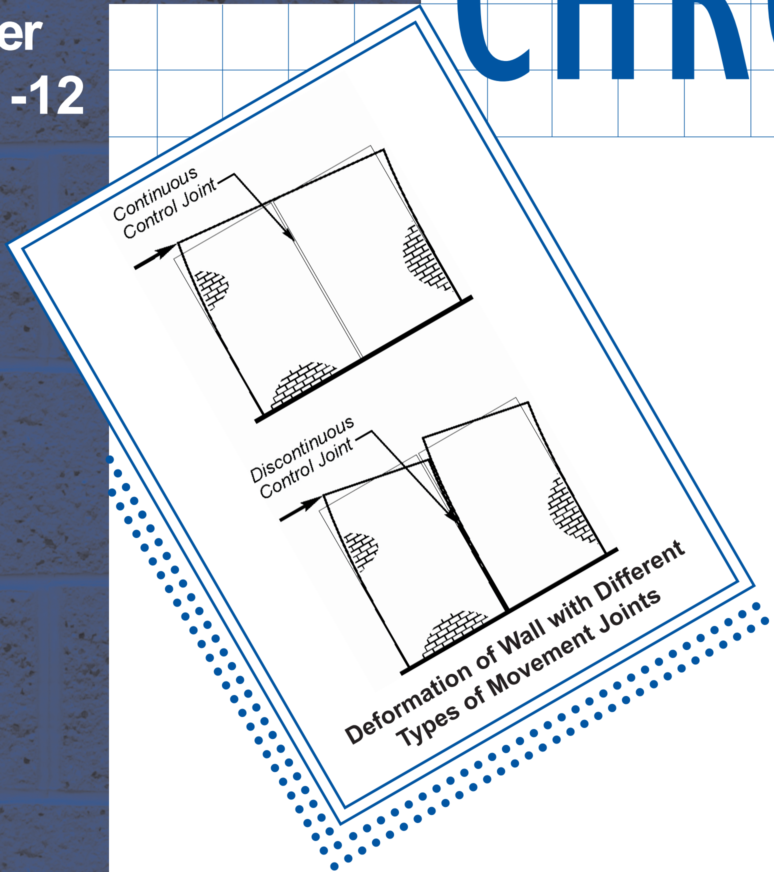
Engineering Notes For Design With Concrete Block Masonry

MASONRY CHRONICLES

Winter 2011-12



The Impact of Movement Joints on the Structural Design of Reinforced Concrete Masonry Walls

Introduction

Cracking is expected to occur when reinforced concrete masonry resists extreme loads. Minor cracking does not typically affect the structural integrity masonry buildings. However, relatively large cracks under low loads due to volumetric changes may sometimes have a negative impact on the aesthetics of a building. In extreme instances, the cracking may diminish the serviceability of a structure by allowing moisture penetration and corrosion of reinforcing steel.

Movement joints can be used to enable masonry to accommodate volumetric changes without significant restraint and the associated cracking. However, engineers must be aware of the impact that these joints have on structural performance and incorporate their effect during the design process.

Shrinkage and Cracking in Concrete Masonry

Shrinkage cracks in concrete masonry construction occur when the volumetric changes that occur due to drying or temperature changes are restrained by relatively rigid elements such as foundations, cross walls or adjacent framing.

Stresses are induced not only by shrinkage when the masonry reduces in volume, but also when it expands as temperatures increase. Cracks due to shrinkage are much more common, so the term "shrinkage cracks" is generally used for all cracks due to dimensional changes in the masonry. When masonry shrinkage is restrained, tensile stresses are induced as shown in Figure 1. If the tensile stresses exceed the cracking stress of the masonry, cracking occurs.

