Why Concrete Cracks

By
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Cracks in concrete are extremely common but often misunderstood. When an owner sees a crack in his slab or wall, especially if the concrete is relatively new, he automatically assumes there's something wrong. This is not always the case. Some types of cracks are inevitable. The best that a contractor can do is to try to control the cracking. This is done by properly preparing the subgrade, assuring that the concrete is not too wet, utilizing reinforcement where needed, and by properly placing and spacing crack control joints and expansion joints. However, sometimes cracks happen in spite of any precautions taken.

The **American Concrete Institute** addresses this issue in ACI 302.1-04. ***"Even with the best floor designs and proper construction, it is unrealistic to expect crack-free and curl-free floors. Consequently, every owner should be advised by both the designer and contractor that it is normal to expect some amount of cracking and curling on every project, and that such occurrence does not necessarily reflect adversely on either the adequacy of the floor's design or the quality of its construction (Ytterberg1987; Campbell et al. 1976)".***

Diagnosing 6 Types of Concrete Cracks

Plastic Shrinkage Cracks

Probably the single most common reason for early cracks in concrete is plastic shrinkage. When the concrete is still in its plastic state (before hardening), it is full of water. This water takes up space and makes the slab a certain size. As the slab loses moisture while curing it gets a bit smaller. Because concrete is a very rigid material, this shrinking creates stress on the concrete slab. As the concrete shrinks, it drags across its granular subgrade. This impediment to its free movement creates stress that can literally pull the slab apart. When the stress becomes too great for the now hardened concrete, the slab will crack in order to relieve tension. ***Especially in hot weather, shrinkage cracks can occur as early as a few hours after the slab has been poured and finished.***

Often, plastic shrinkage cracks are only a hairline in width and are barely visible. However, even though a crack is hairline, it extends through the entire thickness of the slab. It's not just on the surface as one might think.

One factor that contributes significantly to shrinkage is mixing the concrete too wet. If excessive water is introduced into the mix, the slab will shrink more than if the correct amount of mix water were used. This is because the additional water takes up more space, pushing the solid ingredients in the mix farther apart from each other. It's similar to over-diluting a pitcher of Kool-Aid. By doing so, a weaker solution is created. When the excess water leaves the slab, the solid particles have larger voids between them. These empty spaces make the concrete weaker and more prone to cracking.

Unfortunately, wetter concrete is easier to place and finish, especially in hot weather. This is one reason that many concrete finishers add water to concrete mixer trucks: it makes their work easier. A few gallons per cubic yard will not significantly affect the mix. However, if an excessive amount of water is added, one can unwittingly reduce the concrete's strength.

Plastic shrinkage cracks can happen anywhere in a slab or wall, but one place where they almost always happen is at re-entrant corners. Re-entrant corners are corners that point into a slab. For example, if one were to pour concrete around a square column, he would create four re-entrant corners. Because the concrete cannot shrink around a corner, the stress will cause the concrete to crack from the point of that corner (See Figure 1).

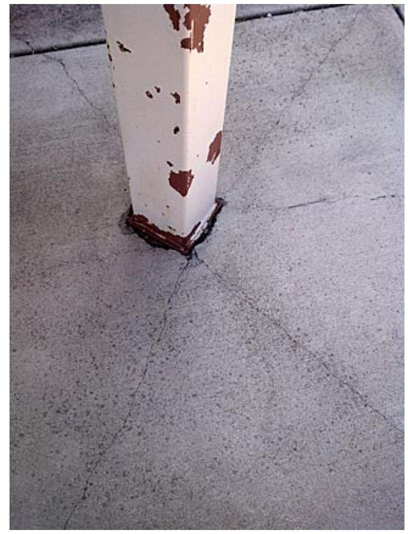

Figure 1 Shrinkage cracks originating at re-entrant corners

Figure 2 Shrinkage crack at slab penetration

A rounded object in the middle of a slab creates the same problem as a re-entrant corner. This is commonly evidenced around slab penetrations such as pipes, plumbing fixtures, drains, and manhole castings. The concrete cannot shrink smaller than the object it is poured around, and this causes enough stress to crack the concrete (See Figure 2).

To combat random shrinkage cracks, control joints (often mistakenly referred to as expansion joints) are incorporated into the slab. Control joints are actually contraction joints because they open up as the concrete contracts or gets smaller. They are simply grooves that are tooled into fresh concrete, or sawed into the slab soon after the concrete reaches its initial set. Control joints create a weak place in the slab so that when the concrete shrinks, it will crack in the joint instead of randomly across the slab (See Figure 3).

Figure 3 A successful crack control joint

Figure 4 A crack next to a too-shallow joint

For a crack control joint to be effective, it should be ¼ as deep as the slab is thick. That is, on a typical four inch thick slab, the joints should be no less than one inch deep; a six inch thick slab would require 1.5 inch deep joints, etc. To minimize the chances of early random cracking, these joints should be placed as soon as possible after the concrete is poured. If the control joint is not deep enough, the concrete can crack near it instead of in it (See Figure 4).

Figure 5 Driveway cracks where joints should have been placed

Crack control joints should be placed at all re-entrant corners and slab penetrations, and evenly spaced throughout the rest of the slab. A good rule of thumb for four inch thick residential concrete is to place joints so that they separate the slab into roughly equal square sections, with no joint being further than about 10 feet from the nearest parallel joint. Following these guidelines, a four foot wide sidewalk would be cross- jointed at four foot intervals. A 16' x 64' driveway would have one joint running up the center lengthways, and joints cut across it every 8 feet.   This pattern would create sixteen 8' x 8' sections. If a driveway is 12 feet wide or less, the center joint up its length can usually be safely omitted, and the cross joints spaced the same distance as the driveway is wide (for example, an eleven foot wide driveway would have no center joint and cross joints every eleven feet). If joints are not placed where they need to be, the concrete will create its own joints by cracking. It's interesting to note that it often cracks in the same pattern as it should have been jointed (See Figure 5).

