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Design Guide for Carbon Fiber Kevlar Grid Staples For Stitching Cracks in Concrete

Tools: Rotary hammer, 1 ¼" carbide drill bit, 3 inch chisel, epoxy dispensing gun

Material: 2-part laminating epoxy, 1" by 12" X 1" by 1" Carbon Kevlar staples.

Understanding crack movement: The first step is to understand the variables that can cause cracking. Cracking of concrete is a natural consequence of the concrete going from a plastic state to a solid state, due in part to stress caused by temperature change and restraint. This is often referred to as drying and shrinkage cracking. Depending on the moisture content, this process is over within a maximum of three years. In poured concrete, cracks are usually vertical in nature. The concrete will typically perform the way it was designed after chemically welding the crack back together.

Structural Cracks: This cracking pattern will be larger in diameter than shrinkage cracks and usually more of a 45° angle. Understanding settlement vs. lateral loading allows for proper procedure of repair. If settlement exists, no method of repair will withstand the in-differential and loading resulting from the settling (whether it be grouting and sealing, or epoxy/urethane grout injection).

Lateral loading may present the same cracking patterns as settling (with the exception of mapping out cracks into floor slab). Distinguish whether there are lateral load or settlement problems. Always check for proper seal plate anchorage (or building staying put and foundation sliding inward). In either settlement or seal plate slide conditions, the problems need to be corrected or cracking will continue (in some cases elsewhere in foundation).

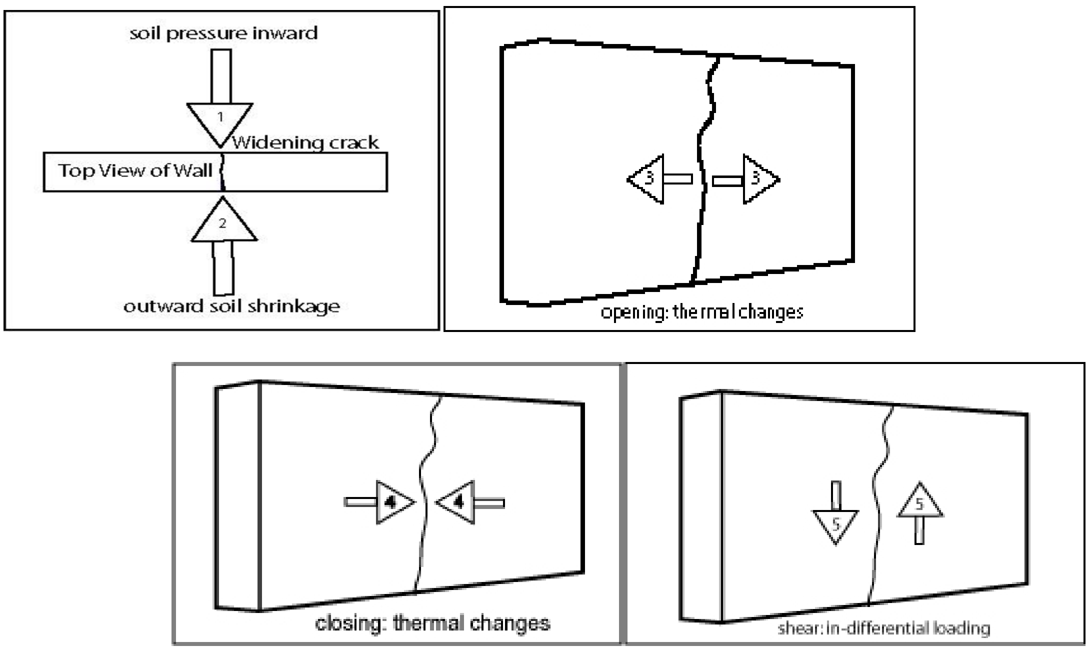
In drying and shrinkage crack repair, the most commonly used technique is a standard epoxy injection or urethane grout. Stitching has proven to take the load away from the repair material glue line and increase long-term success. Time is the enemy of a successful repair of concrete and the interaction between repair material and concrete substrate.

