Concrete Cracking

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1.Introduction:

Committee 201 of the American Concrete Institute in its “Guide for Making a Condition Survey of Concrete in Service,” published in the November 1968 ACI Journal, defines cracks as “an incomplete separation into one or more parts with or without space between .” They are classified by direction, width and depth. Cracks may be longitudinal, transverse, vertical, diagonal or random .

Cracking of concrete (Fig. 1) is a frequent complaint. Cracking is caused by restraint (internal or external) of volume change, commonly brought about by a combination of factors such as drying shrinkage, thermal contraction, curling, settlement of the soil-support system, and applied loads. Cracking can be significantly reduced when the causes are understood and preventive steps are taken.

Fig.1 Cracking of concrete

Cracking falls into the following general categories :

Pattern cracking: fine openings on the concrete surfaces in the form of a pattern; resulting from a decrease in volume of the material near the surface, or increase in volume of the material below the surface, or both.

Checking: development of shallow cracks at closely spaced but irregular intervals on the surface of mortar or concrete.

Hairline cracking : small cracks of random pattern in an exposed concrete surface.

D-cracking: the progressive formation on a concrete surface of a series of fine cracks at rather close intervals, often of random patterns, but in highway slabs paralleling edges, joints, and cracks and usually curving across slab corners.

2.The Causes of Concrete Cracking:

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)".***

Concrete is a brittle material and cracks due to inability to flex under stress. Cracks easily spread through plain concrete because there are no fibers present to hold the surrounding substance together.

After being properly cured concrete will also shrink as it dries. An average concrete slab will shrink 3/4 of an inch for every 100 feet of length. The underside, bound to the sub-grade that prevents it from contracting over its entire length builds internal stresses resulting in shrinkage cracks generally spaced about 20 feet apart. Unfortunately, excess water is sometimes added to the concrete load at the job site. Making the concrete easier to handle by adding water is a short-term solution that will leave long lasting results - more cracks. The wetter the mix laid down, the more it will shrink and crack. Unplanned cracks are usually in the wrong place and never straight. We can design cracks that are pleasing to look at. They are called joints. By grooving the slab at predetermined intervals before it sets, or saw cutting it shortly after setting, we can force the cracks to appear where we want them. As an added bonus the crack is hidden beneath a surface feature that can very aesthetically attractive.

Concrete that has not been cured but allowed to dry out the next day will tend to have more unsightly cracks. It simply lacks the strength needed to hold itself together. Curing is essential for three days and recommended for seven to help unwanted shrinkage cracking.

Cracks that are visible on the surface of concrete are usually the end result of months or even years of interior micro-crack formation, likely from microscopic fractures in the concrete formed during the curing, or drying, process after the concrete was placed. These fractures or fissures developed as excess water came out of the concrete, creating stresses that pulled it apart. The crevices then grew into cracks because the welded wire reinforcing was either not properly placed and did not inhibit their formation or was left out altogether. For years, the tendency for concrete to develop shrinkage cracks during the curing process has been accepted as natural to its use. The problem has been the inability to effectively limit the formation of these stress cracks. Today, fiber-reinforced concrete is minimizing those problems. Secondary reinforcement is not an answer to concrete cracking due to sub-grade failure. When the soil beneath the slab gives way, secondary reinforcement cannot help. But homeowners and contractors with a well-prepared site, who use fibers in their concrete in conjunction with the good concreting practices can expect the slab they just installed to remain structurally sound and attractive well into the future.

The majority of concrete cracks usually occur due to improper design and construction practices, such as:

a. Omission of isolation and contraction joints and improper jointing practices.
b. Improper subgrade preparation.
c. The use of high slump concrete or excessive addition of water on the job.
d. Improper finishing.
e. Inadequate or no curing.
f. Freeze and thaw action.

3.Types of concrete cracks:

3.1.Plastic shrinkage cracks:

It is observed that plastic shrinkage is the most prevalent causes of swift cracks. Before the hardening phase concrete is still in its plastic state which is accompanied by lots of water. This water takes up space, and during the dehydration process the sample segments lose their moisture. As a consequence, while curing, it gets smaller. By virtue of that concrete classified as a rigid material, during shrinkage procedure, some kind of stress on the concrete develops. 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. By the time the stress inside stiffened concrete exceeds specified value, the slab will start to crack so that ensure relieving tension. This phenomenon can be occurred frequently and extremely, particularly, in hot weather as a few hours after the concrete casting.

One of the most prominent factors which is greatly contributed to shrinkage is excessive amount of water inside the mixture. Even though it may enhance the workability of that concrete, 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. Some larger voids will be developed as the water mixed inside the compound is evaporated. Consequently, mentioned vacant spaces can be kept in view as an imperfection, and can ascend the vulnerability of the concrete.

Unfortunately, wetter concrete is easier to place and finish, especially in hot weather. This can provide an appropriate incentive for concrete finishers to add water to concrete mixer trucks: it facilitates their work. A few gallons per cubic yard will not significantly affect the mix. However, if an excessive amount of water is added, one can unintentionally diminish 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 reentrant 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 2).

Figure2 Shrinkage cracks originating at re-entrant corners

Another imperfection evidenced in the middle of a slab which can create the same defect as re-entrant corner would be circular objects. This phenomenon can be frequently observed around slab penetrations including, drains, manhole, pipe frames and plumbing fixtures. The concrete cannot shrink smaller than the object it is poured around, and this causes enough stress to crack the concrete. (see figure 3).

Figure3 Shrinkage crack at slab penetration.

