Controlling Cracks in Concrete Slabs

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The right mix, well-placed control joints, and proper finishing will keep cracking to a minimum

by Dennis Golden

When it comes to concrete slabs, there is one fact that must be faced by homeowners, contractors, and concrete subs alike: Concrete will crack. Period. The challenge for the concrete sub is to work with the material and make it behave in a way that is acceptable to both the customer and the contractor. The key to success is to control *where* the concrete is going to crack, and prepare the customer for the inevitable.

Brittle Behavior

Concrete does its best work under compression. It's great for driving cars on, rolling shopping carts on, even for raising elephants on. But it doesn't have great tensile strength. Picture a glass table cover at a restaurant: It works fine when it's in full contact with the table top. You could probably dance on it without any damage to the glass. Your reputation might be shot, but the glass would be okay. But if you hold one edge of the glass off the table and apply pressure to it, the glass shatters.

Concrete behaves the same way. It's this lack of tensile strength, or brittleness, that most often causes the cracking found in residential slabs. A new slab shrinks as it cures, setting up tensile stresses throughout the slab. When the tensile stresses caused by the shrinkage exceed the tensile strength of the concrete, the concrete surrenders, and a crack appears.

And the cracking's not over when the slab is fully cured. A slab expands as the temperature rises

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Figure 1. *To prevent settlement cracks, the subgrade must be compacted properly. Here, a worker uses a vibratory plate compactor to correctly prepare the subgrade.*

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Figure 2. *The best way to guarantee concrete slump at the site is to perform a cone slump test (left). The wetter the concrete, the higher the slump (right).*

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Figure 3. *Here, 3-inch strips of asphalt-impregnated expansion board isolate a slab from wood framing. The flatworkers can also use the expansion board as a guide for finished slab height.*

and contracts as the temperature drops. This thermal fluctuation guarantees that the slab will always be subjected to tensile stresses.

There's not much you can do to control the shrinkage and external forces at work on the slab. But there are other causes of cracking that can and should be avoided.

Compact Before You Pour

Proper subgrade preparation is essential. If the subgrade isn't compacted properly, the slab will settle and sink. If the slab settles and sinks, you'll be asking it to perform like the glass table top that's extended over the edge of the table, and cracking will occur. To prevent a slab from settling, the subgrade should be a minimum of 4 to 6 inches of well-drained and uniformly compacted material (see Figure 1).

Never pour concrete on a frozen or heavily frosted subgrade. Water expands as it freezes, and when a frozen subgrade thaws out, the slab will settle.

The problem with plastic. A plastic vapor barrier is often specced as part of the subgrade preparation. The plastic keeps ground moisture from coming back up through the slab and affecting floor coverings and creating damp conditions. That's the good side. But vapor barriers can also increase the amount of shrinkage cracking in a slab. That's bad.

Once the concrete is out of the truck and in place, the water in the mix starts to evaporate. If the concrete is poured directly over plastic, the water has just one avenue of escape — through the surface. Once the top of the slab has dried, this subsurface water will cause shrinkage cracking to occur as it forces its way through the surface of the concrete. Fortunately, most shrinkage cracks are more cosmetic than structural, so if the floor is going to be covered, some cracking may be acceptable.

To reduce the chances of shrinkage cracking, cover the vapor barrier with 3 inches of compacted sand before placing the slab (see "Sub-Slab Vapor Barriers," 5/94). This sand can be compacted by a thorough wetting the day before the pour.

Thickness, Strength, and Slump

Before you prepare the subgrade, you'll need to decide how thick the slab should be. The American Concrete Institute (ACI) has broken nonstructural concrete floors into five classes and lists design criteria for each class, including thickness, strength of the mix, and maximum slump (see the table,Recommended Slab Thickness") Concrete subcontractors should pay more attention to slump (Figure 2). It's controlled by the amount of water in the mix: The more water, the higher the slump and the weaker the concrete. When concrete is poured at a high slump because of excessive water in the mix, the ingredients in the mix don't stay together. The water and some of the cement go one direction, the sand and the rest of the cement go another direction, and the stones end up alone in their own pile. To produce strong, durable concrete, all of the ingredients need to be uniformly distributed so the concrete performs as a homogeneous material.

