Evaluating cracks in concrete walls

By Bruce A. Suprenant and Kim D. Basham

To repair cracks in concrete properly, first determine what caused them.

Cracks in concrete can scar a building’s architectural appearance. They can be the cause of leaks from rain or groundwater. Or they can be the first telltale signs of a potential wall collapse. Thus, no crack should go unexamined.

For every crack, a trained investigator should record, with photographs and sketches, the following information:

- Location on the building
- Pattern (horizontal, vertical, diagonal, eggshell)
- Length
- Width (uniform or tapered; if tapered note how)
- Depth (through paint, plaster, entire wall)
- Age (clean crack indicates new; coated with paint or dirt indicates old)
- Active (moving) or dormant

Based on this information, an investigator can assess the cause of the crack, how harmful the crack is, and how best to repair it, if repair is deemed necessary. The location and pattern of cracks are the most important factors in determining their cause. In the drawings shown here, the causes of typical cracks in concrete walls are explained, based on the location and pattern of the cracks.

Measuring crack width

To measure crack width, most investigators use a crack comparator, although a graduated magnifying device is more accurate. Both of these devices are shown in Figure 1.
The crack comparator is easy to use, sufficiently accurate for most jobs, and usually supplied free by companies specializing in failure investigations. Graduated magnifiers cost $50 to $150.

**When is a crack too wide?**

Whether a crack is too wide depends on the type of building, the climate, wall reinforcement, and the type of crack. If the owner spared no cost on the wall’s architectural design, cracks that are 0.01 inch wide may be totally unacceptable. But a homeowner with a 20-year-old concrete basement might be satisfied to have cracks that are less than 1/8 inch wide.

According to the Portland Cement Association (PCA), a crack 0.010 to 0.015 inch wide neither hurts the surface appearance nor disturbs the viewer (Ref. 1). Cracks narrower than 0.004 inch are considered watertight (Ref. 2). Even wider cracks than this may not allow enough water penetration to damage the contents of the building.

So how does one evaluate the width of cracks? Table 1 lists typical design crack widths for reinforced concrete, modified from Reference 2. Based on these values, a way to classify and evaluate crack widths is given in Table 2.

Using Table 2 to classify the crack, the investigator also identifies the allowable exposure for that crack. For example, a crack that is 0.014 inch wide would be classified as “extensive” and usually allowed only in a dry interior wall. If a 0.014-inch-wide crack occurs in an exterior wall, it probably should be repaired. Naturally, the number and length of cracks also influences the investigator’s perception of permissible cracking and choice of repair schemes.

Don’t focus on one crack. Crack widths vary, so measure the width of several cracks. For reinforced concrete structures, the coefficient of variation for crack widths in a single structural element is approximately 40% (Ref. 2). For instance, if the average crack width is 0.050 inch, cracks in a single member could range from 0.040 to 0.060 inch in width.

**Long-term crack widths**

Crack widths in reinforced or unreinforced walls increase with time. But it’s difficult to determine the rate of crack growth and the maximum crack size. For reinforced concrete, a reasonable rule of thumb is to expect the final crack width to be about double the initial crack width (Ref. 2). Also, about 2 years after the crack occurs, its width at the rebar is about equal to its width at the surface.

**Why do cracks occur?**

Cracks result from strains that induce tensile stress in excess of the material’s capacity. Strain can be caused by loads, restraint of volume changes, or material behavior. Volume changes are created by changes in temperature and moisture. Influences on material behavior include freeze-thaw cycles and reactions between cement and aggregate.

Overloads caused by the dead weight of materials, the live load of equipment and people, soil and water pressure, wind, snow, and earthquakes can produce cracks. Deflections and deformations imposed by foundations, frames, roof slabs, and other structural elements also cause cracking.
Cracks in reinforced and unreinforced walls

Wall reinforcing doesn’t prevent cracking, but rather controls cracking. Some cracking is normal in reinforced or unreinforced walls. Typically, reinforced walls have several very narrow cracks at regular crack spacing. When a reinforced wall cracks, the proper amount and spacing of reinforcing maintains the strength and serviceability of the wall.

Unreinforced walls tend to have fewer cracks that are wider than those for reinforced walls. Aggregate interlock between the cracked faces still allows for load transfer and elevation control. If the crack opens too wide, aggregate interlock isn’t effective and the cracked faces move separately. For unreinforced residential basement walls, the National Ready Mixed Concrete Association (NRMCA) recommends repairing cracks when they leak or exceed 1/8 inch in width (Ref. 3).

Beware of a moving crack

The difference between an active or working crack and a dormant crack is important. An active crack can open or close and get longer, but a dormant crack has stopped moving. Dormant cracks tend to be caused by a temporary overload. Active cracks are created by repeated overloading or temperature or moisture changes that continually cause the crack to open and close. Also, a crack caused by a temporary overload can turn into a working crack due to changes in temperature.

If the crack is dormant, then it can be fixed with a rigid filler, such as epoxy or cement. Working cracks, however, should be filled with flexible sealants. If they’re repaired with a rigid material, they’ll only crack again. If the filler is stronger than the concrete, a new crack parallel to the repaired crack probably will occur.

