



White Paper:
Hairline Cracking within Concrete Block Walls

Prepared by:

William C. Bracken, PE and José C. Busquets, PE
Bracken Engineering, Inc.
2701 W. Busch Blvd, Ste 200
Tampa, Florida 33618

November 2014

Hairline cracking within concrete block walls often referred to as stair step cracking or mortar joint cracking does constitute distress but does not constitute “Damage” in that it does not typically compromise structural integrity. Hairline cracking within concrete block walls is caused by stress resulting from shrinkage, creep, and thermal expansion and contraction. All of which are anticipated, can be predicted and need to be accounted for in design and construction. This paper will focus on the greatest contributor of these anticipated causes, concrete masonry shrinkage.

What is ‘Concrete Masonry Shrinkage’?

Concrete masonry is composed of two primary components; the concrete blocks and the cement mortar placed between the blocks. Both are composed of hydraulic cement, mineral aggregates and water. Within any concrete mixture, it’s the hydraulic cement that combines with the water to create the paste that binds the mineral aggregates together. Once combined, the hydraulic cement chemically breaks apart the water molecules using the hydrogen atom and one oxygen atom to form the crystalline structure that gives concrete its strength. This process is called hydration.

In addition to forming the crystalline structure that gives concrete its strength, hydration creates heat as the water molecule’s bonds are broken and results in the release of the free hydrogen atom as a gas. More importantly this process results in a reduction of the volume of material. An additional source of volume reduction is excess water. Specifically, hydraulic cement can only accept a finite amount of water. Therefore, any extra water added to the mix will initially increase the volume but will ‘bleed off’ further reducing the volume as the concrete sets up. Bleeding off of the excess water normally occurs within the first 12 hours after mixing but it takes on average 28 days for the majority of the hydration to occur. After 28 days the hydration process will continue at a decreasing rate and will, depending upon conditions, continue for years after initial mixing.

Concrete masonry shrinkage occurs due to the reduction in volume of both the block and mortar. Given that the block makes up a majority of the wall area, block shrinkage is the primary mechanism driving concrete masonry shrinkage. Therefore, drying shrinkage depends on several factors including method of curing, initial moisture content, cement content and the aggregates used in the block. While shrinkage in concrete masonry varies, there exist published shrinkage coefficients within ACI 530-95 (American Concrete Institute). According to these published coefficients it is typical for 100 lineal feet of masonry wall to experience a reduction in length of 1/2 inch or more.

Geometric Restraints

In order for concrete masonry to structurally perform as intended, to transfer vertical loads and to resist lateral loads, the walls must be restrained. This restraint is accomplished by structurally connecting the wall to the foundation as well as other components such as pilasters and bond beams. In addition to connecting the walls with the foundation and bond beams, walls are typically constructed integrally at corners and at changes in geometry. All of these locations, although necessary for the proper structural performance of the wall, result in restraints within the wall which induce stresses as the wall experiences shrinkage. As with plain concrete, concrete

masonry is strong in compression but weak in tension. Therefore, restrained tensile forces often lead to cracking as the wall acts to relieve the stress.

Block Wall Cracking

When concrete masonry shrinks the cracking that results will form different patterns depending on where the wall acts to relieve the stress. Typically shrinkage cracks manifest themselves at changes in material, changes in geometry such as openings for windows or doors and adjacent to corners. Their patterns can be either in a stair step, horizontal or vertical configuration. Cracking can also occur along the interface of different components within the wall such as the foundation to wall interface or the wall to bond beam interface. Cracking at these locations are typically horizontal in nature (refer to Figure 1).