Exceeding the recommended slump can also result in excessive bleed water. Bleed water is the water in the mix that migrates to the top of the slab immediately after placement. If this bleed water is not allowed to evaporate but is instead troweled back into the slab, it will create a weakened surface layer that will encourage shrinkage cracking, dusting, and possible crazing of the finish surface (see "The Finisher's Art," at right).

Keeping it together. There is a very common misconception that the addition of wire mesh or rebar in the slab will eliminate cracking. It won't. Steel placed in the middle of the slab section will only limit the width of cracks, preventing them from opening up into canyons.

The highly touted fiber mesh that many concrete suppliers offer won't stop cracking, either. I once had an opportunity to pour two 40-yard slabs side by side, one with wire reinforcement and the other with fiber mesh added to the mix. The slab with the wire cracked where predicted, but the slab with the fiber mesh cracked randomly. (I think the mesh additive makes the concrete look stiffer as it comes down the chute, so contractors often add additional water to compensate for what they think is an overly stiff mix.)

Isolation Joints

The Finisher's Art

I have an immense amount of respect for good concrete finishers. Part athlete and part artisan, a finisher develops a sense of feel and timing that can only be gained by years and years of hard work and practice. I wager a claim that this is some of the toughest work in the trades. So it is only respectfully and carefully that I suggest some areas where finishing crews need to pay attention.

The Water Valve

Adding water to the concrete mix opens the door to problems. When a mix is designed, it is based on the relationship between the water and the cement, and the Portland Cement Association has established acceptable limits for this water/cement ratio. When water is added to the mix, strength and surface hardness decrease while shrinkage and cracking increase. The bleed rate also increases and so does the chance for dusting and crazing. Concrete designed to be poured at a 4-inch slump should be poured at a 4-inch slump. If you are not familiar with what a 4-inch slump really looks like, I'll bet money that your ready-mix supplier would trip over himself to show you.

Bleed Water

Troweling bleed water back into the concrete weakens the finished surface layer of the slab by raising the water/cement ratio. Since the very top of the slab gets all of the attention as well as all of the traffic, it should be as strong and durable as possible.

Air Entrainment

In most areas of the country, if the concrete is expected to live outside, it's air entrained. Air entrainment creates billions and billions of microscopic air bubbles in the mix. This gives moisture someplace to hang out during periods of freezing and thawing. Without air in the mix, the surface layer of concrete, which is exposed to cycles of freezing and thawing, will deteriorate much more quickly than air-entrained concrete. Be sure to ask if your supplier provides air entrainment.

Tools to Avoid

I have yet to see a situation where a vibrator was needed when pouring a nonstructural slab. Likewise, the jitterbug should only be used on very low slump placements. The reason that it makes finishing easier is the same reason that it makes the surface much, much weaker: It pushes the large aggregate well below the surface and creates a weak plane where there needs to be a strong one.

— D.G.

Isolation Joints

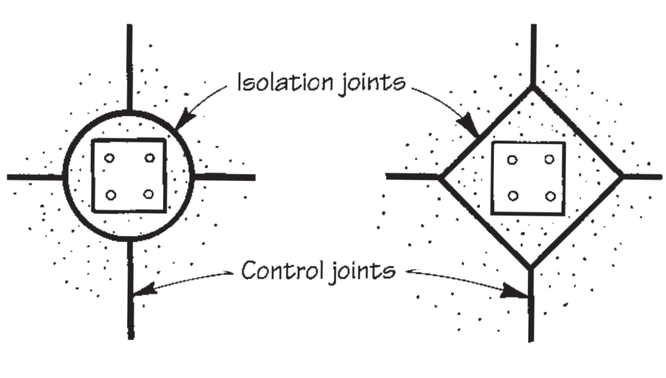

Figure 4. *Columns should be isolated from the slab using blockouts. When forming square blockouts, the points of the square should be positioned to meet the control joints.*

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Figure 5. *Sawn joints are cut with a power saw equipped with a diamond blade. They should be cut soon after the surface hardens.*

