Thermal Cracking in Concrete.

See also our other pages on cracking due to drying and settlement.

Thermal cracking occurs:

1. When concrete cools and shrinks at different rates within a concrete member.

2. When a concrete member cools against another, older member already, and remaining, cold.

The solutions are to help curing concrete retain its heat until it has gained enough strength to resist thermal cracking and to control cooling to limit thermal strains within the concrete. This is most easily achieved by keeping formwork in place longer.
(note: building basements I always use permanent insulating concrete formwork which obviously fits the bill exactly).

Steel reinforcement can be specified to control cracking. The concrete still cracks but the steel immediately takes up the tensile strain restricting the width of the crack. The concrete has to have set sufficiently not to let the steel slip through. Therefore the concrete needs to have strength before it cools and shrinks.
(note: waterproof concrete self-heals up to 0.3mm so clearly any thermal cracks controlled by steel will fill and heal).

When the concrete is first mixed the surface of the cement grains adsorb an amount of water. About 2 hours later the cement begins to hydrate and heat is given off. About 5 hours after water is added the surfaces of the cement grains have created a connected skeleton of hardened crystals (this is the first hardening of cement). Lime is produced which begins to dissolve the glassy surface of any PFA or GGBS in the concrete and they begin to hydrate as well.

The temperature of concrete will peak around 12 hours after first adding water.

The strength of concrete increases for weeks.
(note: waterproof concrete will probably be C35 in 3 to 5 days depending on temperatures).
It is important that the concrete is strong enough to resist cooling (and therefore shrinkage) at the surface while its core remains hot and expanded.

Thermal cracking issues:

1. The thickness of the member cast.

   A beam 1.5m x 1.5m will hold heat at its core a long time.

   A slab just 0.25m thick will lose heat all over quickly.

2. Whether formwork is in place.

   A slab loses heat easily because there is no formwork. This means the chemical reaction will be less fierce as well.

   A plywood wall form will hold heat in but often be removed after only 12 hours.

   Insulating Concrete Formwork will hold in even more heat and remain permanently in place allowing the concrete to gain more strength and grip reinforcement more strongly before it eventually and slowly cools and shrinks.

Other major influences on the maximum temperature are:

1. Cement or a blend of cement.

   PFA and GGBS slow down the rate of cure and produce less heat reducing the maximum temperature and the extent of cooling but lengthening the hardening time.

2. The initial temperature of the cement, aggregate and water.

   Cold ingredients react very much more slowly than hot ingredients.

3. When any formwork is removed.

So if concrete is allowed to reach a very high temperature in the middle while the outside is allowed to cool then the outside and the inside of the same piece will behave differently. But the text books talk of elements over 900mm thick before this is usually an issue.

The process at work within a large-section concrete member is that the surface concrete wants to contract on cooling while the centre remains hot and expanded. Therefore the surface suffers tension because it wants to shrink but is held in expansion by all the concrete between it and the centre.

If reducing thermal expansion is of great importance then it is generally found that crushed limestone aggregate has the lowest Coefficient of Thermal Expansion (CTE).

Water / Cement ratios and ratios of sand to larger aggregate appear to have very little effect. It is the CTE of the larger stones that affect concrete's CTE the most.

Some coefficients of thermal expansion.
Millionths of a m per degree centigrade.
(Due to natural variations these figures are just a guide).

Limestone	8 to 10
Granite	8 to 10
Siliceous River Gravel	12.5
Cement	10
Reinforcing Steel	13

This explains why large reinforced concrete members have a steel rebar cage all round about 40mm beneath each surface. It controls the thermal cracking (whether while curing or in a fire).

Control Joints.

The problem with controlling cracking with reinforcing steel is that the concrete has to crack before the steel takes up the tensile strain and restricts the crack width. This still allows ingress of chemicals that might corrode or discolour and over time the joints will craze and break away at the surface.

Modern thinking for industrial floors - where cracks are possibly of greatest nuisance - is to avoid all cracks and therefore control joints. By reducing the extent of all 3 types of cracking it is considered possible not to have any control cracking and to pour up to 4,000m^3 in a day. (source: Advanced Concrete Technolgy. Processes.)

This shows how all concreting can benefit from quality and care.