Structural cracking in poured concrete: The goal is to return a given structure to its designed condition. You must diagnose and solve initial problem before addressing the cracking. Failure to address cracks will allow cracks to worsen with time. Cracks that are larger than 3/8 of an inch may require a gel epoxy rather than a low viscosity epoxy. By their nature, gels or pastes have less wetting or bonding capabilities than liquid materials. Stitching provides a superior upgrade to these types of repairs, when done in conjunction with crack injection.

How cracks move: Understanding the movement of cracks increases the success rate of repair. There are six ways in which a crack in a below grade poured concrete wall generally moves:

1. Tensile / inward: due to lateral loading
2. Outward: due to shrinkage of soils
3. Opening: due to thermal changes
4. Closing: due to thermal changes i.e. cold, wet, dry, etc.
5. Shear: due to in-differential loading
6. Combination: all of the above conditions, plus the added load of structure

Examples of crack movement:



There are actually more factors than 6, but these are the most common. Many of these six, if not all, are the same in masonry walls (although their behavior is somewhat different)

Imagine one repair material and technique that address all 6 movements.

Carbon fiber reinforcement or steel has little benefit without making concrete one again. A poured wall with three cracks is actually three separate sections of concrete, susceptible to all six movements. In most cases the wall was not designed to be three individual moving sections, unless control joints were part of original design. All control joints must be respected for their purpose. Understanding these principles is the difference between successful crack repairs or mind-boggling failures.

How Carbon Fiber Staples for Stitching Cracks Work:

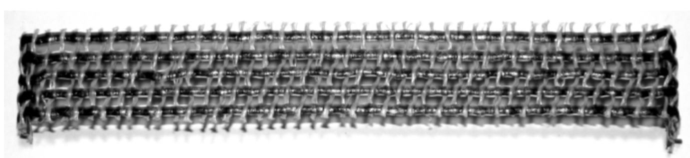
Epoxy injection: This is the best marriage because the two work in harmony. The epoxy does the work of #2 because it creates a wedge instead of a hinge point. It also does the work on #4; the crack cannot close due to its high compression. On numbers 1, 3, 5 and 6 it also performs well to a point. The carbon fiber excels in #1 and #3. It can also increase success in #5 and #6. In #1, the inward movement is a tensile force which carbon is tailor-made for. #3 is also a tensile force. In #5 and #6 you have a combination tensile force or pulling and shear forces. The carbon fiber can be aligned for tensile in a shear force.

Polyurethane injection: Carbon fiber stitching can increase long-term success of polyurethane injections. However, in some instances, they may fight each other over different goals. Urethane by design works by allowing for crack movement. Carbon's purpose by design is to arrest crack movement. Interestingly enough, movement alone is not the enemy of urethane, but rather too much movement. This is where carbon stitches aids polyurethane injections. By eliminating some of the 6 movements, stitches allow the urethane to function better for its designed movement capabilities. Urethane grout is very good in compression but has limited tensile properties. Carbon fibers help dramatically in #1 inward and #3 opening, but help very little in #2 outward and #4 closing of crack. A high compressive material such as epoxy, or cement based grout, must be pushed into the face of the crack to eliminate #2 outward, #4 closing and #5 shearing when using urethane foam as well as aligning carbon properly for shear movement with #5 and #6.

Such materials act as a wedge in these hinge conditions, thus allowing foam to perform to its primary strengths. NOTE: This is not easily done on small or tight cracks. Short of filling entire crack with a high compression material, there is no way of knowing if wedge is sufficient for arresting conditions of hinging.

Carbon vs. Steel: Have you ever seen steel re-rod bend? Once it is bent, it will not bend back to original form. Carbon loads up much quicker, and will not move back. That is why it is important to understand outward movement, etc. Carbon can be used in tensile and in shear by placing loading in tensile or redirecting load.