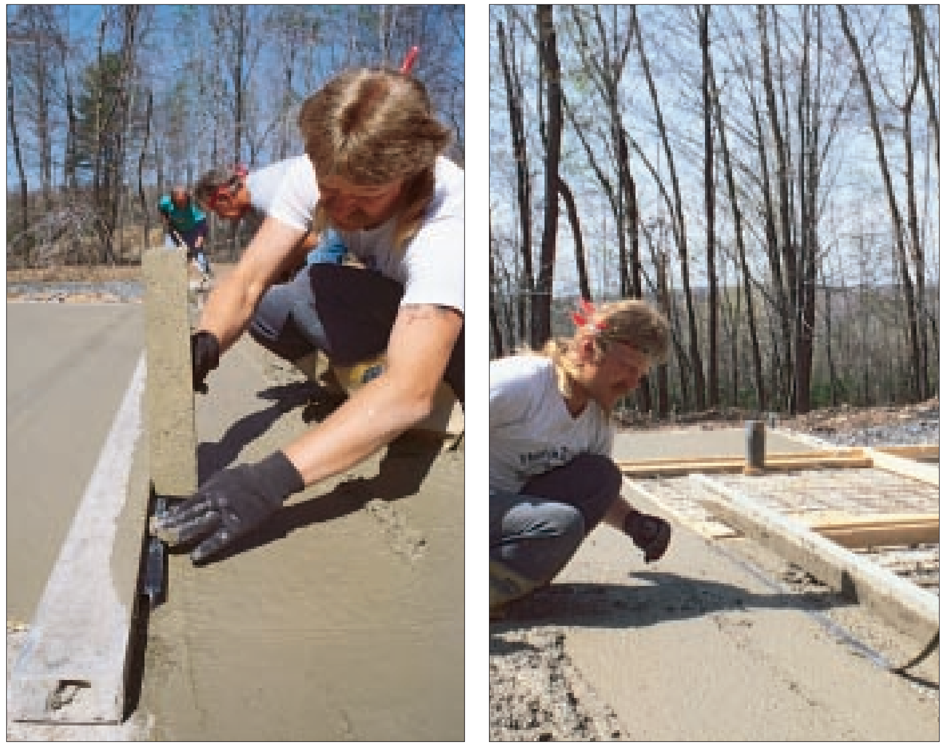

Figure 6. *Two-piece plastic control joint materials are popular on residential sites. The tee-shaped extrusion is pressed into the wet concrete (left), then the top, horizontal piece is "zipped" off, leaving an invisible control joint (right).*

Since you can't prevent cracks altogether, the best approach is to control them with proper joint design and installation. There are two kinds of concrete joints: *isolation*, or *expansion*, *joints* and *control joints*.

Slabs are a bit antisocial — they don't interact well with the structural elements of a building. Nonstructural slabs must be allowed to expand, contract, and move up and down independent of surrounding walls and columns.

Installing *expansion joint* material where the slab meets adjoining walls effectively isolates the slab from the wall. Fastened to the wall before the pour, this material, typically an asphalt-covered fiber board, also serves to establish the finished concrete level (Figure 3, page 22).

Columns must also be blocked out and isolated from the rest of the slab. The blockouts at column bases should be round or square. If they're square, they should be positioned so that the points of the square meet the control joints (Figure 4, previous page).

Recommended Slab Thickness

Floor Class	Application	Minimum Thickness	28-day Strength	Slump
1	Residential or tile covered	4"	3,000 psi	4"
2	Offices, churches, hospitals, schools, ornamental residential	4"	3,500 psi	4"
3	Drives, sidewalks for residences, garage floors	4"	3,500 psi	4"
4	Business or commercial walks	5"	3,500 psi	4"
5	Light industrial & commercial	5"	4,000 psi	3"

Control Joints

This is where you step in and tell the slab where you want it to crack. If you don't, the concrete will crack at random. The most common types of control joints are *sawn joints* and *tooled joints*.

Sawn joints should be cut as soon as possible after the concrete hardens. This can be a real judgment call on the part of the finisher, but it's generally a few hours after the final finish has been applied (Figure 5). If stones pull out when sawing begins, you're too early. If random cracks begin to occur before sawing has begun, you're too late.

Tooled joints are formed using a hand-held grooving trowel and are "cut in" immediately after the bleed water has left the slab.

