Mass Concrete

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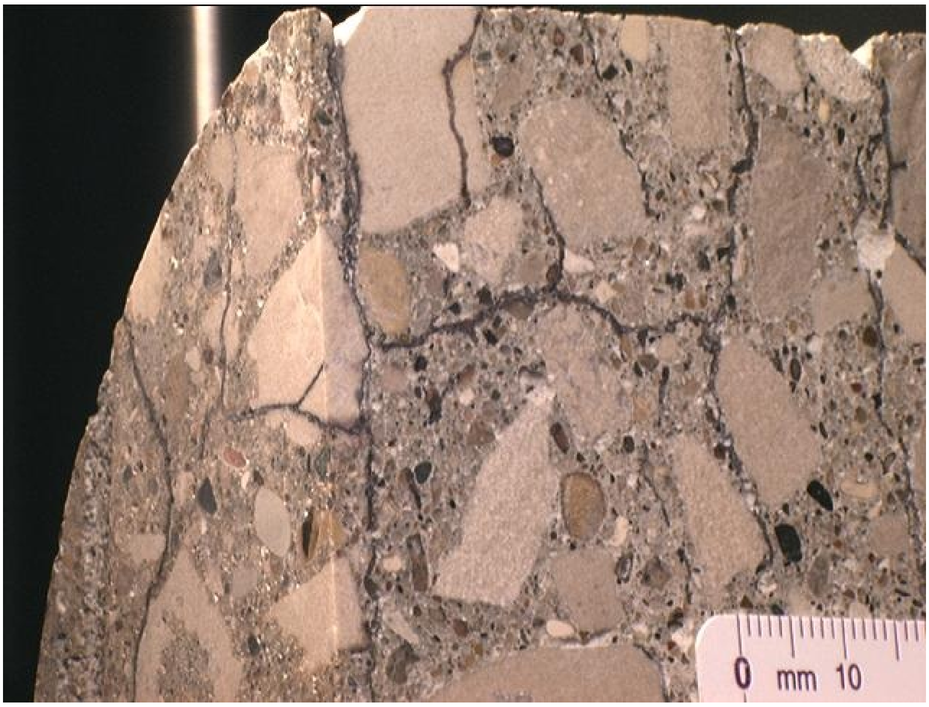
Mass Concrete - What's the big deal?

In conventional concrete, often the goal is to get the concrete placed quickly, have it set quickly and cure quickly to reach strength and functionality as soon as possible. To achieve this, cement formulations have evolved to become hotter, quicker, and more reactive. Mass concrete, however, is a totally different animal. We want the concrete to set slower, cooler, and be less reactive. Why do we want to do this? How do we do it? When do these mass concrete rules come in to effect?

Why do we want Mass Concrete to set slower and cooler?

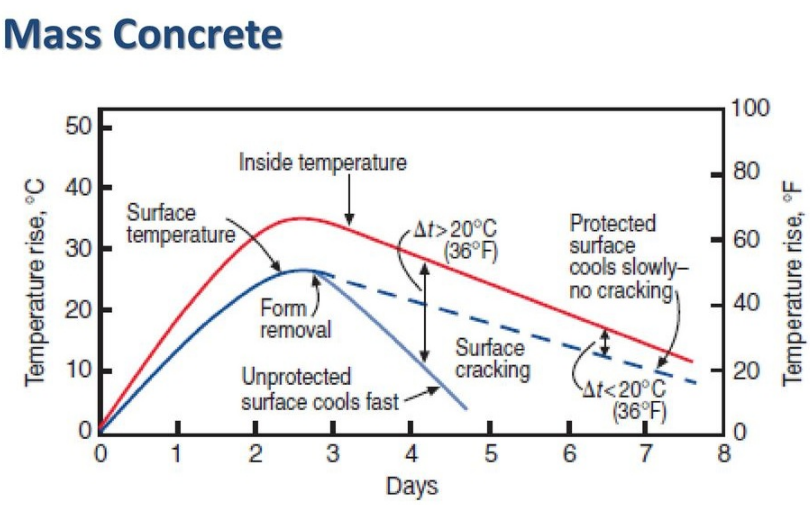
All concrete is exothermic, which means it gives off heat as it sets due to the chemical reactions between the cement and water. The larger a least dimension is on a concrete member, the more massive the concrete member is and the more heat will be generated by that exothermic reaction. Two very undesirable things happen when mass concrete gets too hot. The first is a phenomenon called Delayed Ettringite Formation (DEF). Ettringite is a commonly found substance in hardened concrete that can form as a byproduct of the initial hydraulic cement reaction. At very high temperatures (greater than 160° F), this ettringite can be destroyed and then will reform when the concrete eventually cools. The problem is that the system is static when this DEF occurs and as it expands where there is no room for an expansive material to grow.

Concrete is very strong from a compressive standpoint, but it does not do well when it is pushed apart from the inside. DEF has and can cause failures in mass concrete placements if the internal temperatures exceed 160° F.



