iButton Thermocon: Economically Measure Mortar Temperature Generation to Estimate Time of Set

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ABSTRACT

When marketing a fly ash source for use in concrete products, it is important to understand the impacts of the source on the concrete time of set. Understanding time of set after concrete placement is extremely important to the customer as it often has a direct impact on construction production activities. Accurate measurements create efficiencies in the construction process so that concrete can be finished, forms can be stripped timely and the subsequent activities can continue. However, the current standard method (i.e., using a penetrometer) to measure mortar time of set can be costly and labor intensive since this method requires continual monitoring and notation of resistance measurements.

Mortar time of set correlates to temperature generation through “heat of hydration.” Temperature generation over time can be measured effectively with the use of a calorimeter. However, calorimetry equipment is expensive and not practical for most applications. An alternative instrument that can measure temperature generation over time is the iButton Thermocon. These instruments are practical, easy to obtain. While not as precise as a calorimeter, this instrument will provide data that is reliable and can be useful in estimating set times of various cementitious mix combinations.

PURPOSE

The current standard method to measure a concrete mix's time of set requires using a penetrometer to collect continual resistance measurements. This method can be very time consuming and labor intensive. Waste Management CCP Solutions (WM CCP Solutions) developed an alternate approach to determine concrete time of set by measuring temperature generation over time. Time of set for concrete mixes correlates to temperature generation through "heat of hydration." Instead of using a calorimeter, the current standard method, WM CCP Solutions used an iButton Thermocon, an inexpensive, easy to obtain instrument. Our approach uses equipment that is typically available in most laboratories and is relatively inexpensive to perform.

EQUIPMENT AND MATERIALS

Equipment required for this process includes the iButton elements (i.e., reader, software, and iButton), items for creating the cement mix (i.e., mixer, spatula, scoop, scale), and equipment to cast the mix (i.e., 2"x4" cylinder molds, insulated thermos, filter paper, thermometer, and tongs). Figure 1 provides images of the equipment required during this process. The required materials include the ingredients for the cement mix (i.e., dried concrete sand [100% passing #4 sieve], portland cement, water, and fly ash).

Figure 1. Required Equipment

A. 2x4" Cylinder Molds, No cap necessary
B. Insulated Thermos
C. Scale, Measuring ≥ 1500g
D. Filter Paper, < 2" Diameter
E. iButtons
F. Thermometer
G. Tongs
H. Silicone Spatula
I. 2oz. Scoop