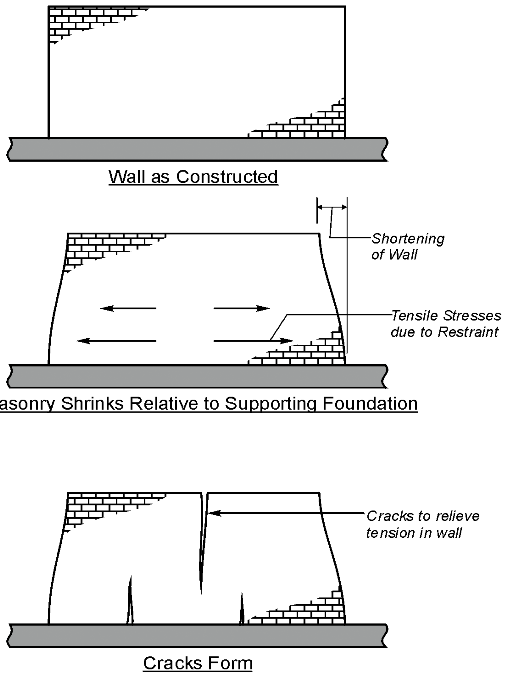


Figure 1 – Exaggerated Illustration of Cracks in Masonry Due to Restraint of Dimensional Changes (Adapted from Masonry Structures by Drysdale et. al.)

Concrete Masonry Association of California and Nevada

Dimensional changes in masonry occur because of three phenomena:

- Changes in volume due to temperature changes.
- Shrinkage due to carbonation shrinkage.
- Shrinkage due to drying.

Three common methods of controlling shrinkage cracking in concrete masonry are as listed below. To achieve best results, a combination of all three methods should be used as permitted by the specific project.

- Provide reinforcing steel to resist the tension stresses caused by shrinkage and thus limit the size of the cracks.
- Use materials (units, grout and mortar) that have a low shrinkage potential.
- Use control joints that permit movement and thereby reduce the tension stresses introduced as the masonry changes volume.

This edition of "Masonry Chronicles" will focus on the use of control joints and their impact on the structural behavior of typical concrete masonry structures.

Movement joints control cracking by permitting the movement of concrete masonry at pre-selected locations in the structure. This is achieved by having a complete break of all materials or by creating weakened planes where cracks are most likely to occur without affecting the building's serviceability or aesthetic features. It is recommended that control joints be spaced no more than 25 feet apart and that the length of each panel created by the control joints does not exceed 1.5 times the wall height, as shown in Figure 2. Control joints should also be placed at locations in the building where stress concentrations are expected to occur. Examples of such locations where control joints should be located are shown in Figure 3. Historically, a control joint is placed on one side of openings that are less than 6 feet wide and on both sides of openings greater than 6 feet wide. Other locations were control joints may be placed include corners of intersecting walls and around pilasters. It is also advisable to locate control joints in line with joints in foundations, floors or roofs so that the movement that occurs at these locations does not result in damage to the concrete masonry.

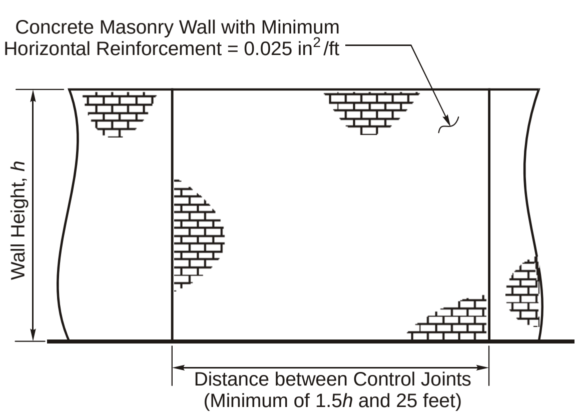


Figure 2 - Recommended Spacing of Control Joints in Concrete Masonry Walls

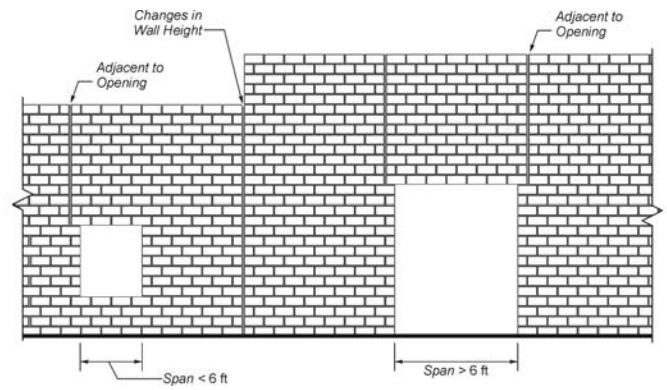


Figure 3 – Recommended Locations of Movement Joints in Concrete Masonry

Types of Movement Joints

As discussed in the previous section, movement joints may consist of a complete break of all materials including grout and reinforcing steel (which are often called discontinuous control joints or expansion joints) or weakened planes that allow cracks to occur at pre-determined locations (continuous control joints). Figure 4(a) shows a typical expansion joint with a break of materials. When forces need to be transferred across a discontinuous control joint, reinforcing steel is placed across the joint and wrapped with a plastic sleeve or grease to prevent bond, as shown in Figure 4(b). The reinforcement must be developed on either side of the joint to ensure adequate force transfer.

