from experience

How to Evaluate Cracks in Buildings

By Nels Roselund

My office phone rings, interrupting my train of thought again. I answer. The voice says, "Are you a structural engineer?" "Yes." "There are cracks in my building and I need you to tell me if it's safe." Why call a structural engineer when a crack is found in a building? There is good reason: Who has better tools to evaluate cracks in a building than a structural engineer? With knowledge of the materials properties, some familiarity with soils, an understanding of statics, and a grasp of load paths, who is better equipped to figure out what moved to form a crack and why it moved? I ask the caller a few questions. Based on the answers, I may be able to give helpful direction without visiting the building, or I may decide to offer to take a look.

Whether I visit the site or not, I will try to understand the crack and discuss with the owner likely causes. I will discuss how to stabilize and repair the crack and what may happen if nothing is done about it. However, I will avoid any discussion about safety. Safety is usually not a structural engineering determination. On the other hand, determination of the causes and significance of a crack, and what to do about it, are structural engineering matters that need to be understood and communicated to the building owner. The owner or whoever is responsible for the use of the building needs to then determine whether the building is safe enough for its intended use. The following is an example to explain what I mean.

I was asked to evaluate a 200 year old masonry church building. "Is it safe?" I was asked. Its walls have prominent cracks that everyone can see, even as they drive by without stopping. The cracks probably date from 1857, when a major nearby earthquake shook a very large area. About 75 years ago, the building was rehabilitated to become a parish church that has been in regular use since. The cracks were plastered over but not repaired structurally. Years passed. Seasonal changes in temperature and humidity, vibrations of nearby rail and highway traffic, and subsequent minor quakes caused the plaster to loosen and fall off, revealing the old cracks. As alarming as the cracks appeared to me, who was I, even a structural engineer, to say that the building was not safe? Had it not been structurally unchanged in 150 years? Had four generations of local families not been nurtured in it and worshiped in it – safely? Was I to arrive at this late date to be the one to determine that the church building was safe or unsafe? That was not my role.

I would, however, try to understand and explain, in lay terms, the cracks and their probable causes and hazards they may pose. I would need to explain the appropriate stabilization and repair of the cracks, as well as the costs and benefits, if any, of performing these repairs. The parish leaders would need a thorough understanding of these things in order to decide whether the building continues to be safe enough for their families to use, and whether or not, or how soon, to begin a repair program. If a repair program is to begin with limited available funds, I may need to help prioritize repairs, considering the costs and benefits of each repair item.

In this case, the structural engineer's role is to understand and report the cause or causes of the crack and determine the structural significance of the crack. In addition, he would determine how to stabilize it, assess whether or not it represents structural damage and recommend how to repair it.

You won't learn very much about a crack by studying it; but you will learn what you need to know about it by studying the building and its environment. To understand a crack, answer these questions:

What building component displaced to open the crack and which way did this component move? By observing the crack and touching it to discover out-of-plane offsets, you can determine whether the movement had an in-plane component, an out-of-plane component or a rotational component (indicated by a varying crack width along its length). Look for other cracks related to the displacement. Usually, at least two cracks are required for a part of a building to move relative to the rest of the building.

Is the moving part continuing to move? Debris, spider webs or paint in the crack may indicate that the crack is old. A blob of un-cracked paint across the crack probably indicates that there has been no movement since the paint was applied. If long-term stability is uncertain, determination of whether movement is continuing may take an extended period of time. Simple, inexpensive but effective crack monitors can be made by either using two business cards and carefully drawn lines, or by using a thumb-applied spot of plaster or mortar across a crack. (See *Figures 1* and *2*, respectively.)

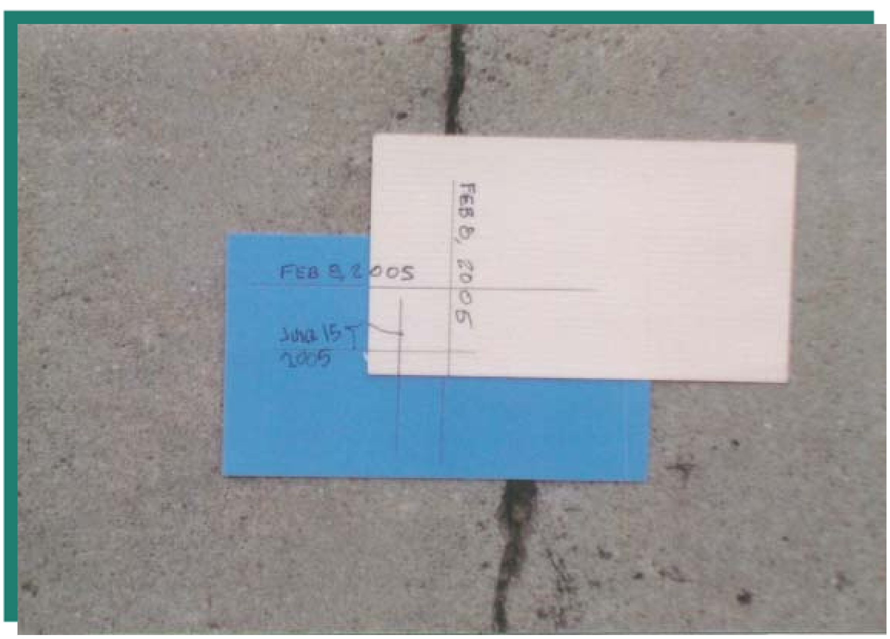

Figure 1: Business Card Crack Monitor. Adhere the cards to the surface, one each side of the crack.