Figure 1. Required Equipment

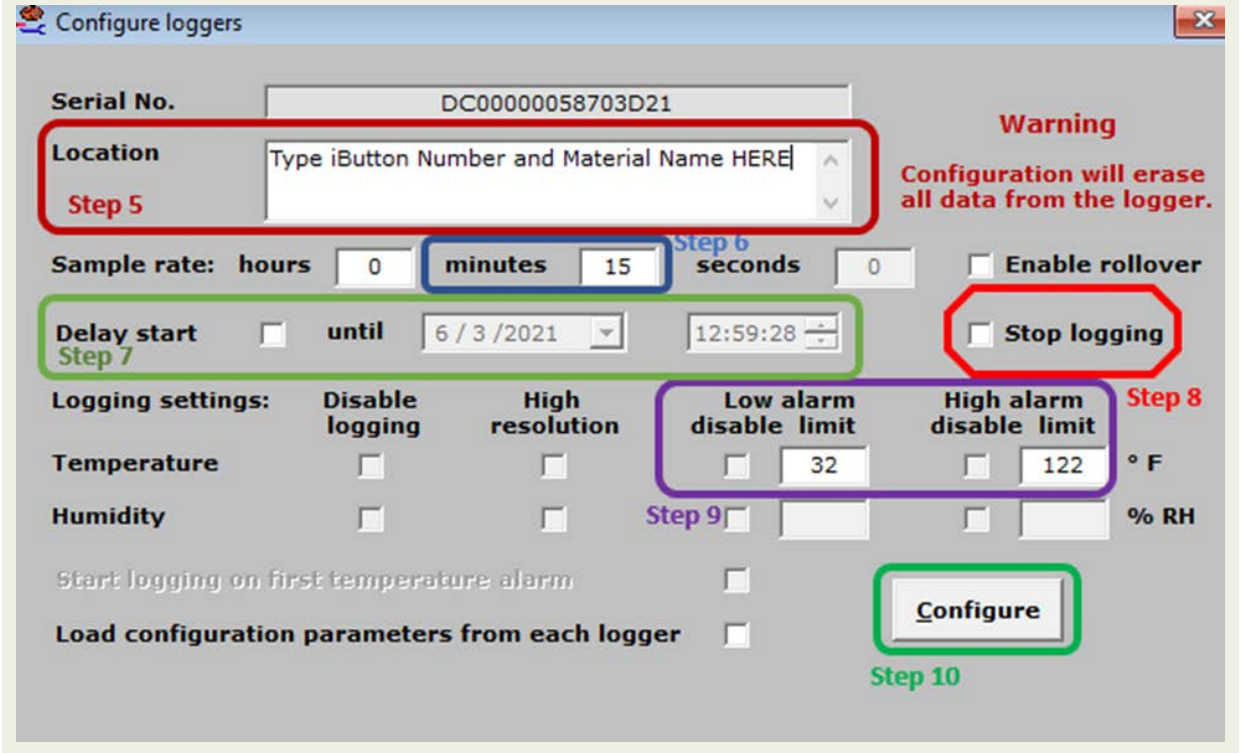
iButton Reader

Multiple Speed Stand Mixer

PREPARE iBUTTON

The iButton should be configured to read the temperature every 15 minutes. The low alarm disable limit should be set to 32°F and the high alarm disable limit to 122°F. As an option, the iButton can be set to start collecting measurements at a certain date and time. The configuration is presented in Figure 2.

Figure 2. iButton Configurations



PHYSICAL PROCESS

The process begins with creating a small batch of the proposed cement mix, enough to fill a 2x4” cylinder mold. Typical weight requirements for a cement only mix and a 25% fly ash replacement mix are provided in Table 1.

Table 1. Typical Cement Mixes

Component	25% Replacement Mix	Cement Only Mix
Cement (grams)	175.9	234.5
Fly Ash (grams)	58.6	0.0
Sand (grams)	593.7	641.4
Water (grams)	129.0	129.0

MIXING PROCESS

Combine the ingredients for the proposed cement mix beginning with the cement and fly ash, if used. Add the water in a manner not to get the sides of the bowl or paddle wet, stirring for 30 seconds. Slowly pour in sand (i.e., approximately 15 seconds) as the batch is mixing and continue to mix another minute. Allow the batch to rest one minute. During this first rest minute after mixing, record the temperature. After rest minute, continue to mix at a higher speed (i.e., 4 for a Kitchen Aid mixer) for an additional 5 minutes.

CASTING PROCESS

After mixing, place 350 grams (g) of the cement mixture into a 2”x4” cylinder mold. Tap the cylinder mold gently on a flat, soft surface to create a smooth surface on top. Place filter paper on top of the specimen followed by the iButton. Using tongs, lower the filled cylinder into the thermos and then close/seal the thermos. Record the time of casting and set the thermos in a location where it will not need to be disturbed while setting.

