

# Monitoring Temperatures in Concrete Construction Using IR Thermometers

by Luke M. Snell

**P**roject specifications can impose limits on the temperatures of concrete constituents, fresh concrete, embedments, casting surfaces, and formwork. In many cases, infrared (IR) thermometers can be helpful tools.

## Use of the IR Thermometer

Objects that are warmer than absolute zero temperature give off IR radiation—electromagnetic radiation with wavelengths between those of visible red light and radio waves. Although we cannot see this energy, we can feel it because it heats objects that it strikes. An IR thermometer simply collects and focuses IR radiation on a detector that converts it into an electrical current; the current increases with the temperature of an object giving off the radiation.

Handheld IR thermometers have been found to work well in the relatively narrow temperature range commonly seen in concrete construction: 0 to 120°F (−20 to −45°C). A search on the Internet will find several inexpensive units in “pistol” or “pocket watch” styles. While the style is not critical to performance, the device has to be robust for use on construction sites. So I recommend that prospective buyers read user reviews carefully and select the IR thermometer that others have found to be dependable. Based on my own experiences, IR thermometers advertised in the mid- to upper-price ranges will meet most needs.

Many IR thermometers have laser pointers. While a pointer is not a part of the IR technology and is not necessary for successful use, it is helpful for verifying that the device is capturing radiation from the intended source. To use an IR thermometer, the operator simply points it at the desired object, pulls the trigger, and reads the temperature on the display. Although IR thermometers are simple to use and provide readings within seconds, there are some things that the operator must recognize:

- An IR thermometer measures only an object’s surface temperature at a single point, not interior or average temperatures. Using the human body as an example, a healthy individual’s core body temperature is typically found

to be about 98.6°F (37°C) when measured with a thermometer under the tongue. I have observed that an IR temperature reading taken on a hand, however, might indicate a surface temperature ranging from about 86 to nearly 97°F (30 to 36°C), depending on ambient temperature.

- Most IR thermometers provide temperatures based on a fixed emissivity value of 0.95. Emissivity is defined as ratio of the energy radiated from a material’s surface to the energy emitted from a blackbody (a perfect emitter) at the same temperature, wavelength, and under the same viewing conditions.<sup>1</sup> Emissivity is thus a dimensionless number between 0 (for a perfect reflector) and 1 (for a perfect emitter). For most items encountered in the construction industry, an emissivity of 0.95 is a reasonable value (reported emissivity values for concrete range between 0.85 and 0.95<sup>2</sup>). IR thermometers shouldn’t be used to measure temperatures of shiny aluminum, polished steel, mirrors, or glass. An IR thermometer also shouldn’t be used to measure the temperature of an object on the other side of a window. The reading will include radiation from the glass itself (and because of the reflectance and transmittance of the glass, even that reading will likely be wrong).<sup>3</sup>
- IR thermometers measure very small changes in current, and the measurements could be affected by changes in the temperature of the device itself. Therefore, an IR thermometer should be kept at a constant temperature while using it. In cold weather, I keep the IR thermometer in my coat pocket. I remove it only as long as needed to take a reading, and then I immediately return it to my pocket until I need to take another reading.<sup>4</sup>
- An IR thermometer can’t take an accurate reading if there is dust, smoke, and/or rain between the sensor and the object. So don’t use the thermometer under those conditions. Also, use a soft cloth to clean the lens on the IR thermometer before each use.<sup>5</sup>
- An IR thermometer must be relatively close to an object when determining its temperature. The appropriate distance is defined by the instrument’s distance-to-spot ratio ( $D:S$ ), which is given

in the thermometer's specification. Most IR thermometers have a  $D:S$  ranging from 8:1 to 10:1, meaning that the IR thermometer should be no farther than 8 to 10 in. (200 to 250 mm) away from an object that is 1 in. (25 mm) in diameter. For determining temperature of soil or concrete slab, I would advise taking several readings as close to the slab as possible.

