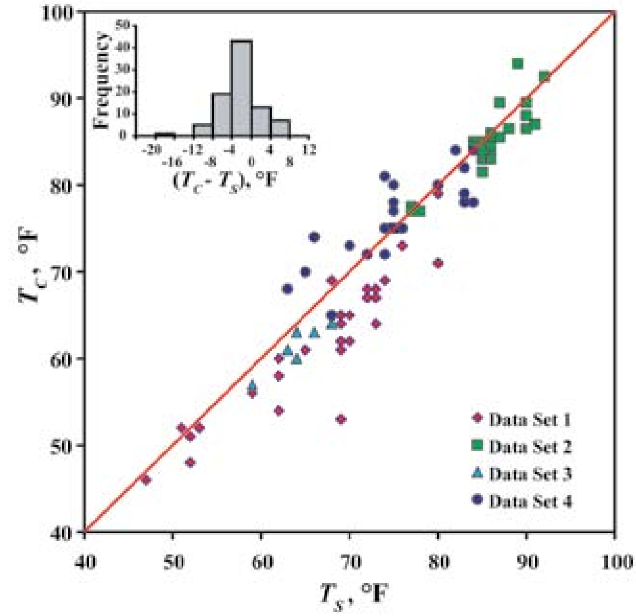

Fig. 3: Comparison of standard temperatures measured per ASTM C 1064 versus temperatures measured with an IR thermometer on the concrete in the chute as it was being discharged. Red line indicates equal temperatures measured using the two methods (°C = 5/9 × [°F – 32])

- The concrete in a wheelbarrow or in the forms;
- The concrete in the chute as it was being discharged from the mixing truck drum; and
- The surface of the mixing truck drum during discharge of the concrete.

In Data Set 3, the temperature of the mixing truck drum was not recorded, and the temperature of the concrete in the wheelbarrow was not recorded for one data point. Each set of temperature measurements was taken over a span of several days by various testing technicians. In each data set, the IR temperatures were measured using the same IR thermometer, but different thermometers were used between data sets. All of the temperature measurements were taken by ACI certified field testing technicians with no formal training in the use of IR thermometers.

COMPARISONS

The standard concrete temperatures (T_S) ranged from 47 to 92 °F (8.5 to 33.5 °C) with the majority of the temperatures (70 out of 88) above 72 °F (22 °C). In Fig. 2, 3, and 4, the standard temperatures are plotted versus the IR temperatures measured for the concrete in the wheelbarrow or forms (T_W), the concrete in the chute (T_C), and the mixing truck drum (T_D), respectively. To analyze the difference between the standard and IR temperatures, the standard temperature was subtracted from the IR temperature for each data point shown in the figures. The results of a statistical analysis of these differences are shown in Table 1. Histograms of the difference values are inset on the graphs in Fig. 2 to 4.

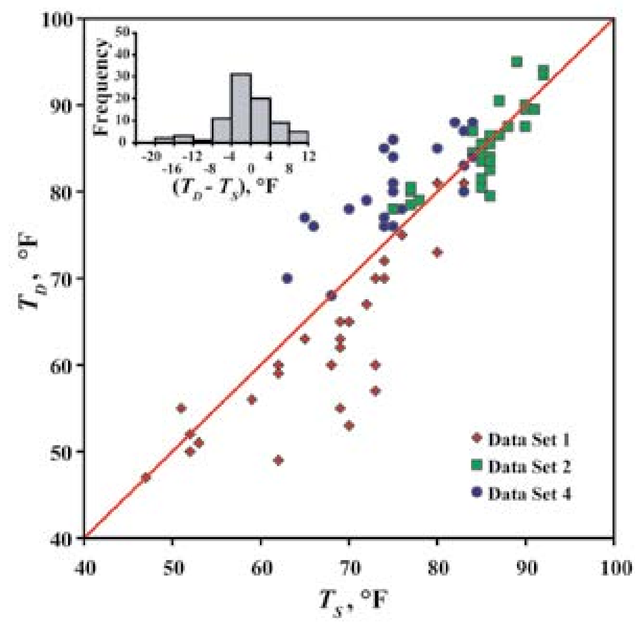

Fig. 4: Comparison of standard temperatures measured per ASTM C 1064 versus temperatures measured with an IR thermometer on the surface of the mixing truck drum. Red line indicates equal temperatures measured using the two methods (°C = 5/9 × [°F – 32])

For the data collected, the differences for $T_W - T_S$ and $T_C - T_S$ were very similar, with averages of –1.9 and –1.7 °F (–1.1 and –0.9 °C) and standard deviations of 3.5 and 3.7 °F (1.9 and 2.1 °C), respectively. These results mean that the IR temperatures underestimated the standard temperature by about 2 °F (1 °C) and, because about 95% of the data in a normal distribution are within two standard deviations of the average, 95% of the IR temperatures were between about 9 °F (5 °C) below and 5 °F (3 °C) above the standard temperatures. The differences for $T_D - T_S$ had an average value closer to zero at –0.4 °F (–0.2 °C), but had a larger standard deviation of 5.7 °F (3.2 °C), resulting in 95% of the data being between 12 °F (7 °C) below and 11 °F (6 °C) above the standard temperature. Clearly, IR temperature measurements of the drum did not estimate the standard temperature of the concrete as well as direct IR temperature measurements of the concrete.

A HELPFUL TOOL

IR thermometers can be used at job sites as auxiliary equipment along with standard test equipment. The authors are not suggesting that the IR thermometer be used in place of measurements per ASTM C 1064, but they can be useful for determining when concrete temperatures are near the point where steps must be taken to adjust the temperature or as a quick check of these steps between routine quality assurance tests. This will allow tracking of temperature changes to spot any irregularities in concrete temperatures at the time of delivery.

Infrared technology is relatively new and is not fully used in concrete construction. These devices can be used whenever estimates of temperatures are needed or when comparison temperatures are required. These applications can be as diverse as documenting cold weather concrete curing methods, ensuring concrete is not placed on frozen ground, or monitoring the temperatures of steel forms and reinforcement. When used properly, IR thermometers can become a valuable tool for several temperature-related issues on job sites.

References

1. ASTM C 1064/C 1064M-05, "Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete," ASTM International, West Conshohocken, PA, 2005, 3 pp.

2. http://www.raytek-northamerica.com.

Selected for reader interest by the editors.

Luke M. Snell, FACI, is the Director of the Concrete Construction Resource Unit and a Professor of Construction Management at Southern Illinois University-Edwardsville (SIUE), Edwardsville, IL. He is Chair of ACI Committee 120, History of Concrete, and the ACI International Committee. Snell is a member of the ACI Chapter Activities Committee and several other ACI technical and educational committees. He has been on the SIUE faculty for more than 20 years.

Mark A. Cheek, FACI, is Vice President of Beta Testing & Inspection, LLC, New Orleans, LA. He has more than 15 years of experience in construction materials testing and inspection. He is a member of the ACI Chapter Activities Committee, the ACI Certification Programs Committee, and ACI Committees C 610, Field Technician Certification; 214, Evaluation of Results of Tests Used to Determine the Strength of Concrete; 228, Nondestructive Testing of Concrete; and the ACI Young Member Award for Professional Achievement Committee.