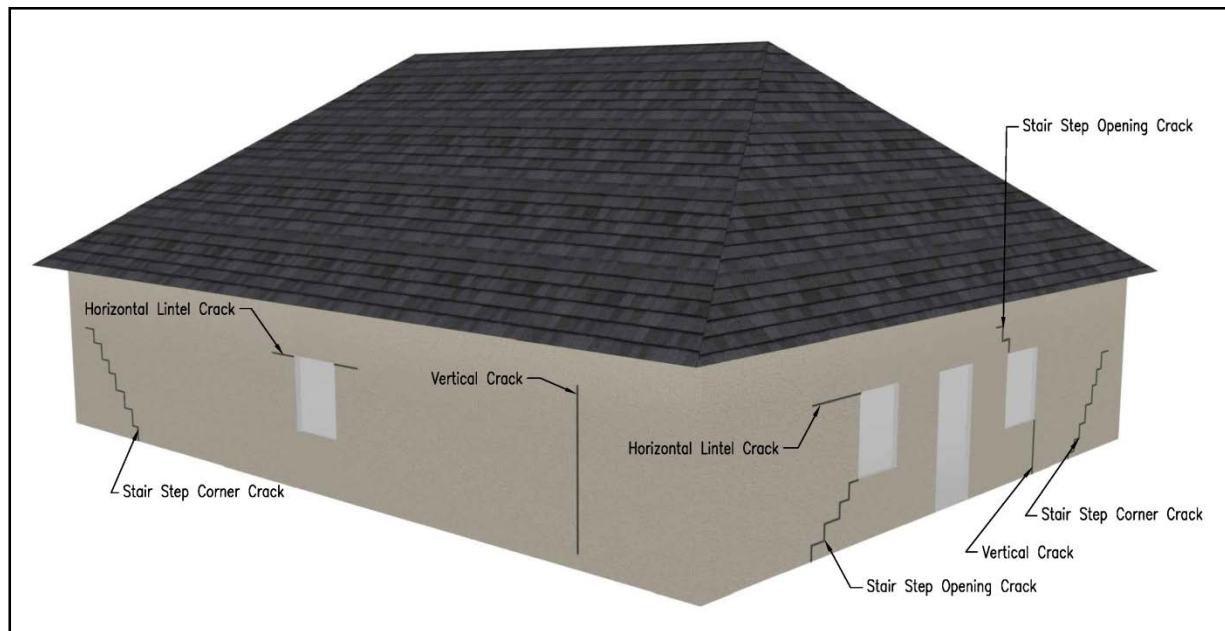


Figure 1: Image of structure depicting the location of typical shrinkage cracks

Leads

A common location for a stair step crack to occur is at the corners of wall sections, where there is a transition from the block wall's lead sections to the infill sections (see Figure 2). Specifically, when constructing a concrete masonry wall, a mason will commence with the construction of the leads or corners first and will typically use quicker setting, higher strength mortar. Once the leads have setup, the remainder of the wall is constructed using mortar that does not have the strength of the mortar within the



Figure 2: Photograph of a lead section of block wall.

leads. As a result the corners of the walls are essentially stiffer and more rigid than the remainder of the wall. Therefore as the masonry within the wall shrinks, a stair step crack will develop along this change in stiffness, inherently behaving like a cold joint within the wall.

Openings

Stair step cracks will also develop at the corners of door and window openings. This occurs because larger openings create geometry changes within the wall assembly that serve to concentrate shrinkage stresses. This same phenomenon exists with other materials, like steel and wood. In these materials the size and location of holes are restricted so as to minimize stress concentration or localized stress increase. In concrete masonry, as the wall undergoes its anticipated shrinkage, the stress developed at the corners of the door and window openings will result in either a stair step crack or in some instances a vertical crack, if the corner cell is reinforced.

Lintels

Horizontal cracks typically develop along the interface between precast concrete lintels and those portions of the wall supporting them. This occurs when a window opening creates a divide within the wall section, similar to a control joint in a floor slab. As the wall shrinks, the wall section on either side of the opening behaves as unit. As the wall sections attempt to pull away from the opening, stress builds up along the precast lintel that is bridging the two wall sections. This condition results in horizontal friction or shearing of the mortar between the wall and the precast lintel.