Delayed Ettringite Formation in concrete

The other great concern for mass concrete is thermal cracking. This occurs when there is a hot center of a concrete member and cool outer faces. This differential in temperature causes differentials in shrinkage. Where the cool concrete meets the hot, you'll likely get a crack. Specifications often state the maximum temperature differential between the core and a face. It may look something like this:
0-24hrs: 20° F
24-48hrs: 30° F
48-72hrs: 40°F
Over 72hrs: 50° F

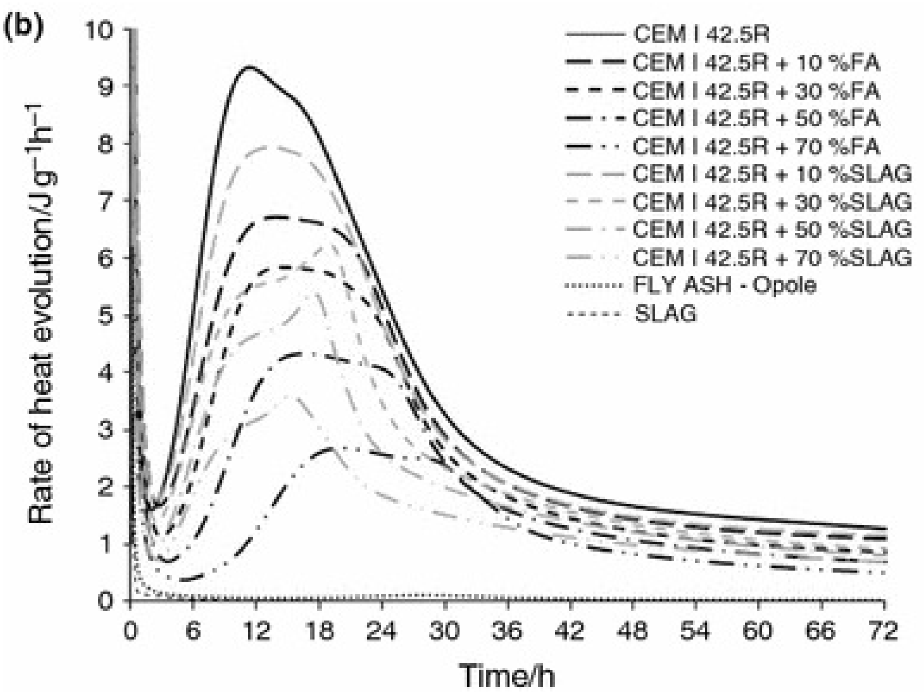


So, How do we address these issues?

Primarily, there are six levers we can pull to protect against these threats to mass concrete.

- - Reduce the cementitious content. Since cementitious materials reacting with water are the source of the heat being generated, by reducing the cementitious materials per yard, we reduce the heat potential of the concrete member. Often, mix designs are way overdesigned for strength. Mass concrete is the time to lean the mixes up as much as possible while still achieving the required strength.

- - Use larger aggregate. Larger aggregate helps in two ways. First, it can allow you to further reduce the needed cementitious materials in a mix, and if you use large enough aggregate, they can can serve as “cold spots” in your concrete member that can help counter-act the exponential growth of heat.
- - Maximize SCM's. Some Supplementary Cementitious Materials are very effective at reducing the heat of hydration, because they react with water much slower than cement. This reduces the “peak” heat output and elongates the time when the mix is reacting. The best SCM for this is Class F Fly ash, used at 40-50% replacement. If strengths are a particular concern and there is not a quality Class F ash available, this may not be the right path. Another option is using Slag at ~70% replacement. High slag mixes tend to be sticky and bleed a lot, so care must be taken that finishing operations can overcome these challenges. Class C Fly Ash does bring some minimal reduction in heat of hydration, but often not enough for mass concrete.



Note the heat evolution “peak” in the graph, and how higher %'s of Class F ash or Slag reduce and delay the maximum heat output.

- - Cool the concrete. A known mix design with a known least dimension will have a consistent and predictable (for a thermal engineer) heat rise. If we know the value of how much heat will be generated and what our projected core temperature will be we can reduce the initial concrete temperature to impact the final core temp. For example, let's say we know that a mix and dimension will result in 80° F temperature rise during curing. If it's the middle of summer and concrete temperatures are 90° F, we would end up with a core temperature of 170° F. This would put us in danger of DEF. So, we could drop the concrete placement temperature by 20° F and place the concrete at 70° F, resulting in a core temperature of 150°F.

There are a number of ways to cool concrete, depending on the magnitude of cooling needed. Most of the available concrete cooling methods are listed in Technical Bulletin #7, but they essentially are cold water, ice, sprinkling stockpiles and shading for minor cooling, and liquid nitrogen or wet belt systems for drastic cooling needs. The latter two are incredibly effective but almost prohibitively expensive.

- - Cooling Tubes. Piping can be run through the concrete member which can transport cold water through the mass of the concrete and cool it from the inside. This is a very effective measure for supermassive placements.
- - Insulate the faces of the concrete. Cooling the center of the concrete can go a long way towards minimizing the temperature differential between the core and a face, but especially in winter, sometimes the face needs to be insulated or even have heat blown on it to keep it within tolerance. This insulation should stay on for 5-7 days or until the internal temperature is within 50° F of the ambient temp.

How do I know if my concrete pour is considered Mass Concrete?

The most important measure of your concrete pour is your greatest least dimension. That's pretty confusing so we'll explain it better: If your concrete pour is not perfectly cubical, figure out the thickest part of the thinnest dimension of your pour. So if you are pouring a 50'x60'x5' slab, but the last 10' of the slab thickens to 6', then 6' is your greatest least dimension. Mass Concrete is defined slightly differently by different specifications but normally you see requirements begin when the greatest least dimension is 4' or 4.5'. From 4' to around 7' would be considered small mass concrete. In this range temperature monitoring of the core and face is a good idea, and all efforts should be made to use the above tools to keep the concrete in a safe temperature and differential range. Above 7' greatest least dimension, we would describe the concrete as large mass. This likely requires the input of a thermal control engineer to model and help develop mix designs, trial batches to verify the modeling, and thermal control plans for managing both core temperature and differentials.

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