- IR thermometers use a Class II laser to identify the measurement location. This is the same laser that is used as a pointer for slide presentations. This type of laser does not give off harmful radiation or influence the surface temperature of the object being evaluated. However, the beam should not be directed at any person, as eye damage may result. The user should also avoid indirect exposure caused by reflections off glass, mirrors, or shiny objects.<sup>6,7</sup>
- An IR thermometer is not a toy and should not be used by children without adult supervision.
- As with any thermometer, an IR thermometer needs to be checked for accuracy. I recommend checking temperatures against a reference thermometer by taking readings of materials that are at least 30°F (16°C) apart. Precise calibrations can be made using an IR comparator,<sup>8,9</sup> but I also use concrete samples and a standard concrete thermometer for calibrations. If measurements indicate that the device is not functioning correctly, it should be returned to the supplier for recalibration.

## When to Use IR Thermometers

I have used IR thermometers for checking fresh concrete temperatures. Also, I've identified other applications mentioned in ACI documents, where an IR thermometer would be an appropriate tool for temperature monitoring or control.

## Measuring Fresh Concrete Temperatures

ASTM C31/C31M, "Standard Practice for Making and Curing Concrete Test Specimens in the Field," requires that temperatures be taken whenever concrete is to be sampled. This test (designated by ASTM C1064/C1064M) measures the internal temperature of the concrete. The temperature measuring device used for testing freshly mixed concrete must be capable of accurately measuring temperature to  $\pm 1^\circ\text{F}$  ( $0.5^\circ\text{C}$ ) per ASTM C1064/C1064M, "Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete." An IR thermometer typically has an accuracy ranging from 2 to 3°F (1 to 1.5°C), so it doesn't meet the standard. However, an IR thermometer can still be used for spot checking throughout a long placement.

I have used IR thermometers to measure concrete temperatures on several concrete samples and found that the internal concrete temperature can be evaluated as the concrete enters the chute (as it is being discharged from the truck) or immediately after it is collected in a wheelbarrow.<sup>10,11</sup>

Although the IR measurements do not replace the required ASTM temperature test, they do make it possible to get an estimate of the concrete temperature without interfering with the placements. Standing a safe distance away, the user can "shoot" the concrete as it is being discharged. This can be extremely valuable

temperature information for the batch plant, especially when the placements are approaching temperature limits.

## ACI 306R, Guide to Cold Weather Concreting<sup>12</sup>

4.4—"The actual temperature of the concrete surface determines the effectiveness of protection, regardless of ambient temperature. Therefore, it is desirable to monitor and record the concrete temperature. ...Record concrete temperatures at regular time intervals, but not less than twice per 24-hour period. Include temperatures at several points within the enclosure and on the concrete surface, corners, and edges. There should be a sufficient number of temperature measurement locations to show the range of concrete temperatures throughout the structure."

When using protection during cold weather concreting, concrete surface and internal temperatures must be monitored with temperature measuring devices that are left in place throughout the protection period. An IR thermometer does not measure internal temperatures and is not a device that can be "left in place," so it cannot be used as the only thermometer. However, it is logical to use it to supplement the surface thermometer. An IR thermometer will allow the contractor to take several (sufficient) temperature readings to determine the range of concrete temperatures throughout the structure.

5.6—"Heat aggregates sufficiently to eliminate ice, snow, and frozen lumps of aggregate. ...Avoid overheating so that the spot temperatures do not exceed 212°F (100°C) and the average temperature does not exceed 150°F (65°C) when aggregates are added to the batch."

If the concrete is too hot, water demand increases and air entrainment is difficult to control in the fresh concrete. An IR thermometer can be used to quickly scan the heated aggregates to make sure that the stated recommendations are followed.

## 5.7—Calculation of Mixture Temperature

A complex formula is given to estimate the temperature of a concrete mixture. This formula requires knowing the temperature and mass (weights) of each ingredient in the concrete mixture. A detailed discussion of how to use this formula is given in references; refer to "Batching of Concrete in Cold Weather."<sup>13</sup> Research done on projects in Mongolia indicates that an IR thermometer can provide the necessary temperature data for these equations.

6.2—"...any embedment having a cross-sectional area greater than 1 in.<sup>2</sup> (650 m<sup>2</sup>) should be no colder than 10°F (-12°C) immediately before placing the concrete at 56°F (13°C) around it. Ideally, the embedment should be heated to the temperature of the concrete immediately before concrete placement. ...The contractor should prepare, as part of his placement plan, the methodology for determining the temperature of embedments using infrared thermometers or similar devices..."