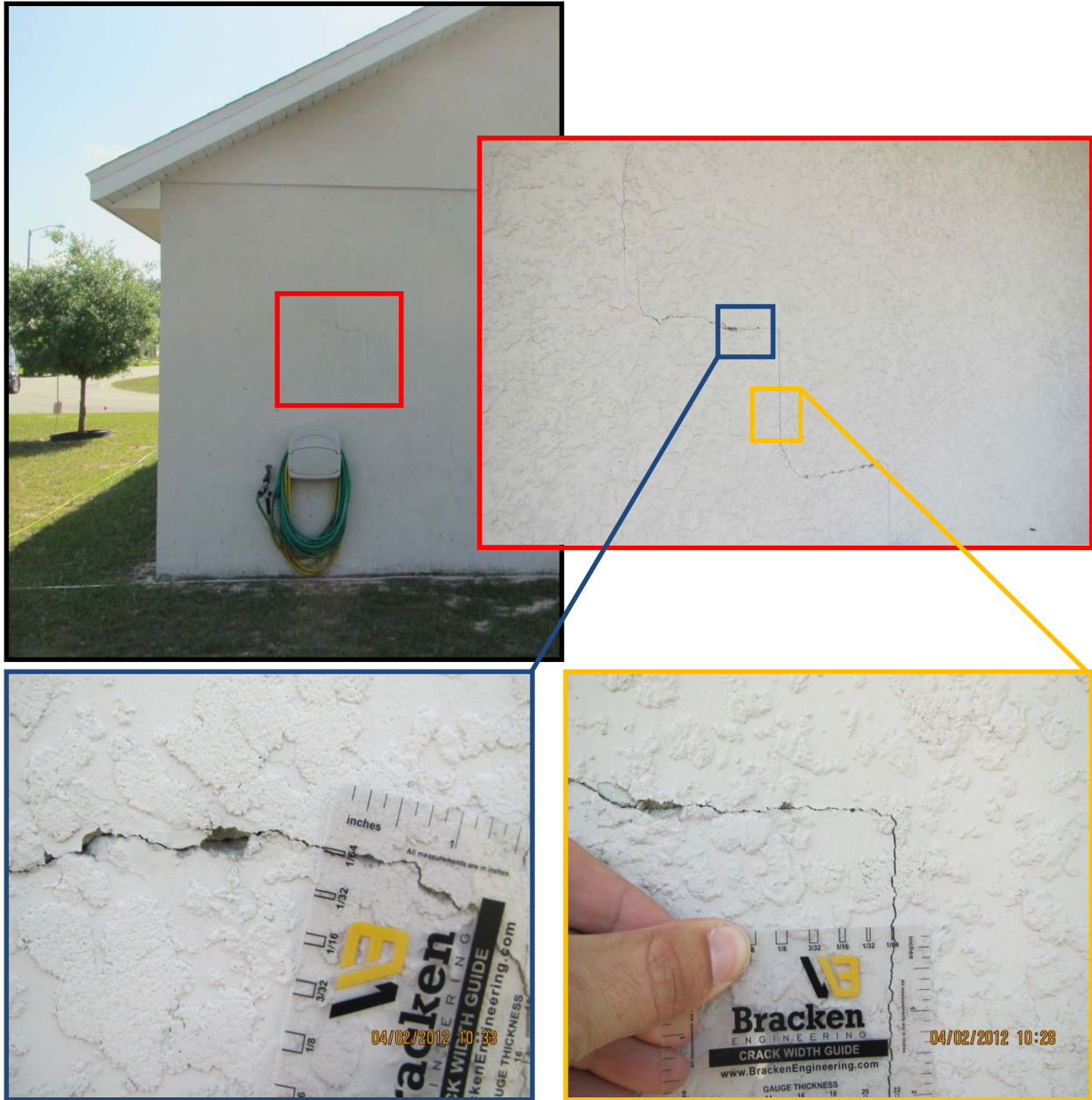
Reinforced Cells

Vertical cracks typically occur within the field of a wall or alongside reinforced openings. This occurs when internal stresses associated with shrinkage causes cracking between the internally reinforced grout filled cells and the adjacent unreinforced sections. Varying material properties relate directly to varying material strengths. In the case of concrete masonry assemblies; a typical concrete block has a compressive strength of roughly 2000 psi as does most common mortars. Grout however can range in compressive strength from 3000 psi to more than 5000 psi. These varying strengths result in varying behavior and performance. It is this fluctuation and resulting change in volume that creates internal stresses. As the volume of the wall changes and shrinkage stresses build cracking occurs between the much stronger reinforced grout filled cell and the adjacent unreinforced sections.