Plastic extrusions are pressed into the wet concrete as the pour progresses to form control joints. One of the most popular is the "zip strip" type, a two-piece tee-shaped extrusion. The 10-foot lengths are tapped into the slab with the butt of a hand float and the top portion of the tee is "zipped" off, leaving the remaining vertical sec-

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Figure 7. *Rectangular slabs tend to crack in the middle. Control joint spacing should equal slab width.*

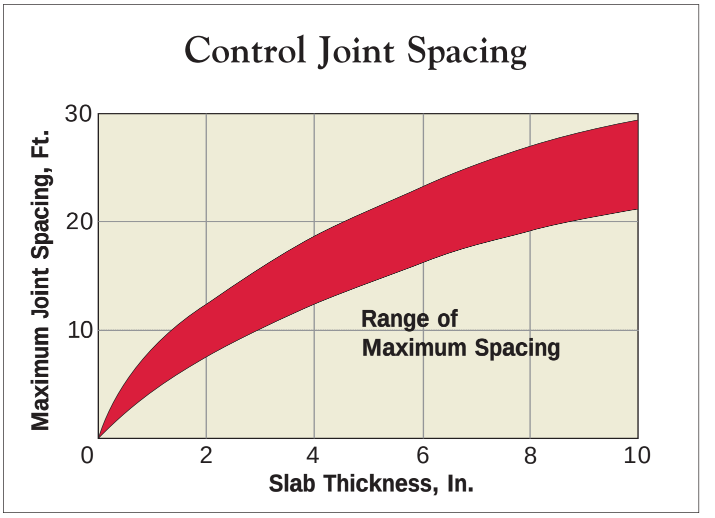

Figure 8. *The maximum spacing for control joints depends on the thickness of the slab. The shaded area of the graph indicates the acceptable range.*

tion 1/8 inch below the surface of the slab (Figure 6). Check with your concrete supplier for availability in your area.

No matter which method you use to create control joints, you should follow a few rules of thumb:

- Control joints should be no less than one-fourth the thickness of the slab in depth. This ensures the concrete will crack where you put the joint.
- Joint spacing should equal slab width. Slabs that are rectangular in shape tend to crack in the middle (Figure 7).
- Maximum joint spacing for 4-inch slabs is between 12 and 18 feet (Figure 8).

Where random cracking is better. There are some situations where random cracking is actually preferred. If the slab is going to serve as the base for a tile floor, a random crack will often do less damage to the tile than a poorly aligned control joint. Ideally, a tile joint should fall directly over the control joint, but this is difficult to achieve in the real world.

Figure 9. *These galvanized steel forming materials create a "keyed" control joint — essentially a tongue-and-groove — that helps keep adjacent slab sections in a flat, horizontal plane.*

Keyed Joints

This method is probably the most reliable jointing method for the conscientious concrete crew because it vertically aligns adjacent slab sections. These tongue-and-groove joints are most easily formed by using a manufactured galvanized piece of "keyway" material whose width matches the thickness of the slab (Figure 9). Most suppliers of forming accessories stock this item.

The galvanized strip is typically installed just below the surface of the slab. Once it's in, you're done — the crack will appear above the strip. No gas-powered saws to worry about, no expensive diamond saw blades to fret over. During the pour, however, the crew has to realize that the keyway shouldn't be kicked, tripped over, smacked with a shovel, or otherwise moved.

Construction joints. All a construction joint actually does is draw the line where the concrete placement ended on a given day. For thin, lightly loaded floors, a straight-formed "butt joint" is adequate. For more heavily trafficked and loaded applications, a keyed joint may be more appropriate.

Cure It Before It Ails You

Proper curing is essential for controlling cracks as well as for producing strong concrete. Cement and water have a kind of love/hate relationship. When placing fresh concrete, too much water can cause a variety of problems. But once the slab is poured and finished, moisture should remain in the slab as long as possible.

The cement needs the water to complete the chemical process of hydration. If the water in the slab is allowed to evaporate too quickly, the rate of shrinkage — and shrinkage cracking — will increase. Curing is the process of insuring that the water stays a part of this codependent relationship. It's important to plan on a method of curing *before* you pour. (For more on curing under a variety of conditions, see "Curing Concrete," 3/93; "Cold-Weather Concreting," 1/95; and "Hot-Weather Concreting," 8/95.)

If it sounds like a quality slab requires a whole lot of planning and a bushel of effort, you're right. Pouring a first-rate slab requires hard work and concentration from the time the project is conceived until the time that it becomes a rock-hard reality. But when the job is done properly, the rewards can last almost forever. ■

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