This section references a particular research study and provides guidance to the contractor. According to this research, IR thermometers are an effective means of determining if the embedment needs to be heated or if it is at a satisfactory temperature.

6.3—"Concrete should not be placed on frozen subgrade."

If the subgrade is below freezing or if the temperature is much higher or lower than the subgrade, this can result in

differential rates of setting between the top and bottom of the concrete. This can also result in plastic shrinkage cracking, blistering and/or delaminations.

An IR thermometer will allow the user to easily assess the temperatures of the subgrade by measuring the temperatures of the soil surface at several locations and determining if the temperature of the subgrade is above freezing.

#### ACI 305R, Guide to Hot Weather Concreting<sup>14</sup>

6.2.6—“For moist curing, use water with a temperature no more than 20°F (11°C) cooler than the concrete temperature to avoid thermal shock....”

An IR thermometer can be used to measure the surface temperature of a water conduit or tank. Measurements should be checked with a standard concrete thermometer, however, to verify that the finish on the measured surface doesn't create erroneous readings. Also, note that readings can be made only after the container and water temperatures equilibrate.

#### ACI 302, Guide for Concrete Floor and Slab Construction<sup>15</sup>

4.6—“When slabs are placed on ground, there shall be no more than 30°F (17°C)—ideally 20°F (11°C)—difference between the temperature of the base and concrete at the

time of placement.”

An IR thermometer will allow the contractor to take several readings of both the base and the concrete during placement to make sure the temperatures ranges are adequate.

4.6—“Temperatures inside the building should be maintained above 50°F (10°C) during placing, finishing, and curing the concrete.”

An IR thermometer can help the contractor to determine if heaters are needed.

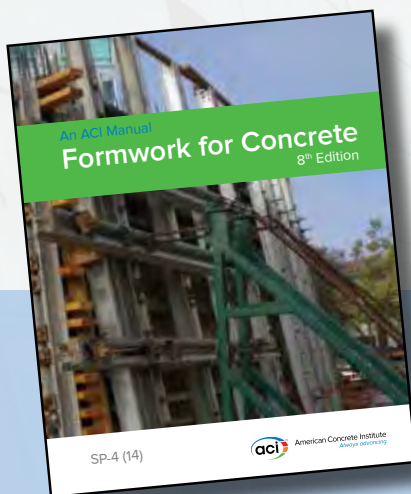
#### ACI 301, Specifications for Structural Concrete<sup>16</sup>

4.2.2.6—“When the average of the highest and lowest ambient temperature from midnight to midnight is expected to be less than 40°F (5°C) for more than three successive days, deliver concrete to meet the following minimum temperature immediately after placement:

- 55°F (13°C) for sections less than 12 in. (300 mm) in the least dimension;
- 50°F (10°C) for sections 12 to 36 in. (300 to 900 mm) in the least dimension;
- 45°F (7°C) for sections 36 to 72 in. (900 mm to 1.8 m) in the least dimension; and
- 40°F (4°C) for sections greater than 72 in. (1.8 m) in the least dimension.

# Formwork for Concrete

Completely revised and updated; still the formwork reference of choice



The 8th Edition, authored by David W. Johnston, North Carolina State University, is a major revision of the document to bring it up-to-date with “Guide to Formwork for Concrete (ACI 347R-14).” Revisions include referencing current standards and practices, removing outdated or irrelevant material, adding content on new developments in formwork technology and practice, and updating the look and layout of the document.

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*“The temperature of concrete as placed shall not exceed these values by more than 20°F (11°C).”*

These requirements are twofold. Concrete gives off a lot of heat during the hydration process. Larger sections will create their own heat, thus allowing the contractor to place the concrete at a lower concrete temperature. The second part of this is to limit the temperatures to no more than 20°F (11°C) above these minimum values. If the concrete is too hot, it can flash set and have a greater risk for shrinkage cracks. An IR thermometer can provide a quick temperature check on each load of concrete to make sure these limits are being obtained and to provide guidance for modifications to the mixing procedures if necessary.

