



MASS CONCRETE PLACEMENT: HOW TO USE TEMPERATURE MONITORING TO MEET A REQUIRED SPECIFICATION



Maintaining appropriate temperatures and temperature ranges within mass concrete is a key to maintaining its durability and longevity. The risk of temperature-related concrete damage increases if the temperature of concrete gets too high or the temperature differential between the hottest interior point and the surface and/or edge gets too large. Therefore, many agencies include specifications that require early-age concrete temperature not exceed some maximum internal temperature limit and that temperature differentials in early-age concrete stay below some maximum limit.



What is considered mass concrete?

The American Concrete Institute (ACI) offers a simple definition of mass concrete. According to ACI 116R, mass concrete is “any volume of concrete with dimensions large enough to require that measures be taken to cope with generation of heat from hydration of the cement and attendant volume change, to minimize cracking.”

How large is large enough?

Specifications vary among different agencies; mass concrete is defined by most specifications based on the element's dimensions. Structural concrete with a least dimension greater than 3 feet (0.9 m) is a commonly used guideline for determining mass concrete. The dimension for classifying mass concrete ranges from 1.5 feet to 6.5 feet.

Keep in mind that this specification refers to dimension only. The content of the cementitious mixture used in the mass concrete will also have an impact on the concrete temperatures within those placements.

Common examples of structures often categorized as mass placements of concrete include:

- Bridge Piers
- Structural Columns
- Mat Slabs
- Girders
- Footings
- Thick Slabs



Why is mass concrete temperature monitoring so important?

Mass placement temperature monitoring ensures you stay within specifications and reduces the risk of concrete developing severe cracking that could result in costly repairs or reconstruction.



Heat generation occurs as the cementitious material in a concrete mixture hydrates—the majority of heat is generated in the first days following placement. This heat is the highest at the center of the structure and dissipates out through the sides of the structure as it tries to reach an equilibrium temperature with the ambient conditions around it. In mass placements, because there is so much concrete being placed at once and hydrating, a lot of heat is generated and released, creating two primary concerns:

1. Exceeding maximum internal temperatures.
2. Exceeding a maximum temperature differential between the hotter and cooler part of the element.

Maximum internal concrete temperature

Because heat dissipates more slowly in thicker placements than thinner ones, mass placements can get very hot. When internal concrete temperatures get high, there is an increased potential for Delayed Ettringite Formation (DEF). DEF is a materials-related issue that can lead to severe cracking. Typically, the maximum internal temperature is specified as 158°F—sometimes as high as 160°F—because the risk for DEF increases above that temperature.

Mass concrete temperature differential

In mass placements, the difference of temperature between the hotter and cooler part of the element—usually defined by many specifications as the core and surface—is the temperature differential. Large temperature differentials in mass concrete structures can cause severe cracking.

Temperature differentials cause tensile stresses in concrete. If the stresses are greater than the concrete strength, cracking will occur. These cracks can be severe, so to reduce the risk for damage, many agencies state that the temperature difference between the hottest part of the concrete and the closest exterior surface of the concrete should not be greater than 35°F (19° C). In some situations, this requirement may be too restrictive; in others, cracking may still occur below the recommended temperature differential.

specifications and must be developed and approved in advance of construction.

A thermal control plan includes calculations for both the maximum internal temperature and maximum temperature differential the concrete element is expected to experience. These calculations are based on the size and shape of the element being cast, the mix design proposed, ambient conditions, and curing processes. The purpose of the calculations is to show the owner-agency that internal concrete temperatures will be within the specified requirements for maximum temperature allowed and maximum differential allowed.

Contractors can take advantage of advanced technology to monitor internal concrete temperatures and temperature differentials: temperature sensors that record and store temperature data internally,



How is temperature monitoring performed?

Every mass concrete project requires the contractor to monitor the temperature for several days after placement, sometimes even up to three weeks or longer. The temperature monitoring procedure that a contractor intends to follow usually must be described in a thermal control plan. The design calculations used in the plan must conform to the governing agency's

and specialized equipment and software for acquiring and storing the recorded data. Specifications for temperature sensor placement vary from project to project. The thermal control plan will identify the locations where concrete temperature sensors will be placed. However, in general, temperature monitoring sensors should be placed at the hottest location of the concrete and a few inches below the nearest surface from the hottest location.

Installed sensors should continue to monitor concrete temperature for the amount of time specified in the thermal control plan. After placement, mass concrete temperature readings may be acquired as frequently as every hour. After the concrete begins to cool and/or the temperature differential remains within the specified range for several consecutive days, the temperature readings can be acquired less frequently.

Modern sensor technology offers users the ability to define the desired time intervals for acquiring sensor data. Once acquired, the data can be downloaded into software or a mobile app and used to generate reports of temperature history and temperature differential data for easy disbursement.

Some mass concrete placement projects require installation of a redundant set of sensors at locations near the primary set. Data from these redundant sensors is usually only acquired and recorded in the event the primary temperature sensors fail. Should any of the primary temperature monitoring equipment fail, the contractor must take immediate steps to fix it. If the primary system cannot be fixed, the backup temperature monitoring system must be put into service.

Failure to properly monitor the temperature of mass placements during the heat dissipation phase can result in the mass concrete element being rejected. Rejected concrete elements usually must be removed at the contractor's expense.

Other benefits of temperature monitoring

While this paper speaks specifically about meeting mass placement specifications, there are other ways that monitoring temperatures in general can be beneficial. This data can also be used for:

- Characterizing materials
- Investigating interactions
- Tracking uniformity
- Timing finishing activities
- Tracking hydration
- Calculating concrete maturity

Conclusion

Minimizing the risk of temperature-related damage is a fundamental part of every mass placement project. There are two main temperature-related issues to monitor for: maximum internal temperature and temperature differential. Exceeding specified limits puts concrete at increased risk of severe cracking. Thermal control plans describe the temperature monitoring procedures that a contractor intends to follow.

COMMAND Center is a system developed specifically for monitoring internal concrete temperatures and estimating concrete strength by the maturity method. COMMAND Center sensors are the most affordable self-logging sensors available for this purpose, and greatly simplify the process. COMMAND Center offers free software for viewing and analyzing data, and both wired and wireless data retrieval options that are suitable for any mass placement project.



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