

Concrete Property Test

Workability 1-6: Cementitious Heat Generation - Coffee Cup

Purpose – Why Do This Test?

The coffee cup test procedure can be used to monitor the uniformity of cementitious materials that are supplied on a paving project. To effectively monitor the uniformity of the cementitious materials, it is necessary to perform this test at least once each day that portland cement and/or supplementary cementitious materials (SCMs) are delivered to the project. This test should not be used to accept or reject materials that are supplied. However, it should serve as a process control and troubleshooting aid. If the workability of the mixture changes significantly during construction, the coffee cup test results can be reviewed to identify whether a change in the cementitious materials is contributing to the workability issue. Conversely, the coffee cup test results may indicate that the cementitious materials have been consistent, suggesting that the workability issue is caused by another factor.

Principle – What is the Theory?

Cementitious paste mixtures generate heat as they hydrate. Although this test is not capable of identifying specific chemical changes in the cementitious materials, monitoring the heat generated by paste mixtures prepared from project materials can identify whether changes in the cementitious materials have occurred.

Test Procedure – How is the Test Run?

Paste mixtures are prepared in the same proportions as the project mixture design, and the temperature of these mixtures is recorded over time.

Test Apparatus (figure 1)

- Slotted tube sampler as described by ASTM C 183 is preferred.
- Airtight sample containers for portland cement and SCMs capable of holding 10 lb of material.
- Clean plastic gallon jug for mixing water sample.
- Five one-liter plastic beakers.
- Plastic tub for cooling or warming test materials in ice water or warm water.
- Digital scale that measures mass to the nearest 0.1 g.

- Sealable plastic mixing bottle.
- Test container with Styrofoam cork and insulated enclosure.
- Thermometer capable of measuring to the nearest 0.1°F (temperature sensors that measure and record the temperature of the sample over time may also be used).

Test Method – As Developed by the CP Tech Center, Iowa State University

1. Obtain representative samples of portland cement, any SCMs, and mixture water. Cementitious samples should be obtained in accordance with ASTM C 183 whenever possible. If project conditions do not allow this, care should be taken to assure that the material samples are representative of the materials being delivered to the project site.
 - a. A minimum 10 lb grab sample should be obtained from bulk storage and bulk shipping containers.
 - b. Measure and record the temperature of the cementitious materials immediately after sampling.
2. Calculate the mass of materials required for the test.
 - a. If no SCMs are utilized in the mixture, the standard test requires 500 g of portland cement and 200 g of water (test #1).
 - b. When SCMs are used in the mixture, replace the portland cement with a portion of SCMs equivalent to the mixture proportions (test #2).

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Figure 1. Cementitious heat generation test equipment and materials

FOR MORE INFORMATION

- i. Example—the project mixture design calls for 423 lb of portland cement and 141 lb of fly ash.
Total cementitious materials = 564 lb
Portland cement = 423 lb (75%)
Fly ash = 141 lb (25%)
- ii. Materials required for the test
 1. Test #1: portland cement + water
Portland cement = 500 g
Water = 200 g
 2. Test #2: portland cement + SCMs + water
Portland cement = 375 g (500 g • 75%)
Fly ash = 125 g (500 g • 25%)
Water = 200g
 3. Total materials required for test #1 and test #2
Portland cement = 875 g
Fly ash = 125 g
Water = 400 g
- c. Label and store the remaining portland cement and fly ash in airtight containers. This material can be used for further testing if necessary.
3. Cool or warm the cementitious materials and water to $70^{\circ}\text{F} \pm 3^{\circ}\text{F}$.
 - a. Transfer the required total mass of portland cement + 100 g to a plastic beaker.
 - b. Transfer the required total mass of SCMs + 50 g to a plastic beaker.
 - i. Cool portland cement and SCMs by bathing the beakers in ice water; stir occasionally to thoroughly cool the entire sample.
 - ii. Warm portland cement and SCMs by bathing the beakers in warm water; stir occasionally to thoroughly warm the sample.
 - c. Transfer the required total mass of water + 100 g to a plastic beaker.
 - i. Water may be cooled by adding ice or chilling in a refrigerator; stir occasionally to thoroughly cool the entire sample.
 - ii. Water may be warmed in a microwave oven or by bathing the beaker in warm water; stir occasionally to thoroughly warm the sample.
4. Test #1: portland cement + water.
 - a. Weigh 500 g of portland cement that has been cooled or warmed to $70^{\circ}\text{F} \pm 3^{\circ}\text{F}$ and transfer to a sealable mixing bottle.
 - b. Weigh 200 g of mixing water that has been cooled or warmed to $70^{\circ}\text{F} \pm 3^{\circ}\text{F}$ and transfer to the mixing bottle containing the portland cement.
 - c. Seal the mixing bottle.
 - d. Start a timer.
 - e. Vigorously shake the mixing bottle containing the portland cement and water until the timer reaches 1 minute.
 - f. Transfer the paste mixture from the mixing bottle to an insulated container and insert a thermometer.
 - g. Record the temperature of the paste when the timer reaches 2 minutes and continue to record the temperature at one-minute intervals until the timer reaches 11 minutes (10 temperature readings).
 - h. Discard the paste mixture; clean and dry all test equipment.
5. Test #2: portland cement + SCMs + water (when SCMs are used).
 - a. Weigh the required amount of portland cement that has been cooled or warmed to $70^{\circ}\text{F} \pm 3^{\circ}\text{F}$ and transfer to a sealable mixing bottle.
 - b. Weigh the required amount of SCMs that has been cooled or warmed to $70^{\circ}\text{F} \pm 3^{\circ}\text{F}$ and transfer to a sealable mixing bottle.
 - c. Seal the mixing bottle and agitate the portland cement and SCMs to obtain a homogeneous mixture.
 - d. Remove the lid from the mixing bottle.
 - e. Weigh 200 g of mixing water that has been cooled or warmed to $70^{\circ}\text{F} \pm 3^{\circ}\text{F}$ and transfer to the mixing bottle containing the portland cement and SCMs.
 - f. Seal the mixing bottle.
 - g. Start a timer.
 - h. Vigorously shake the mixing bottle containing the portland cement, SCMs, and water until the timer reaches 1 minute.
 - i. Transfer the paste mixture from the mixing bottle to an insulated container and insert a thermometer.
 - j. Record the temperature of the paste when the timer reaches 2 minutes and continue to record the temperature at one-minute intervals until the timer reaches 11 minutes (10 temperature readings).
 - k. Discard the paste mixture; clean and dry the test equipment.