To combat random shrinkage cracks, control 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 Fig.4).

Figure 4 A successful crack control joint.

In order to diminish the likelihood of early random cracking, these joints should be placed exactly after the concrete casting. If the control joint is not deep enough, the concrete can crack near it instead of in it. 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. (See Figure 5).

Figure 5 A crack next to a too-shallow joint

3.2.Expansion Cracks:

It is so apparent that in hot weather a concrete slab, the same as anything else, will enlarged. Expansion in concrete is another reason for concrete cracking. 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.

Two separate surfaces can be subdivided by an isolation joint or expansion joint as a boarder. 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).

Figure 6 Foam expansion joint separating driveway and curb.

3.3.Cracks caused by heaving:

In addition to stated issues which have been covered in previous pages, ground motion brought by freezing cycle. 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 7).

Figure 7 Tree roots lifted and cracked this sidewalk

3.4.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 Figure8).

Figure 8 Note the cracks in the sidewalk and street over
this poorly compacted water line trench.

3.5.Cracks Caused by Overloading the Slab:

Last but not least factor which contributes to cracking is subjecting to the extreme loading on the top of the slab. It has been proved that concrete is very strong and sturdy material; however, still it has some limitation for compressive stress. On the basis of diverse admixture in concrete, it a wide variety of strength can be seen. 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 beyond the ability of the ground underneath the concrete. This is especially true after periods of heavy rain or snow melt when the ground is saturated and soft. When groundwater migrates under the concrete it causes the underlying soil to become soft or spongy. Overloading 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 9). Driving heavy vehicles off the edge of a slab creates a similar type of crack. (See Figure 10).

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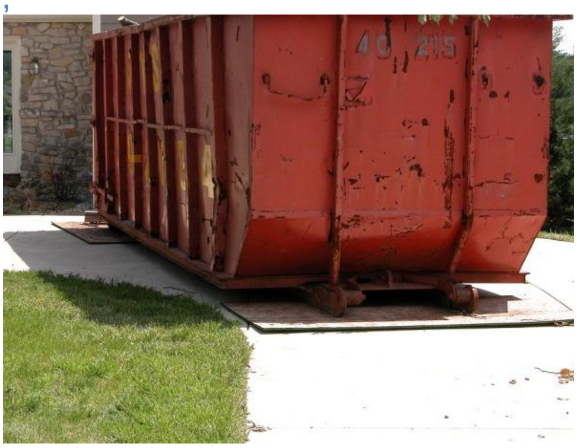

Figure 9 Large weights can crack a slab.

Figure 10 A heavy truck drove over this sidewalk , cracking the edge.

4.Prevention and repairing of cracking:

A. There are some consideration before concreting to reduce or prevent cracking:

Cracking in concrete can be reduced significantly or eliminated by observing the following practices:

1. Use proper subgrade preparation, including uniform support and proper sub-base material at adequate moisture content.

2. Minimize the mix water content by maximizing the size and amount of coarse aggregate and use low-shrinkage aggregate.

3. Use the lowest amount of mix water required for workability; do not permit overly wet consistencies.

4. Avoid calcium chloride admixtures.

5. Prevent rapid loss of surface moisture while the concrete is still plastic through use of spray-applied finishing aids or plastic sheets to avoid plastic-shrinkage cracks.

6. Provide contraction joints at reasonable intervals, 30 times the slab thickness.

7. Provide isolation joints to prevent restraint from adjoining elements of a structure.

8. Prevent extreme changes in temperature.

9. Properly place, consolidate, finish, and cure the concrete.

10. Avoid using excessive amounts of cementitious materials.

11. Consider using a shrinkage-reducing admixture to reduce drying shrinkage, which may reduce shrinkage cracking.

12. Consider using synthetic fibers to help control plastic shrinkage cracks.

B. But, for repairing the cracked concretes after hardening we need to consider the following steps:

The technique for patching cracks will depend on the size of the crack:

Narrow Cracks:

a.Remove any loose debris from the crack and surrounding area with a wire brush and broom.

b.Narrow cracks can be filled with a masonry crack filler that comes in a cartridge designed to be used in a caulking gun. Or you can fill the cracks with a vinyl concrete patching compound applied and smoothed with a putty knife. Vinyl concrete patching compound does not require the use of a bonding agent.

Wide Cracks:

a.Use a small sledge hammer and chisel to undercut the edges of the crack as illustrated at right. Undercutting the crack makes it wider at the base than at the surface, providing a mechanical method of "keying" the patch in place for a more secure and permanent repair.

b.Clean the area in and around the crack with a wire brush and broom. Wash the area with a stream of water.

c.Mix vinyl patching compound as directed by the manufacturer and trowel the compound into the cracks. Tamp the mixture to remove air pockets. If you use patching mortar instead of vinyl patching compound, either mix it with bonding agent instead of water or coat the edges of the surface to be repaired with bonding agent.

d.Smooth the mixture with the trowel.

e.When the patch has set (see manufacturer's instructions for the patch compound you are using), smooth or brush the surface to match the surrounding area.

Fig.11 crack repairing.

5.Conclusion:

In the result we can clearly see that crack is an issue that never ends and we always see crack when we are dealing with concrete, there are many different kind of cracks and different causes of occurring cracks that we should consider during designing the mix and concreting to prevent or reduce cracking. Also, it has mentioned how to repair cracked concrete depending on the size or width of cracks. As a result, we can say that engineers should be aware before and during the casting concrete the causes of cracking and avoid them to have the minimum cracking after construction and hardening.

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