There are three inexpensive ways to tell if a crack is active or dormant. The easiest way is to measure the crack width with a crack comparator at regular time intervals, such as every day or week. Record both crack width and the date of measurement. Always measure the crack width at the same location. Draw a line across the crack to mark where you measured it. Do this at three or four places along the crack. On exterior walls, use a waterproof marker. Changes in crack width indicate an active crack.

Another inexpensive method is to spot-patch the crack with plaster (Figure 2). Use hot water to speed the set of the patch. Note the date the patch was placed and inspect it at regular intervals to see if it has cracked. A cracked patch shows the crack is active. To be sure the patch doesn’t crack from drying shrinkage, use a nonshrink patching material.

A two-piece crack monitor that sells for less than $15 also can be used to detect crack movement (Figure 3). One of the two plastic pieces has red cross hairs; the other plastic piece has a grid system with a zero mark at the center. The two-piece unit is connected by a piece of tape so that the intersection of the red cross hairs on the one piece coincides with the zero mark on the grid of the other piece.

The monitor is laid across a crack and each end is attached to the wall, usually with epoxy or a fast-setting glue. After the adhesive cures (about 15 minutes for the

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### Table 1. Typical Design Crack Widths, inches

<table>
<thead>
<tr>
<th>Interior Exposure</th>
<th>Crack Width</th>
<th>CW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry atmosphere</td>
<td>0.016</td>
<td></td>
</tr>
<tr>
<td>Wet or moist atmosphere</td>
<td>0.012</td>
<td></td>
</tr>
<tr>
<td>Exterior Exposure</td>
<td>0.008</td>
<td></td>
</tr>
<tr>
<td>Where watertightness is required</td>
<td>0.004</td>
<td></td>
</tr>
</tbody>
</table>

Modified from Reference 2.

### Table 2. Classification of Crack Widths

<table>
<thead>
<tr>
<th>Crack Classification</th>
<th>Crack Width</th>
<th>CW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Fine (Watertight)</td>
<td>CW</td>
<td>0.004</td>
</tr>
<tr>
<td>Fine (Exterior Exposure)</td>
<td>0.004 &lt; CW</td>
<td>0.008</td>
</tr>
<tr>
<td>Medium (Interior Exposure—Wet)</td>
<td>0.008 &lt; CW</td>
<td>0.012</td>
</tr>
<tr>
<td>Extensive (Interior Exposure—Dry)</td>
<td>0.012 &lt; CW</td>
<td>0.016</td>
</tr>
<tr>
<td>Severe</td>
<td>CW &gt; 0.016</td>
<td>—</td>
</tr>
</tbody>
</table>

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Figure 2. This vertical crack is plastered to determine if the crack is active or dormant. If the crack is active, the patch will eventually crack. Dormant cracks can be filled with epoxy or cement. Active cracks that are still moving should be filled with a flexible sealant.
glue and 24 hours for the epoxy), cut the tape holding the two pieces together and record an initial value. Now, if either side of the crack moves, one of the plastic pieces moves. The red cross hairs, originally at the initial value, slide over the grid system indicating the amount of horizontal and vertical movement. Both the amount and direction of movement can be observed.

**Evaluate cracks early**

If cracks aren’t examined, evaluated, and—if necessary—repaired, they can grow from an eyesore into a costly headache. The larger cracks get, the more wind-driven rain they let into the wall. Water, in turn, can corrode metal components, cause efflorescence, and, if it freezes, spall the concrete. Some cracks can even lead to wall collapse. Cracks are a warning that shouldn’t be ignored.

**References**

2. ACI 224R-92, “Control of Cracking in Concrete Structures,” American Concrete Institute (ACI), 1992.

Kim Basham is an assistant professor of civil engineering at the University of Wyoming, Laramie.

**Examples of Nonstructural Cracks in Concrete Walls**

(Modified from Ref. 4) These cracks usually don’t affect the structural integrity of the wall or lead to significant concrete deterioration.

**A. Plastic Settlement - Reinforcing**

After initial placement and vibration, concrete continues to consolidate. Plastic concrete may be locally restrained by rebar, previous pours, or formwork. Concrete consolidates around these local restraints, causing cracks adjacent to the restraining element.

**B. Plastic Settlement - Arching**

See previous explanation for drawing A.

**C. Plastic Shrinkage**

Occurs at the exposed top of the wall when the fresh concrete loses moisture rapidly. High wind, low humidity, and high temperatures evaporate surface moisture faster than it’s replaced by bleedwater. Typical plastic shrinkage cracks are shallow and short and occur in all directions.

**D. Early Thermal Contraction**

Cement hydration produces heat, causing the temperature of the concrete to rise. After a few days, the concrete cools, causing a contraction. If this contraction is restrained by previous pours or internally by differences in cooling, cracks may develop. Early thermal cracking usually occurs within a few weeks after concrete placement.

**E. Long-term Drying Shrinkage**

Drying shrinkage, caused by loss of moisture, induces volume changes that are restrained by rebar and interconnecting walls and slabs. The combination of shrinkage and restraint causes tensile stresses that can crack the concrete. Drying shrinkage cracks typically occur 2 to 4 weeks or more after concrete placement.

**F. Crazing**

Localized drying shrinkage. Low-permeability forms (steel or plastic) or early form removal increase the occurrence of crazing.

**G. Alkali-aggregate Reactions**

Alkali in the cement can react with silica in the aggregate to form a swelling gel. The swelling gel creates an expansion, producing tensile stresses that can cause the concrete to crack.