Output – How Do I Interpret the Results?

Plot the test results on a graph as shown in figure 2. Significant differences in the peak temperature and/or the time required to reach peak temperature may indicate changes in the cementitious materials.

Tests #1A and #1B were performed on material from the same sample. The shape of the temperature profiles for #1A and #1B is essentially the same and the difference between temperature readings is less than 1°F. Tests #2 and #3 were performed on samples obtained one day after tests #1A and #1B. The shape of the temperature profiles for tests #2 and #3 is obviously different than for tests #1A and #1B. Maximum temperature for test #2 is 2.3°F greater than the average peak temperature of tests #1A and #1B, while the difference in peak temperature for test #3 and the average maximum temperature of tests #1A and #1B is 2.7°F.

The change in shape of the temperature profile and the difference between maximum temperatures observed for tests #2 and #3 as compared to tests #1A and #1B indicate that the portland cement changed from one day to the next. If the workability properties of the mixture had been adversely affected, the coffee cup test results could have been reviewed to identify that the change in cement contributed to the change in workability. Comparing the test result of actual mixture proportion of cement and SCMs with that of the cement only can help identify which material may be contributing to the problem.

Construction Issues – What Should I Look For?

Changes in workability, water demand, and early stiffening may be caused by changes in the cementitious materials. Cementitious heat generation test results may be used as a troubleshooting aid when these issues occur by either identifying that the cementitious materials did change, or confirming that they were unchanged and did not contribute to the problem observed in the concrete mixture.

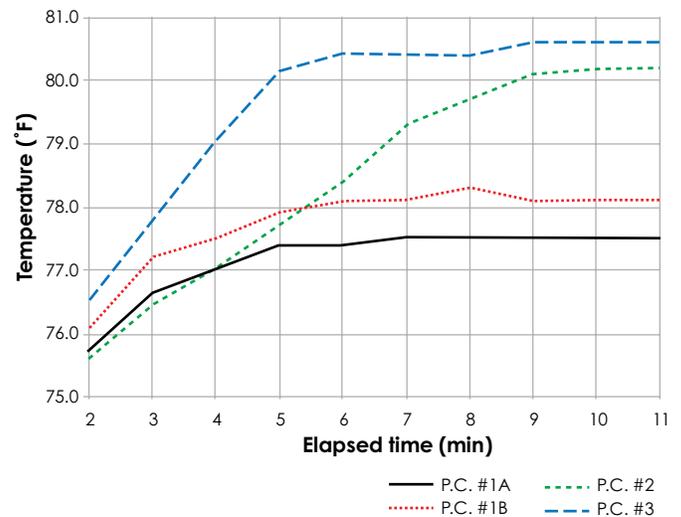


Figure 2. Cementitious heat generation (coffee cup) test results

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