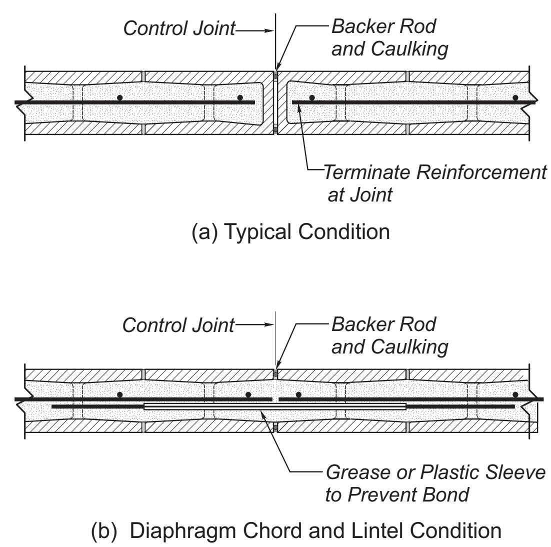


Figure 4 – Discontinuous Control Joints in Concrete Masonry

A common control joint used in the western United States, where seismic design requirements usually require solid-grouted walls, consists of a continuous mortar joint that extends over the height of the wall as shown in Figure 5. The continuous joint results in a break in the running bond layout of the concrete masonry units. Mortar at the control joint is typically raked back to weaken the vertical plane so that cracks are more likely to be located at the joint when movement or shrinkage occurs. In some cases, half of the horizontal reinforcing steel is terminated at the joint to provide an even weaker joint. A sealant is usually applied along the joint to prevent penetration of moisture into the building through the cracks. Since grout and horizontal reinforcement are continuous, special detailing is not required when forces need to be transferred across the joint.

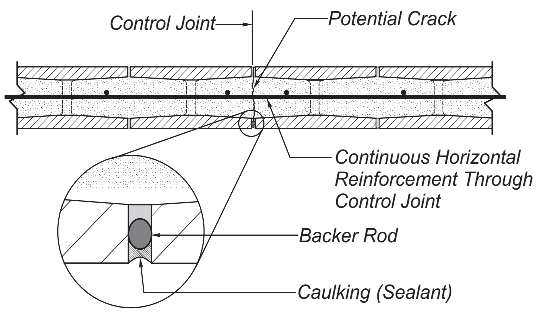


Figure 5 – Continuous Control Joint in Concrete Masonry

Movement Joints and Structural Design

The type of joints used depends on the specific project requirements and must achieve a balance between providing effective crack control and satisfying the structural design requirements.

The discontinuous control joints shown in Figure 4(a) allow the most movement and are thus extremely effective in controlling cracks in concrete masonry. However, special detailing is required as shown in Figure 4(b) when forces need to be transferred across the joint. This condition typically occurs at lintels, when the reinforcing needs to be developed beyond the edge of an opening; and at floor or roof levels, when the diaphragm chord reinforcement, which must be continuous, is placed within the wall. In addition, since there is complete break in materials, each segment of wall between discontinuous joints must be designed as a separate element. This will result in a reduced strength when compared to a wall without discontinuous joints.

Continuous joints can be extremely effective since no special detailing is required around openings or at chords. If half of the horizontal reinforcement is terminated at the joint to provide a weaker plane, the wall design must consider the reduction in reinforcement.

To illustrate the structural impact of movement joints on concrete masonry walls, consider the walls shown in Figure 6. The masonry in the 8-inch thick wall has a specified compressive strength of 1500 psi and Grade 60 reinforcement consists of #4 bars spaced at 16 inches on center in each direction.