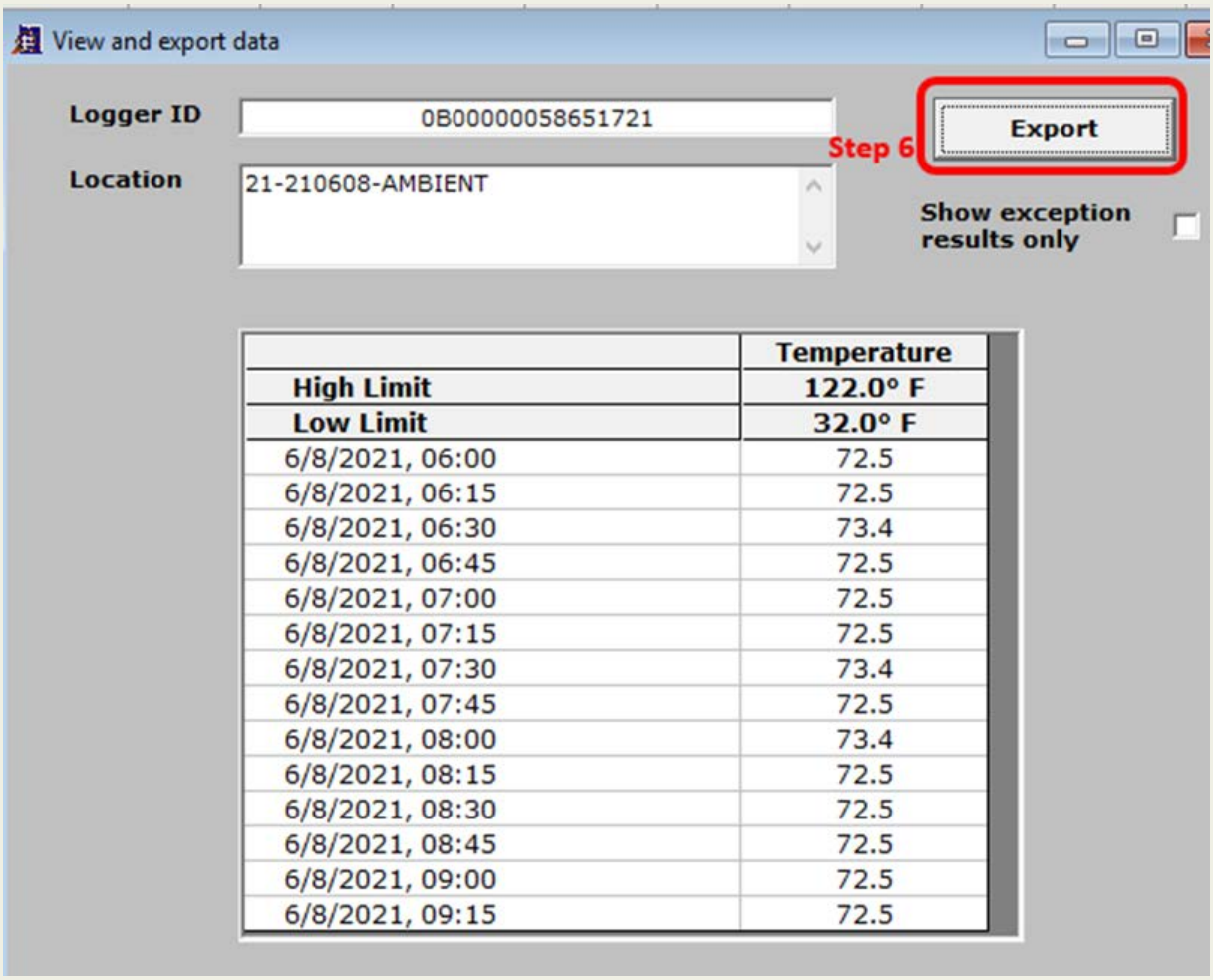
DETERMNING TEST DURATION

The duration that temperature data is collected will be determined by the person requesting and/or performing the test. For a test whose purpose is to determine the anticipated time of set for the cement mix, the duration may be based upon historic data for the specified mix. Tests where no historic data is available (e.g., a new fly ash source is being evaluated) may require a series of samples run over varying time frames. Typically, time of set is achieved within 5 to 6 hours, so durations longer than that time frame should not be necessary.

EXTRACT DATA

After the mix has reached the specified set time, remove the iButton from the thermos and connect it to the computer with the iButton software. Download the data from the iButton and export the information to the desired location. Then configure the iButton to stop logging the temperature. The iButton will deactivate and clear all recorded data.

Figure 3. iButton Data Download



	Temperature
High Limit	**122.0° F**
Low Limit	**32.0° F**
6/8/2021, 06:00	72.5
6/8/2021, 06:15	72.5
6/8/2021, 06:30	73.4
6/8/2021, 06:45	72.5
6/8/2021, 07:00	72.5
6/8/2021, 07:15	72.5
6/8/2021, 07:30	73.4
6/8/2021, 07:45	72.5
6/8/2021, 08:00	73.4
6/8/2021, 08:15	72.5
6/8/2021, 08:30	72.5
6/8/2021, 08:45	72.5
6/8/2021, 09:00	72.5
6/8/2021, 09:15	72.5

RESULTS

The results of the temperature generation during time of set for Cement only, Cement with Class F fly ash and Cement with Class C fly ash is shown in Figure 4. These measurements were readily obtained in a laboratory setting with minimal resource use.

Figure 4. Temperature Generation Results