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Placers Association

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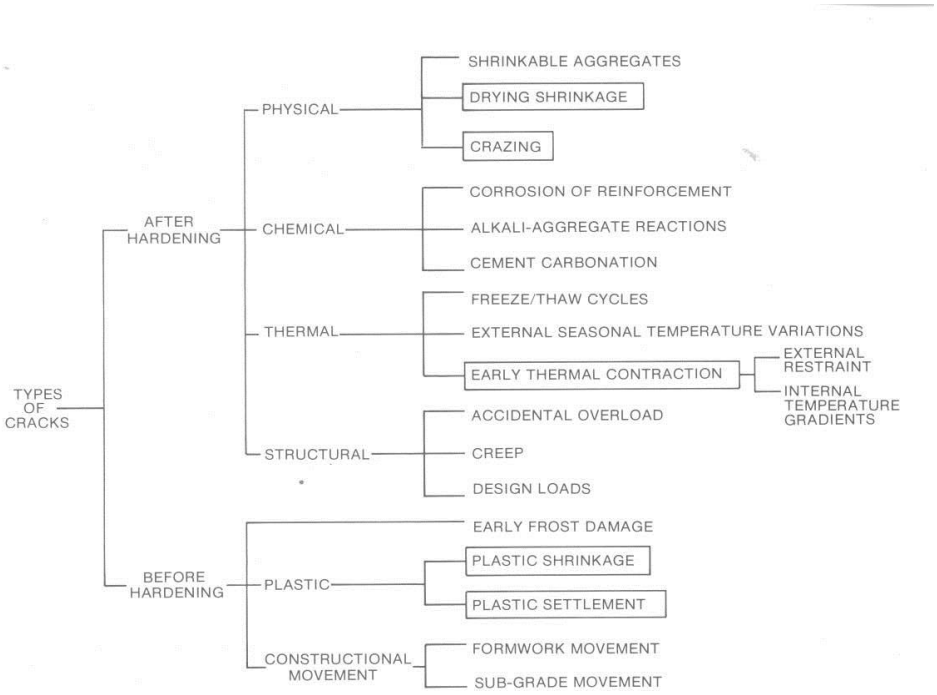
A hitch hiker's guide to early cracking

Diagnosing why a concrete element has cracked can be very challenging. Timing is everything in determining the possible cause(s) of a crack.

There is a family tree of cracks, with branches differentiated by timing.



Some types of cracking (for example, corrosion, freeze thaw, accidental overload) will not involve us as placers. Basically, our principle area of concern are cracks which have appeared in the concrete in the first 24 to 48 hours.

This means that we, as placers, will be looking at cracks which are evident before hardening, or which are thermally induced overnight after placing.

Sometimes early shrinkage movement may occur in areas already damaged by cracking due to plastic or early age thermal cracking, but the predominant cause is always what caused the initial crack, and we are not usually concerned about secondary movements in these already damaged areas.

