TEK NOTES

NCMA TEK NOTE 10-1A

The following information was taken in part from NCMA TEK note 10-1A. For more complete information please see the entire NCMA TEK note 10-1A at www.prairie-stone.com, NCMA TEK note link.

Crack Control in Concrete Masonry Walls

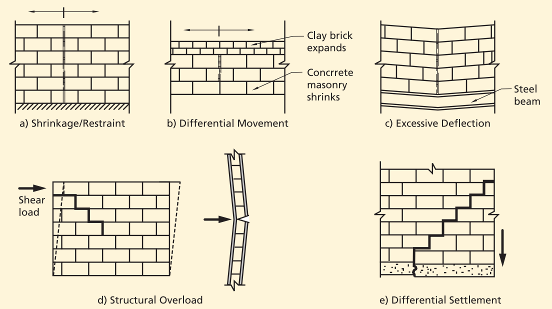
Cracks in buildings and building materials normally result from restrained movement. This movement may originate within the material, as with volume changes due to moisture loss or acquisition, temperature expansion or contraction, or may result from movements of adjacent or supporting materials, such as deflection of beams or slabs. In many cases, movement is inevitable and must be accommodated or controlled.

Designing for effective crack control requires an understanding of the sources of stress which may cause cracking. It would be a simple matter to prevent cracking if there were only one variable, however, prevention is made more difficult by the fact that cracking often results from a combination of sources.

Causes of Cracking

There are a variety of potential causes of cracking. Understanding the cause of potential cracking allows the designer to incorporate appropriate design procedures to control it. The most common causes of cracking in concrete masonry are shown in Figure 1 and are discussed below.

— Figure 1 —
Proper Design Can Avert Cracking of These Types



Shrinkage/Restraint

Cracking resulting from shrinkage can occur in concrete masonry walls because of drying shrinkage, temperature fluctuations, and carbonation. These cracks occur when masonry panels are restrained from moving.

Drying Shrinkage

Concrete products are composed of a matrix of aggregate particles coated by cement which bonds them together. Once the concrete sets, this cementitious-coated aggregate matrix expands with increasing moisture content and contracts (shrinks) with decreasing moisture content. Drying shrinkage is therefore a function of change in moisture content.

Although mortar, grout and concrete masonry units are all concrete products, unit shrinkage has been shown to be the predominate indicator of the overall wall shrinkage, principally due to the fact that it represents the largest portion of the wall. Therefore, the shrinkage properties of the unit alone are typically used to establish design criteria for crack control.

For an individual unit, the amount of drying shrinkage is influenced by the wetness of the unit at the time of placement, as well as the characteristics and amount of cementitious materials, the type of aggregate, consolidation, and curing. Specifically, drying shrinkage is influenced in the following ways:

- walls constructed with "wet" units will experience more drying shrinkage than drier units;
- increases in cement content increase drying shrinkage;
- aggregates that are susceptible to volume change due to moisture content will result in increased shrinkage; and
- units that have undergone at least one drying cycle will not undergo as much shrinkage in subsequent drying cycles (ref. 7).

Typical drying shrinkage coefficients range from 0.0002 to 0.00045 in./in. (mm/mm) or 0.24 to 0.54 in. (6.1 to 13.7 mm) in 100 ft (30.48 m).

Temperature Changes

Concrete masonry movement has been shown to be linearly proportional to temperature change. The coefficient of thermal movement normally used in design is 0.0000045 in./in./°F (0.0000081 mm/mm/°C) (ref. 2). Actual values may range from 0.0000025 to 0.0000055 in./in./°F (0.0000045 to 0.0000099 mm/mm/°C) depending mainly on the type of aggregate used in the unit. The actual change in temperature is, of course, determined by geographical location, wall exposure, and color.

As an example, a wall constructed during 70°F (21°C) weather and subjected to a minimum temperature of 0°F (-18°C) results in a shortening of about 0.38 in. (9.7 mm) in a 100 foot (30.48 m) long wall using the 0.0000045 in./in./°F (0.0000081 mm/mm/°C) coefficient.