Carbon fiber staples for stitching cracks: The next logical step in the progress from steel stitching dogs and the creation of flat carbon stitches is the Carbon Kevlar Grid Staples. They are 8" long on profile with 1" each side protruding backwards:



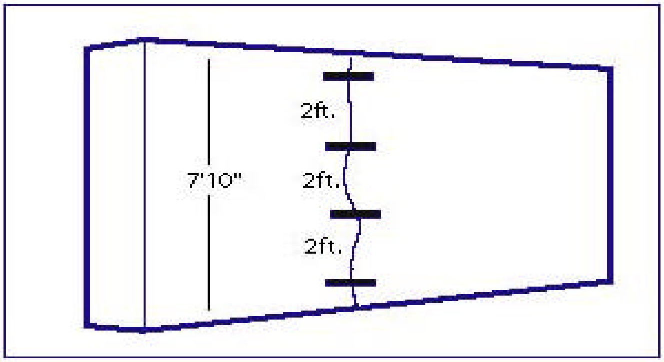
5-80k tows equals 6,600 in tensile strength. This is equal to #5 or 3/8 steel rebar, yet with an elongation of 1½ % is much stiffer than rebar at roughly 6½%. This offers a much tighter crack control than traditional steel.

Anchoring: By anchoring ends of staples into concrete or masonry, fewer loads are exerted on weak surface substrate and transferred into actual concrete or masonry. This improves its entire inter-workings with the repair material of choice.

Spacing: Many engineering organizations (such as The American Concrete Institute and The Army Corp of Engineers) make reference to stitching dogs, stapling, and doweling. Due to the intertwining of the 6 factors discussed earlier, they only make recommendations rather than guidelines.

For instance, you may repair a crack in tension unaware of shear movement and suffer failure due to combination loading. To calculate actual movements and loadings is difficult. However you can assume movements and gain assurance of a successful repair based on experience and education.

Guide for Stitching Cracks: Most common drying and shrinkage cracks are vertical (basically straight up and down) and are mostly affected by tensile forces:



Note: Carbon fiber tows are perpendicular to the crack face to maximize tensile function in conjunction with injecting the crack.

Stapling Structural cracks: These are usually caused by settlement, lack of reinforcement, in-differential loading, or improper anchorage at top or inadequate concrete. Once cracking occurs, lateral forces also contribute.

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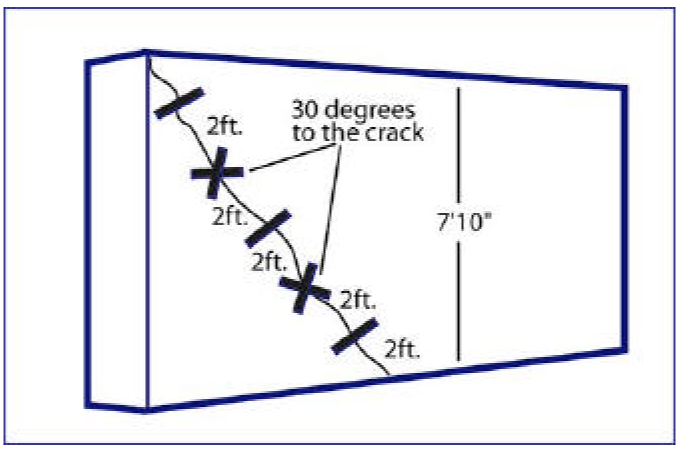

Note: These types of cracks experience all six loads. Carbon fiber and repair materials are not very good in shear loads, which may be the dominant movement. However, aligning the carbon tows at 30° to the expected shear loads will load the carbon in tension, allowing carbon to function in shear.

Finally: The straight Carbon Kevlar Grid Strap works similar to the Staple. The Staple simply improves the bond, pull-off and performance on cracking because of less surface area relative to the straps.

This is designed to be a simple guide to understanding crack movement and carbon fiber function in repair, not Technical Specification in nature.