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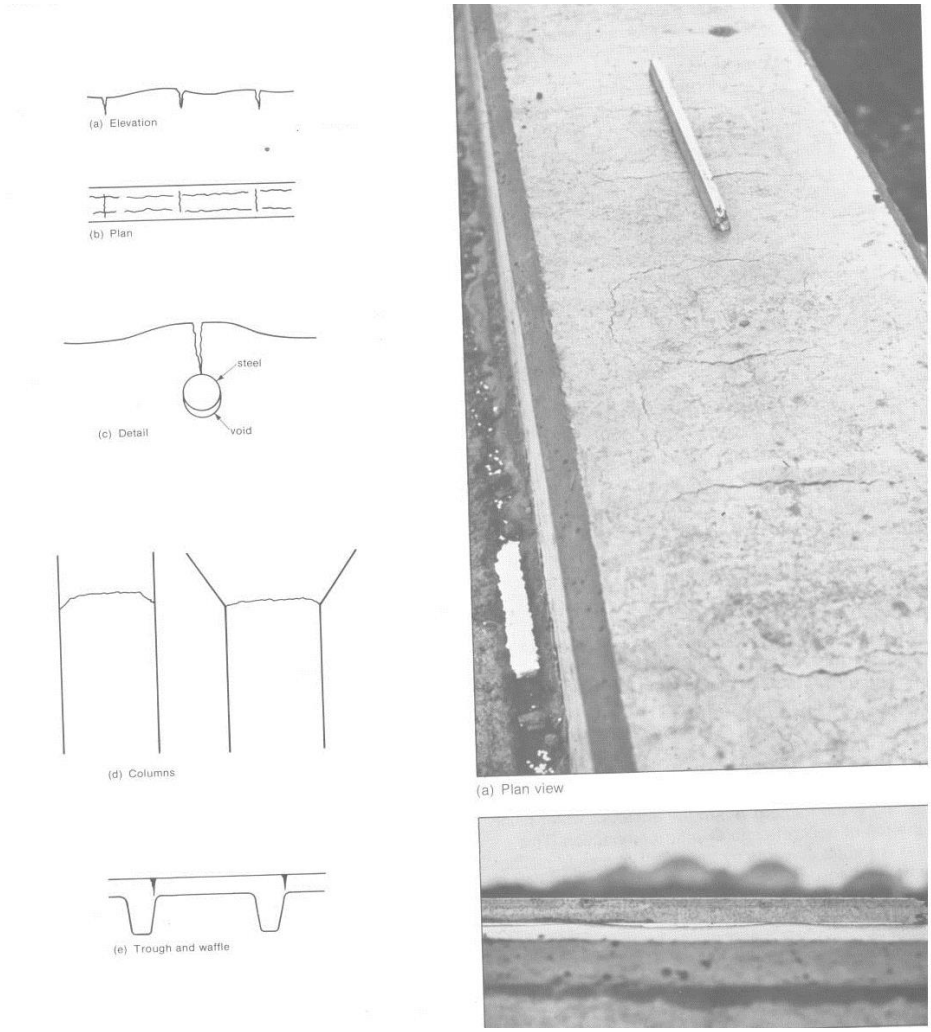
Plastic settlement cracking.

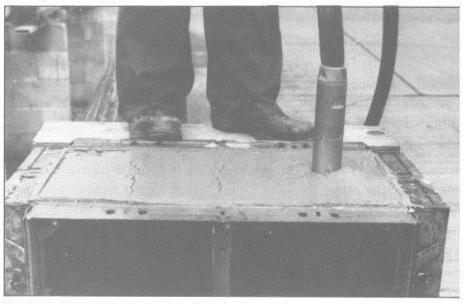
This type of cracking is often considered by contractors as a problem with no solution. In fact it is the easiest on site problem to address. It can only occur if there is some sort of restriction that stops the concrete from settling in the form (or slab) without any restraint to settlement. Thus, form ties, reinforcement steel, or changes in geometry in formwork can all induce restraint and lead to plastic settlement cracking. This is especially the case with high bleed mixes (less common these days) or in relatively thick slabs or wall sections, deep raft pours, or high column lifts.

Figure 1. Plastic settlement.

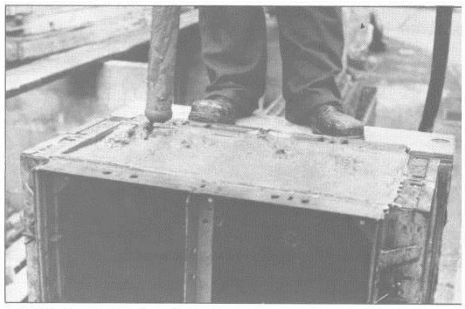


The fix is to re-vibrate the concrete immediately that these cracks are evident on the surface. (See Figure 2) If you can reintroduce the immersion vibrator into the concrete and withdraw it without leaving a hole, then all is well.

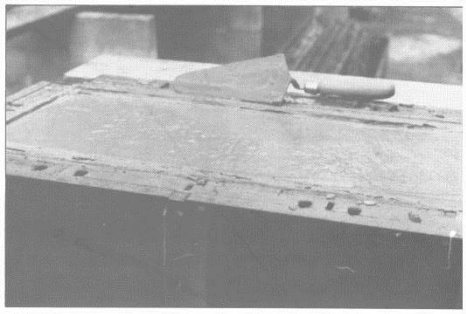
Figure 2. Reconsolidation.



(a) Two hour old concrete with plastic settlement cracks



(b) Withdrawal of poker vibrator



(c) Concrete after final trowelling

Plastic Shrinkage.

