Concrete Property Test

Strength Development 2-2: Heat Signature (Adiabatic Calorimetry Test)

National Concrete Pavement Technology Center

www.cptechcenter.org

Purpose – Why Do This Test?

Heat signature is a representation of the heat of hydration generated by a specific concrete mixture over time. Variations in the chemistry and dosage of portland cement and supplementary cementitious materials (SCMs), along with interactions between them and chemical admixtures, may be flagged by the heat signature. Changes in the heat signature of a concrete mixture can impact construction issues related to strength development and proper saw timing.

Principle – What is the Theory?

Chemical reactions that occur as concrete hardens emit heat (heat of hydration). By insulating a standard cylinder of concrete from the influence of outside temperatures and using sensors to record the heat generated by the concrete, it is possible to measure the heat signature of a concrete mixture. A chart that plots time on the x-axis and temperature change on the y-axis is produced from this data.

Graphing the temperature difference is preferable to graphing the actual concrete temperature. Even though the heat signature curve for the same mixture will be different depending upon the beginning temperature of the mixture, it is easier to compare the curves when the results are normalized by using the temperature difference (ΔT) as the value for the y-axis.

$$\Delta T = T_n - T_0$$

T_n = Temperature of the concrete sample at time n (after the initial temperature reading)

T_0 = Initial concrete temperature at the beginning of the test

Test Procedure – How is the Test Run?

A concrete cylinder(s) is placed inside an insulated container that is equipped with temperature sensors that record the temperature of the concrete sample(s) at 15-minute intervals. The temperature and time data are transmitted to a personal computer, where data are stored and analyzed.

Test Apparatus

- Calorimeter: insulated container equipped with temperature sensors (figure 1).
- Standard concrete cylinder(s).
- Personal computer.

Test Method

1. Prepare the test apparatus for use—program the temperature sensor(s) to measure and record temperature at a regular time interval (3 to 15 min.).
2. Sample the mixed concrete and cast the concrete cylinder(s).
3. Insert the temperature sensor into the cylinder(s) and record the time when it is inserted into the fresh concrete.

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Figure 1. Calorimeter

4. Place the concrete cylinder(s) in the insulated container and close the container.
5. Maintain the temperature of the environment where the insulated container is located at 73˚F ± 3˚F.
6. Open the container at the conclusion of the test and download the temperature data from the sensor.
7. Graph the temperature data with time on the x-axis and ΔT on the y-axis.
8. Record and note the following values on the heat signature graph:
    a. Maximum temperature (T_{max}).
    b. Minimum elapsed time at which T_{max} occurs.
    c. Maximum slope between two individual temperature measurements (S_{max}, ˚/h).
    d. Minimum elapsed time at which S_{max} occurs.
    e. Average slope from the minimum temperature to the maximum temperature (S_{avg}, ˚/h).

Output – How Do I Interpret the Results?

The current practice for interpreting heat signature results is empirical—the curves should be visually compared to each other and differences in the maximum temperature, average slope, and maximum slope should be noted as compared to heat signature curves that have been characterized qualitatively. As a history or library of heat signature curves is developed, the mixtures and corresponding heat signature curves should be characterized by field observations and field test results. Some suggested general guidelines for characterizing the performance of the mixture that relate to heat signature curves are as follows:

- Random cracks occurred with this mixture due to slow strength development.
- Random cracks occurred with this mixture due to rapid strength development.
- Workability issues due to early stiffening.
- Workability issues related to hot weather or elevated concrete temperature (>85˚F).
- If the field performance of a mixture was good, note the range of concrete temperatures that the mixture was placed at (e.g., 66˚F to 88˚F).

A heat signature curve can be compared to the curves of other mixtures during the mixture design stage to identify whether the mixture will perform well in the field (figure 2). The example shown in figure 2 illustrates the heat signature curves developed during the mixture design stage for various projects. Qualitative comments regarding the field performance of each mixture are necessary to assist in identifying potential problems that may occur with the mixture that is being tested in the lab.

Significant changes in the heat signature may also indicate that the source materials have changed or that there was a problem with batching.

During the mixture verification stage, the heat signature curve of the project batched mixture is compared to the curve from the mixture design stage to evaluate whether the materials have changed significantly (figure 3).

Construction Issues – What Should I Look For?

Heat signature of portland cement concrete should be utilized as a tool for evaluating the early-age properties of a concrete mixture during all three project stages. Issues, such as random cracking of the pavement due to the rate of strength development (too slow or too fast), hot/cold weather placement issues, and the variability or change in raw material properties during construction, can be identified using heat signature testing.

Changes in heat signature may impact the following concrete properties:

- Workability and consolidation.
- Rate of strength gain.
- Ultimate concrete strength.
- Initial window for sawcutting contraction joints.