Carbonation

Carbonation is an irreversible reaction between cementitious materials and carbon dioxide in the atmosphere that occurs slowly over a period of several years. Since there currently is no standard test method for carbonation shrinkage, it is suggested that a value of 0.00025 in./in. (mm/mm) be used. This results in a shortening of 0.3 in. (7.6 mm) in a 100 foot (30.48 m) long wall.

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NCMA TEK NOTE 10-1A (*continued*)

Restraint

Differential Movement
Various building materials may react differently to changes in temperature, moisture or structural loading. Any time materials with different properties are combined in a wall system, a potential exists for cracking due to differential movement. With concrete masonry construction, two materials in particular should be considered: clay brick and structural steel.

Differential movement between clay brick and concrete masonry must be considered when the two are attached since concrete masonry has an overall tendency to shrink while clay brick masonry tends to expand. These differential movements may cause cracking, especially in composite construction and in walls that incorporate brick and block in the same wythe.

When clay brick is used as an accent band in a concrete masonry wall, or vice-versa, the differential movement of the two materials may result in cracking unless provisions are made to accommodate the movement. To reduce cracking, slip planes between the band and the surrounding wall. Horizontal reinforcement or more frequent control joints or a combination thereof can be used to control cracking. See Crack Control for Concrete Brick and Other Concrete Masonry Veneers (ref. 6) for more information on these approaches.

Excessive Deflection
As walls and beams deflect under structural loads, cracking may occur. Additionally, deflection of supporting members can induce cracks in masonry elements.

Structural Overload
All wall systems are subject to potential cracking from externally applied design loads due to wind, soil pressure or seismic forces. Cracking due to these sources is controlled by applying appropriate structural design criteria such as allowable stress design or strength design. These criteria are discussed in detail in Allowable Stress Design of Concrete Masonry and Strength Design of Concrete Masonry (refs. 1 and 9).

Settlement
Differential settlement occurs when portions of the supporting foundation subside due to weak or improperly compacted foundation soils. Foundation settlement typically causes a stair-step crack along the mortar joints in the settled area, as shown in Figure 1. Preventing settlement cracking depends on a realistic evaluation of soil bearing capacity, and on proper footing design and construction.

CRACK CONTROL STRATEGIES
In addition to the proper design strategies discussed above for structural capacity and differential movement, the following recommendations can be applied to limit cracking in concrete masonry walls.

Control Joints
Control joints are essentially vertical separations built into the wall to reduce restraint and permit longitudinal movement. Because shrinkage cracks in concrete masonry are an aesthetic rather than a structural concern, control joints are typically only required in walls where shrinkage cracking may detract from the appearance or where water penetration may occur. TEK 10-2B (ref. 4) provides much more detailed information on control joint details, types and locations.

Reinforcement to Limit Crack Width
In addition to external restraint, reinforcement causes some internal restraint within the wall. Reinforcement responds to temperature changes with corresponding changes in length; however, reinforcement does not undergo volumetric changes due to moisture changes or carbonation. Consequently, as the wall shrinks, the reinforcement undergoes elastic shortening (strain) which results in compressive stress in the steel. Correspondingly, the surrounding masonry offsets this compression by tension. At the point when the masonry cracks and tries to open, the stress in the reinforcement turns to tension and acts to limit the width of the crack by holding it closed.

Studies have shown that reinforcement, either in the form of joint reinforcement or reinforced bond beams, effectively limits crack width in concrete masonry walls. As indicated previously, as the level of reinforcement increases and as the spacing of the reinforcement decreases, cracking becomes more uniformly distributed and crack width decreases. For this reason, a minimal amount of horizontal reinforcement is needed when utilizing the NCMA recommended maximum control joint spacings (refs. 3 & 4).

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Control Joints For Concrete Masonry Walls-Empirical Method, TEK 10-2B. National Concrete Masonry Association, 2001.