This is the most common problem that we have to deal with. Industry knowledge of this, its causes and remedies, is patchy at best. The point at which plastic cracking has occurred is often the initiator of all subsequent movement in the slab. For this reason it is crucial that all practical steps be taken to minimize the risk of plastic cracking.

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When and why.

If it is a good day to hang out the washing, then stay at home and do the washing, especially if a decision has been made to place concrete with no controls on placing operations to minimize the drying effects of warm temperatures and winds.

Plastic cracking occurs when the evaporation rate at the surface of the concrete exceeds the bleed rate of the concrete. Modern concrete bleeds much less than it used to. The ongoing potential for plastic cracking is high and can occur at any time of the year.

Drivers for this phenomenon are: concrete temperature, warm air, breeze, and relative humidity. When the evaporation rate exceeds 0.5 kgs per square metre per hour then cracking is probable.

Generally, assume the concrete temperature to be 3 to 5 degrees above ambient on a cloudy day, and 8 to 10 degrees above ambient on sunny days. The darker coloured concretes add a couple more on to these values.

Because of this phenomenon, darker concretes are more prone to plastic cracking as they elevate the temperature of the concrete and drive an even faster drying rate.

Low bleed, or zero bleed concretes are highly susceptible to plastic cracking. This is especially true for any mixes with silica fume, blast furnace or fly ash based cements.

Highly sanded mixes, and mixes with higher cement contents (pump mixes) also fit this category, as do mixes with high levels of water reducers. As a rule of thumb, assume at any mixes with total water contents below 160 kg will be more susceptible to this problem.

There is some evidence to suggest that air entrained mixes are less prone to cracking; this is counter intuitive (air entrained mixes generally bleed at lower rates) but they reduce the surface tension in the capillaries, possibly reducing the risk.

Retarders will increase the risk of plastic cracking due to the reduced rate of hardening in the concrete.

Broomed surfaces are more prone, due to the increase surface area available for the moisture to evaporate from.

Silicate based curing compounds will be totally ineffective in controlling plastic cracking as they need a considerable period of time to react with the free lime in the concrete.

Minimising the risks.

- Consider the weather conditions and do not place concrete in high temperatures or wind.
- Consider using a harder mix (is the pump mix really needed?)
- Can the evaporation rate be reduced? (wind breaks, misting etc)
- Use repeated applications of anti-evaporative films
- Apply a curing membrane immediately after finishing operations are complete.
- Do not use retarders or high dosage rates for water reducers.

Figure 3. ACI Nomograph.

Use 0.5 as the critical evaporation rate.,

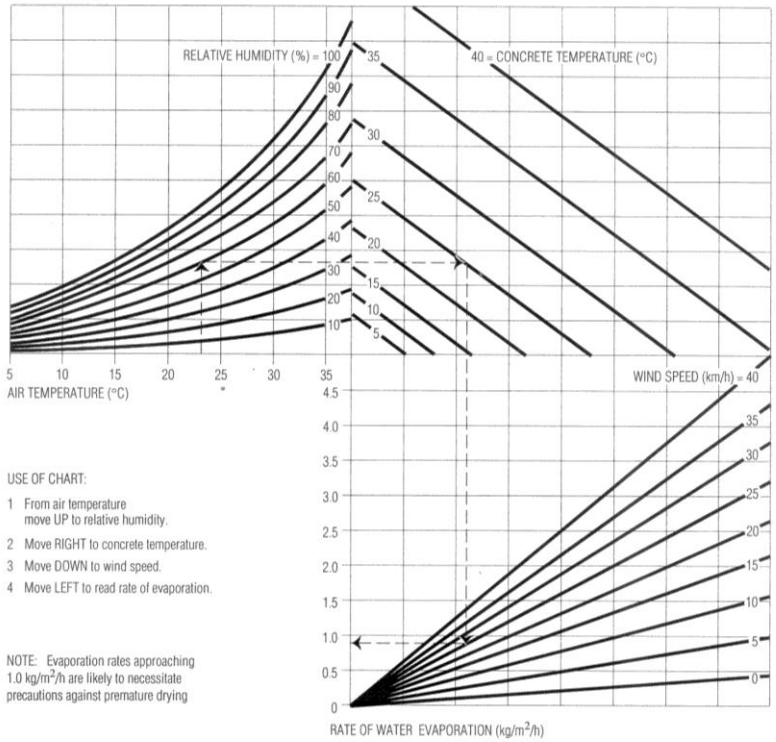

Figure 1: Effect of concrete and air temperatures, relative humidity and wind velocity on the rate of evaporation of surface moisture from concrete (after ACI 305[2])