Expansion Cracks

Another reason that concrete cracks is expansion. In very hot weather a concrete slab, like anything else, will expand as it gets hotter. This can cause great stress on a slab. As the concrete expands, it pushes against any object in its path, such as a brick wall or an adjacent slab of concrete. If neither has the ability to flex, the resulting force will cause something to crack.

Figure 6 Foam expansion joint separating driveway and curb

An **expansion joint** is a point of separation, or isolation joint, between two static surfaces. Its entire depth is filled with some type of compressible material such as tar-impregnated cellulose fiber, closed-cell poly foam, or even lumber (See Figure 6). Whatever the compressible material, it acts as a shock absorber which can "give" as it is compressed. This relieves stress on the concrete and can prevent cracking.

Expansion joint material can also prevent the slab from grinding against the abutting rigid object during periods of vertical movement. During these times of heaving or settling, expansion joint material prevents the top surface of the slab from binding up against the adjacent surface and flaking off (See Figure 7).

Figure 7 Expansion joint between these slabs would have prevented chipping

Cracks Caused by Heaving

Figure 8 Tree roots lifted and cracked this sidewalk

Another factor which contributes to cracking is ground movement brought on by freeze/thaw cycles. During such cycles, the frozen ground can lift as much as several inches, and then settle again when the ground thaws. If the slab is not free to move with the soil, the slab will crack.

The presence of large tree roots can also cause concrete to heave. If a tree is located too close to a concrete slab, the growing roots can lift and crack the concrete (See Figure 8).

Cracks Caused by Settling

Conversely, if a large tree is removed from near a concrete slab the buried roots will decompose. The resulting void can cause the ground to settle and the concrete to crack. Settling is also called *subsidence*.

Subsidence is very common over trenches where utility lines and plumbing pipes are buried. Often times, the utility trench is not compacted when it is refilled. If concrete is placed atop a poorly compacted trench, the void created by subsidence can cause a crack across the unsupported concrete slab (See Figure 9).

Figure 9 Note the cracks in the sidewalk and street over this poorly compacted water line trench

Figure 10 Sidewalk and step settled back toward the house. Note that the step has been capped to compensate

Another place where concrete commonly subsides is near a house. Whether the home is built on a basement or crawlspace, the over-dig is subsequently backfilled. Unless the backfill material is compacted in lifts as the over-dig is filled, it will settle over time. This settling will cause any concrete poured atop it to settle along with it. Many times this settling will cause the concrete to crack and tilt back toward the house, creating negative slope (See Figure 10).

Cracks Caused by Overloading the Slab

Another factor which contributes to cracking is placing excessive weight atop the slab. Although it is a very strong material, concrete still has load limits. When you hear someone speak of 4,000 psi concrete, they are referring to the fact that it would take 4,000 pounds per square inch of pressure to crush it. Residential concrete, however, is rarely overloaded as far as compressive strength is concerned. That is to say, the weight doesn't usually pulverize or crush the concrete. What is more common is that the excessive weight is too much for the ground underneath the concrete. This is especially true after periods of heavy rain or snow melt when the ground is saturated and soft.

Figure 11 Large weights can crack a slab

When groundwater migrates under the concrete it causes the underlying soil to become soft or spongy. Excessive weight on the slab at this point can press the concrete down. Since the flexural strength of concrete is less than its compressive strength, the concrete bends to its breaking point. Homeowners who place large recreational vehicles or dumpsters on their driveways are more likely to see this type of cracking (See Figure 11).

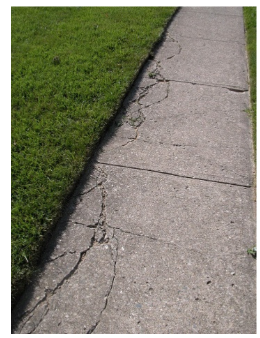

Figure 12 A heavy truck drove over this sidewalk, cracking the edge

Driving heavy vehicles off the edge of a slab creates a similar type of crack. (See Figure 12).

Cracks Caused by Premature Drying

Figure 13 Crazing cracks caused by premature drying

Crazing cracks are very fine surface cracks that resemble spider webs or shattered glass. They can happen on any concrete slab when the top loses moisture too quickly. Crazing cracks can be unsightly, but are not a structural problem. They are so fine that there is no way to repair them (See Figure 13).

Crusting cracks often happen during the concrete stamping process. They usually occur on sunny or windy days when the top of the slab dries out sooner than the bottom. The top becomes crusty so when the stamp is embedded, it pulls the surface apart near the stamped joints causing small cracks around the outside edges of the "stones". Although they are cosmetically unappealing, crusting cracks present no structural problem but may be patched if desired

Figure 14 Crusting cracks caused by premature surface drying

The Importance of Reinforcement

The use of synthetic fibers, reinforcing wire mesh, or rebar can add some extra support to concrete, but none of them will prevent cracking. In fact, too much steel can actually *cause* a slab to crack by restraining normal concrete shrinkage. However, if cracks happen, reinforcement can hold the different sections together.

The presence of reinforcement can be the difference between a crack remaining hairline in nature or separating and becoming wider and unsightly. Steel reinforcement can also keep the concrete on both sides of a crack on the same horizontal plane. This means that one side doesn't heave or settle more than the other, which could cause a tripping hazard.

It is sometimes impossible to determine exactly what caused a particular crack. However, proper site preparation and good concrete finishing practices can go a long way towards minimizing the appearance of cracks and producing a more aesthetically pleasing project.