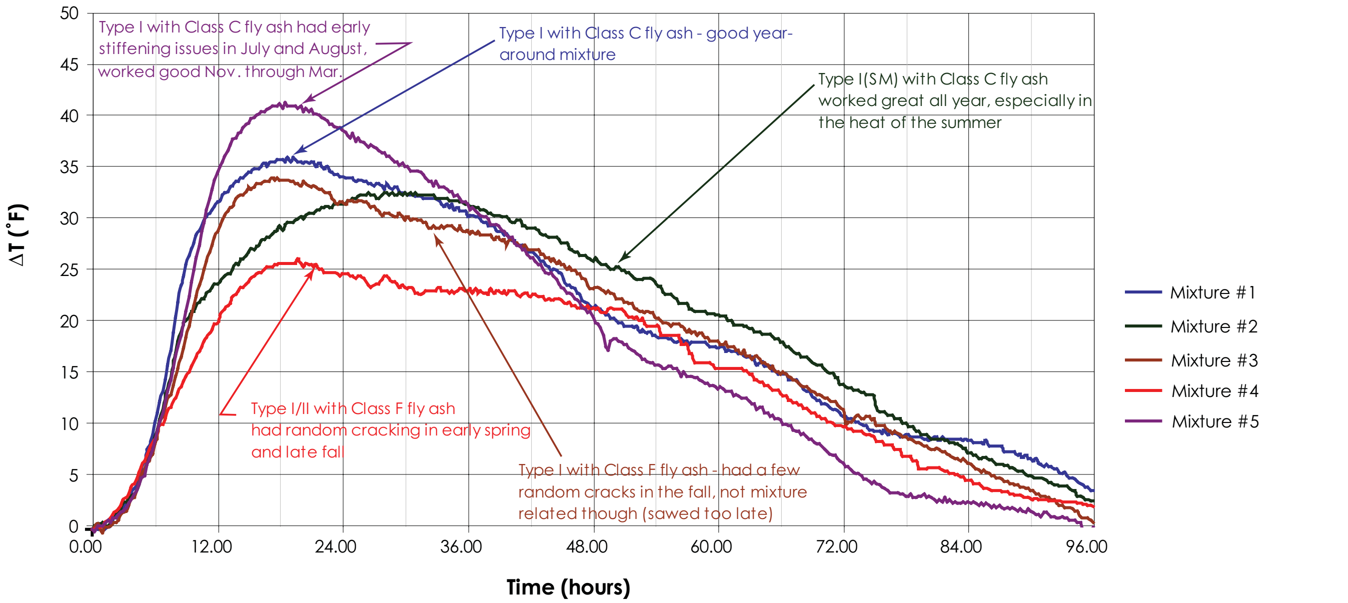
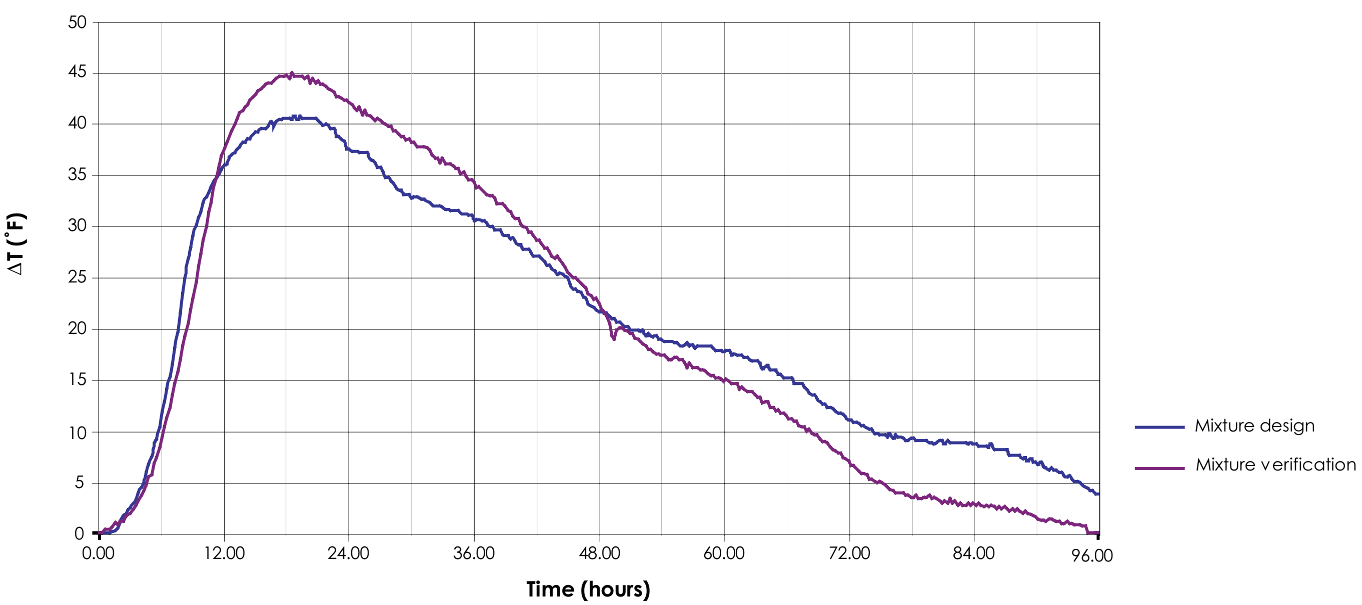


Figure 2. Qualitative comparison of heat signature curves during the mixture design stage



	Maximum ΔT ˚F	Elapsed hours to max. ΔT ˚F	Average slope from time 0 to max. ΔT ˚F/h	Maximum slope ˚F/h	Elapsed hours to max. slope ˚F
Mixture design	40.70	18.75	2.17	7.29	7.75
Mixture verification	44.91	18.50	2.43	6.22	9.25
Difference	4.20	-0.25	0.26	-1.07	1.50

Figure 3. Comparison between mixture verification and mixture design heat signatures

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This test summary is one of a set of summaries originally published in chapter 7 of the *Testing Guide for Implementing Concrete Paving Quality Control Procedures* (Fick, G., Iowa State University, Ames, Iowa, 2008). The testing guide is a product of a 17-state, Federal Highway Administration pooled-fund project, Material and Construction Optimization for Prevention of Premature Pavement Distress in PCC Pavements, TPF-5(066). The project was managed by the National Concrete Pavement Technology Center at Iowa State University.