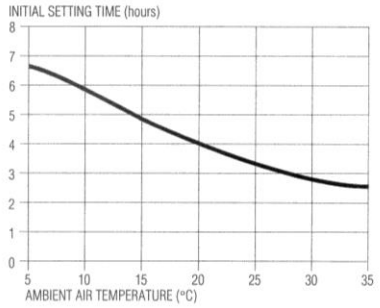

Figure 2: Influence of air temperature on setting times of concrete made with Type GP cement

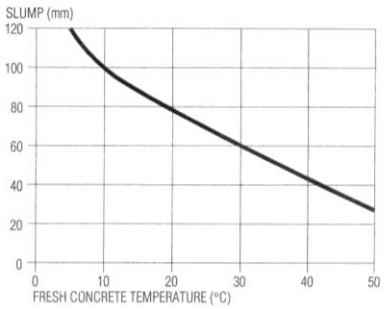

Figure 3: Decrease in workability of fresh concrete (as measured by slump), made with constant water content, as temperature increases

You can visit the Allied Concrete Website (http://www.alliedconcrete.co.nz/plastic_cracking.html) to access the plastic cracking calculator.

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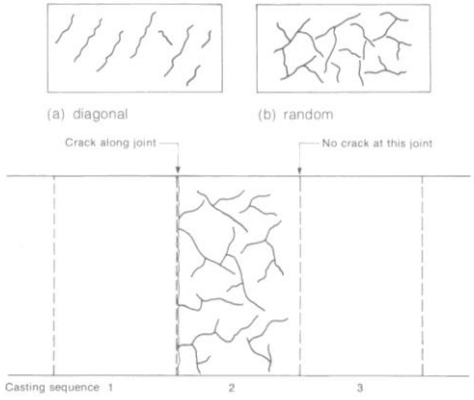
Easy fixes.

You need to be careful when offering repair options to owners, as quite often the end target is a constantly moving one that has no endpoint and you can inadvertently end up owning an even bigger problem if the fix is not acceptable to the owner,. This point needs to be clearly covered in any initial discussions about offering repair options.

For early age cracking, often the easiest solution is to brush in dry cement straight after the problem is seen. This is best done when the slab is coldest and the cracks the widest. Subsequent movement will still occur and my be visible.

An alternative is to inject a structural repair resin, such as a low viscosity epoxy. Repairs such as these will always be visible.

Figure 4. Schematic of plastic cracking.



(c) in a restrained bay

Figure 15 : Plastic shrinkage cracks

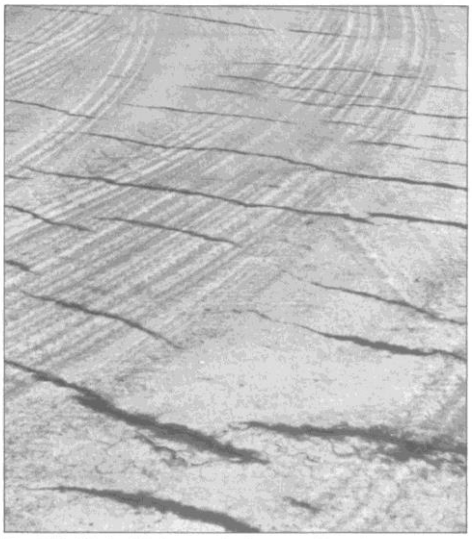


Figure 16 : Plastic shrinkage cracks in a concrete road

Although the cracks can be very wide at the top (up to 2 or 3 mm) they rapidly diminish with depth (Figure 19). Nevertheless, in all but minor cases they will usually pass through the full depth of a slab, in contrast with most types of plastic settlement cracks.

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Early age thermal cracking.

Slabs.