*“Unless otherwise specified or permitted, the temperature of concrete as delivered shall not exceed 95°F (35°C).”*

An IR thermometer again allows the user to test each truck and to provide feedback to the batch plant if the concrete is approaching this limit.

5.3.2.1.b—*“Unless otherwise permitted, do not place concrete in contact with surfaces less than 35°F (2°C).”*

This specification is to include all surfaces that concrete can be cast against and to ensure the heat in the concrete is not appreciably reduced by the cold forms. An IR thermometer allows the user to quickly assess the surface temperatures or the forms and make sure they are above 35°F (2°C). If the surface needs to be heated, an IR thermometer can be used to verify when the required temperature has been reached.

5.3.2.1.c—*“When temperature of reinforcement, embedments, or forms is greater than 120°F (50°C), use a fine mist of water to moisten the hot surface immediately before placing concrete.”*

In periods of intense sunshine and hot weather, reinforcement, embedments, and/or forms will often be warmer than 120°F (50°C). An IR thermometer can be used to quickly measure the temperatures of these items.

5.3.6.5—*“Immediately after placement, protect concrete from premature drying or excessively hot or cold temperatures...Remove protection so that the maximum decrease in temperature measured at the concrete surface in a 24-hour period shall not exceed the following:*

- 50°F (13°C) for sections less than 12 in. (300 mm) in the least dimension;
- 40°F (10°C) for sections from 12 to 36 in. (300 to 900 mm) in the least dimension;
- 30°F (7°C) for sections 36 to 72 in. (900 mm to 1800 mm) in the least dimension; and
- 20°F (4°C) for sections greater than 72 in. (1800 mm) in the least dimension.

*“Measure concrete temperature using a method acceptable to the Architect/Engineer, and record the concrete temperature.”*

In cold weather, the contractor may use plastic covering or blankets over the concrete. Section 7.2 of ACI 306R outlines a procedure for the contractor to monitor the temperature of in-place concrete: *“place temperature probes near the corners or*



**There are many IR thermometers on the market. Shown are examples of the typical pistol grip and pocket watch styles**

*edges of the member where ambient temperature influence is most critical.”* The contractor may ask the Architect/Engineer to approve the use of IR thermometer to accomplish the required monitoring by lifting the covering to briefly expose the surface. If approved, IR temperature readings should be taken and recorded twice a day for the specified protection/curing period.

### ACI-CRSI Certification, Adhesive Anchor Installer<sup>17</sup>

*“Provided that the adhesive was properly stored, the concrete temperature and moisture content will have a more significant impact on the bonding characteristics of the adhesive than the air temperature to which it will have limited exposure. An inexpensive tool that can be used to check the temperature of the hole is the hand-held infrared temperature gun. It is a highly recommended tool for an installer to use prior to injecting adhesive into the hole.”* (Condition of Concrete section in Chapter 4)

This document specifically recommends the use of an IR thermometer to measure the temperature of the concrete. It points out that air temperatures should not be used and that the temperature of the concrete surrounding the hole is more significant for adhesive anchor installation.

### Summary

An IR thermometer is a valuable tool for evaluating the surface temperature of an object. Note that this article is not an exhaustive study of all of the possible situations where IR thermometers might be used in concrete construction. As users gain confidence and experience with this equipment, it's anticipated that other unique applications for IR thermometers will be found.

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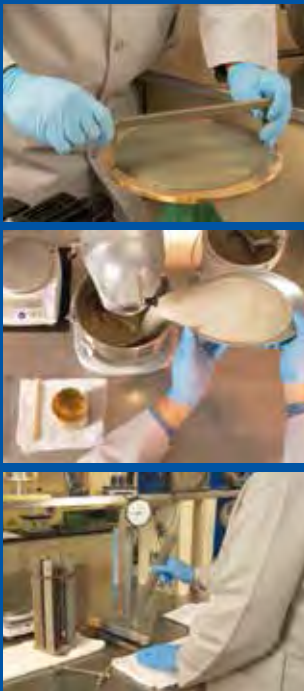
Note: Additional information on the ASTM standards discussed in this article can be found at [www.astm.org](http://www.astm.org).

Selected for reader interest by the editors.



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- ▶ ASTM C266 – Gillmore Time of Setting
- ▶ ASTM C1437 – Flow of Mortar

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