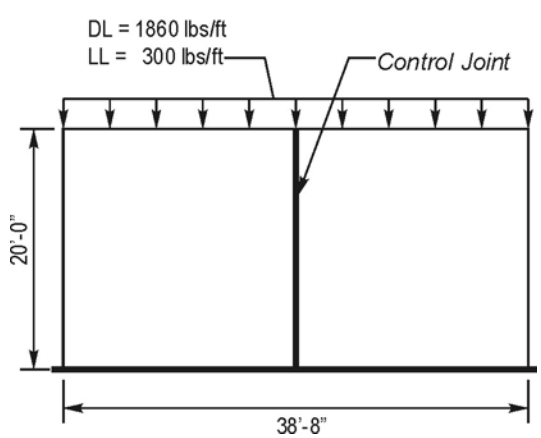


Figure 6 – Masonry Wall with Control Joint

If the wall is designed with discontinuous control joint with a break in all materials, the strength of the entire wall is given by the sum of the strength of each wall segment. Then, using strength design procedures:

$$\phi M_n = 2(1696) = 3382 \text{ kip-ft}$$

$$\phi V_n = 2(199) = 398 \text{ kips}$$

Note that if the wall is located in seismic design categories D, E or F, the wall must be a special reinforced masonry wall and horizontal reinforcing must be anchored with a standard hook around a vertical reinforcing bar on each side of the control joint.

If the wall is designed with a continuous joint with all reinforcement continued through the joint:

$$\phi M_n = 6772 \text{ kip-ft}$$

$$\phi V_n = 398 \text{ kips}$$

If half of the horizontal reinforcement is terminated at the continuous joint to provide a weaker plane and increase the likelihood that a crack will occur at the joint:

$$\phi M_n = 6772 \text{ kip-ft}$$

$$\phi V_n = 329 \text{ kips}$$

The calculations show that the flexural capacity of the wall when a continuous joint is used is over twice the capacity when a discontinuous joint is used. There is also a reduction in the shear strength of the wall if some of the horizontal reinforcement is terminated at the joint.

Effects of movement joints such as those illustrated in the above example should be considered when designing masonry structures and weighed with the need provide crack control.

This edition of Masonry Chronicles was written by Chukwuma Ekwueme, PhD., S.E. of Weidlinger Associates, Inc., Marina Del Rey, California.

About the Author

Dr. Chukwuma Ekwueme is an Associate Principal with Weidlinger Associates, Inc. He received his BEng from the University of Nigeria and MS, DEng, (Degree of Engineer) and PhD Degrees from the University of California, Los Angeles. He is a registered Civil and Structural Engineer in the State of California and a registered Structural Engineer in Nevada.

Dr. Ekwueme is a member of the Masonry Standards Joint Committee (MSJC) and on the Board of Directors of the Masonry Society (TMS). He is also active in several other organizations such as the American Society of Civil Engineers (ASCE), Structural Engineers Association of California (SEAOC) and the American Concrete Institute (ACI).

Dr. Ekwueme has written several publications and co-authored CMACN's "Seismic Design of Masonry Using the 1997 UBC," and the 2006 and 2009 editions of "Design of Reinforced Masonry Structures". He has also received awards for his work as a structural engineer.

Concrete Masonry Association
of California and Nevada
6060 Sunrise Vista Drive, Suite 1990
Citrus Heights, CA 95610
(916) 722-1700
Info@cmacn.org
www.cmacn.org

Presort
Standard
U.S. Postage
PAID
Premit No. 604
Sacramento, CA

CHANGE SERVICE REQUESTED

Why Masonry?

www.whymasonry.org

CMACN PRODUCER MEMBERS

Producer Members are an individual, partnership, or corporation, which is actively engaged in the manufacture and sale of concrete masonry units.

- Air Vol Block, Inc.
- Angelus Block Company, Inc.
- Basalite Concrete Products, LLC
- Calstone Company, Inc.
- CEMEX
- Desert Block Company, Inc.
- Oldcastle APG West, Inc.
- ORCO Block Company, Inc.
- RCP Block & Brick, Inc.
- Tri Delta (an Oldcastle Company)

Please go to www.cmacn.org for additional information on the latest design tools, previous “MasonryChronicles,” additional publications, links to our Members, links to other associated organizations and much more.