These types of cracks will occur in slabs as early as the first 24 hours after pouring, typically overnight. As a general rule, temperature drops of 12 degrees is enough to instigate this. So, a fine warm afternoon, followed by a chilly evening (with or without a frost) can bring this type of failure. This phenomenon will sometimes mirror the location of earlier plastic cracking especially if the concrete had not been reconsolidated to its full depth.

Walls.

This is a complex subject and is only dealt with superficially here.

These cracks are usually seen where a slab has been cast onto an existing slab. Typically, these cracks are spaced at about 1 to 1,2 metres apart, with the outer cracks angling towards the adjacent sides of the pour. They extend to about 70% of the wall height and seldom extend to the top of the wall.

This is usually a design issue rather than one we are responsible for. The use of low heat cements, additional steel, amended cover etc can all reduce the impact of this type of failure.

The incidence of cracking is influenced by:

- Formwork. Timber is worse than steel, due to its better insulative properties.
- Type of aggregate. Limestone is better than basalt or greywacke.
- Reinforcement (more and smaller bars) and cover (width of cracking can be reduced by increasing the steel percentage)
- Stress raisers. Sudden changes in section profile, box-outs, tie bolt holes
- External restraint. Include movement joints, reduction in time between pours
- Internal; restraint. Consider delaying the removal of formwork 9especially timber) or use insulation.

Beware using Duracem as a fix for this problem. Based on our recent experience, never try to supply Duracem-based concrete with a slump below 180 mm. Ensure that the water cement ratio is never below 0.40. Slump control can be a nightmare. Hand finishing can develop into a nightmare scenario also.

Craze cracking.

This type of cracking is not generally speaking a structural or serviceability issue. It is caused by the cement paste on the surface of the cast face or finished slab surface shrinking due to its relatively higher water cement ratio when compared to the rest of the concrete.

These cracks do not extend into the body of the concrete and do not represent a durability issue.

See Figure 5 for an image of typical craze cracking.

Figure 5. Craze cracking.

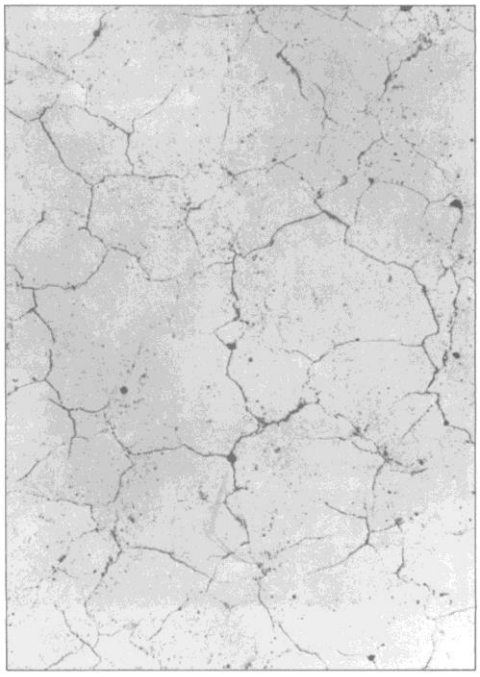

Figure 33 : An example (actual size) of crazing on concrete cast against a smooth polished form face. The crazing is accentuated by deposits of soot after several years' exposure

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Delamination.

Delamination failure is where the top surface of a slab separates from the body of the concrete as small plates of mortar. See Figure 6. These are usually about 3 to 5 mm in thickness and vary in size, from the size of a 20 cent coin to the size of a business card.

The usual cause is the early finishing of the slab before it has completed the bleeding process. The early finishing operations seal the top surface and the bleed water forms a lens under the top layer of mortar. As the concrete dries in service, the mortar shrinks and cracks, or wheeled traffic cracks and breaks away the top surface.

Soft mixes are more prone to this problem, so consider revising mix designs when this problem becomes more persistent.

Figure 6. Typical examples of delamination.

Repair methodology:

Identify all unsound areas. This can be done by dragging a light chain or keys over the suspect areas. A change in note indicates an area of delamination. Remove all unsound areas and repair with micro-mortars such as Sika Monotop Fairing compound.

Use an acrylic based bonding compound to strongly fix the repair mortar to the previously prepared substrate.

Cure with a high solids acrylic or wax based curing compound. Seek specialist advice as to what is the most appropriate for each instance.