Characteristics of Shrinkage Cracks

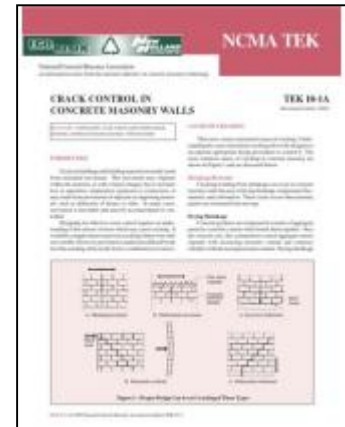
When examining cracking within a concrete block wall, it is essential to evaluate not only the pattern and location of the crack but also the characteristics of the crack. For example, in a stair step crack, if the separations along the vertical legs of the crack are uniform and there is not a measureable separation along the horizontal legs of the crack then this crack is consistent with shrinkage where the wall is moving horizontally and shearing along the mortar joint, as opposed to displacing vertically.

This same concept of horizontal shearing of the mortar joint, can also be found along the block wall to foundation interface as well as the precast lintel to block wall interface. Similar to the differential shrinkage and stiffness discussed at internally reinforced grout filled cells, the foundation is typically solid concrete that will shrink at a different rate than the masonry block wall sitting atop it.



Accounting for Shrinkage within Concrete Block Walls

Shrinkage stress within concrete masonry block walls is a mechanism which is anticipated and one which should be accounted for in design and construction. In fact, the American Concrete Institute within its requirements for masonry structures (ACI 530-95) Section 5.2.4 specifies that the effects of forces and deformations due to shrinkage should be accounted for in the design of concrete masonry. In addition, the National Concrete Masonry Association's TEK 10-1A lists drying shrinkage as the first cause of cracking. Therefore, it is imperative when analyzing the causes of cracking within a concrete masonry wall that one fully understands all the mechanisms associated with cracking of concrete masonry.



Effects of Shrinkage Cracks on Concrete Block Walls

Shrinkage cracks within concrete block walls typically do not affect structural integrity or the wall's ability to serve its intended function. However, to make this determination one must first establish whether the wall is reinforced or unreinforced and whether a notable loss of contact has occurred. The goal of this evaluation is to establish whether the load path has been compromised or not.

When reinforcing is present, the tension capacity of the masonry can be neglected because the steel serves to transfer the tensile forces. Therefore, a crack with no loss of contact will still allow loading to be transferred without affecting the wall's load path. In other words, shrinkage cracking in a reinforced concrete block wall will not affect the wall's structural integrity or its ability to serve its intended function.

When evaluating unreinforced concrete block walls, the characteristic of the crack and the location of the crack need to be considered. Unreinforced concrete block walls do have an allowable tensile capacity when evaluated in combination with its compressive load however performance can possibly be affected when a notable loss of contact exists. When such a condition exists numeric evaluation is required so as to determine whether the separation has altered the load path and if so whether a stress increase or load path discontinuity has occurred in the balance of the structural system.

Conclusion

Hairline cracking within concrete block walls resulting from concrete masonry shrinkage is an anticipated and predictable occurrence. As such, its presence may constitute distress but does not constitute "Damage" in that it does not typically compromise the wall's structural integrity.

References

Materials relied upon in the development of this paper include:

- *ACI 530-95/ASCE 5-95/TMS 402-95: Building Code Requirements for Masonry Structures*
- *TEK Note 10-1A: Crack Control in Concrete Masonry Walls*. National Concrete Masonry Association Web site: <http://www.ncma.org>
- *TEK Note 10-2B: Control Joints for Concrete Masonry Walls – Empirical Method*. Retrieved June 6, 2006, from National Concrete Masonry Association Web site: <http://www.ncma.org>
- *National Concrete Masonry Association*. “*TEK Note 10-1A: Crack Control in Concrete Masonry Walls*.” 6 June 2006. <<http://www.ncma.org>>.
- *Portland Cement Association*. “*Masonry Cement Mortars*.” 6 June 2006. <<http://www.portcement.org>>.
- *Safe and Sound: Masonry for Senior Housing*. *Masonry Today*, vol. 12, no. 2. Winter 2002. <<http://www.cement.org/bookstore/profile.asp?itemid=PL382>>.
- *Taly, Narendra*. *Design of Reinforced Masonry Structures*. New York: McGraw-Hill, 2001.