Why did it move? There are many conditions that cause cracks to form and building parts to move. Examples of these are heaving or consolidation of foundations and slabs, expansion of corroding embedded steel, overstressing of structural elements, earthquake shaking, differing response to loads, moisture or temperature of different adjacent structural materials concealed by finishes. Also, inherent properties of materials can cause cracks. For example, for concrete, shrinkage cracks form as it

Figure 2: Mortar Thumbprint Crack Monitor

cures; in large timber members, seasoning checks form which can be very prominent but are usually structurally unimportant. This is not an exhaustive list – the possibilities are endless.

In my experience, water is the usual suspect. It may be water from a breached roof-drain system, a landscape irrigation system, or a leaking plumbing system that has penetrated the bearing soils of foundations. It may be water that has penetrated masonry or concrete to corrode embedded steel. Or it may be water from a long undetected roofing or plumbing leak that has promoted wood-rot that has weakened a structural member.

How can the condition be stabilized? The cause or causes of the crack must be addressed and any underlying moving parts must be stabilized before repairs are made, or else the repairs may be damaged by further displacements. If the cause is a seasonal water source, it may take the passage of the dry season, or even the passage of a full year, to determine whether or not the stabilization effort has been effective.

Does it need to be repaired structurally and, if so, how? The Building Code requires a building to be maintained in a safe and sanitary condition. Repairs to structural elements shall be made such that the elements will comply with the code under which it was constructed. Structural repairs, if needed to restore the strength of the structure or to protect the building from future damage, should be included in your report as a requirement. Aesthetic repairs may be included in your report as recommendations, to be followed at the owner's discretion.

There is no end to the kinds of cracks you may be called on to evaluate. Here are some examples of types of cracks that you may be challenged to evaluate. The challenge may be to understand the cause, or it may be to communicate your understanding to the owner that the crack poses no hazard.

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An unreinforced masonry wall that is adjacent to an intersecting wall with a diagonal crack starting at the intersection and rising from its base or sloping downward from its top: This is a good illustration of the importance of studying the building, not the crack, because the crack probably indicates either foundation settlement, or an outward tilt of the intersecting wall. If the crack varies in width and is wider at the top, the portion of wall above the crack has probably moved with the tilted intersecting wall, leaving the portion below the crack, and the rest of the wall behind. The crack is evidence of the displacement of the tilted intersecting wall and may represent an increment in a progression towards instability of the tilted wall. In a multistory building with a vertical stack of windows near the intersection, this kind of crack, rather than rising continuously from the base to the top of the wall, may rise in a zigzag pattern through the spandrels of the stack of windows. The cause of a tilted wall may be foundation settlement under the wall or a lack of wall anchors secured to the adjacent diaphragms, which was a common characteristic of older unreinforced masonry buildings. Lack of anchorage makes them vulnerable to separation from the building when subjected to lateral forces. To assure capacity is provided to restrain the wall against further tilting, repairs may need to include foundation underpinning, installation of wall anchors secured to the adjacent diaphragms and strengthening of the diaphragms.

Reinforced concrete walls and slabs: Fine cracks distributed over an extent of wall or slab cannot be avoided in ordinary reinforced concrete. A clear explanation to a worried owner that the fine cracks in his building indicate the reinforcing steel is doing its job may be all that is needed. Without reinforcing, a 50-ft length of concrete may develop a single ½ inch wide crack, or two ¼ inch wide cracks due to shrinkage. With reinforcing, many fine cracks will result instead, without structural damage.

A reinforced brick parapet with a long crack in the horizontal top surface: If the parapet does not have a coping, or if the original coping has been damaged or removed, storm water may have stayed on the wall long enough to penetrate the wall to the reinforcing steel where it helped start a corrosion process. As steel corrodes, it expands (rust occupies many times the volume of steel that produced it). The expansion of the top layer of horizontal steel can initiate a crack that extends to the top of the parapet, providing a route for rain water to flow into the wall and follow the crack deeper into the wall. When water reaches the corroding bars, the corrosion accelerates. When the water has penetrated to the next layer of horizontal reinforcing, the crack formation accelerates further. This process can lead to an internal plane of separation between parts of the parapet at each side of the curtain of reinforcing steel that effectively disconnects them from the reinforcing steel. It will probably be necessary to remove and rebuild the parapet, and to install an effective coping. If repairs are delayed too long and corrosion reaches the anchor bolts and other embedded items, repairs may become *very* costly.

Cracks due to structural overload: In my experience, cracks that pose real hazards are rarities. But we must always be alert to the possibility that excessive flexural cracks, diagonal cracks that may indicate impending shear failure and cracks accompanied by noises or visible movement would call for caution, evacuation, immediate shoring and/or removal of loads.

Cracks alarm building users and owners. However, the alarm is rarely justified. The structural engineer must not get caught up in the alarm. Be the cool evaluator. Do not look at a crack as the structural problem. The crack is a source of clues that will help you understand the structural problem. Thoughtfully use what you know about material properties, statics, and load paths to understand the cause and structural significance of the cracks. Determine what it would take to stabilize and to repair them. Afterwards, put your efforts into helping the owner or user understand your evaluation so that they can make the right decision as to what to do about the cracks in their building.▪

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