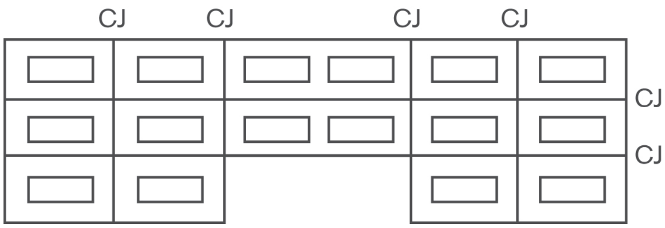
Building materials are dynamic substances which will change size and position due to a change in their environments. This is particularly true of commercial buildings which will be emphasized here. Since commercial buildings typically have more rigid structural frames than residences, the differential movements between the different materials is more critical. Therefore, when brick veneer is placed on commercial buildings special design considerations must be implemented: i.e., control joints.



These joints are used to prevent cracking in the brick as they and the other materials along the perimeter of the building move at different rates and directions. The determination as to where to place control joints is based on the material and building movements. It is then possible to evaluate where the control joints need to be placed.

What is a control joint? Some people call these joints expansion joints. It does not matter what the joint is called so long as the joint breaks up the brickwork into panels which will not crack or bow due to the various building movements. The control joint is a continuous space where the brickwork does not touch. The width of the joint, typically 3/8" to 1/2" (10-12mm), is dependent on the building movements and is kept water tight by a backer rod and a commercial sealant that can withstand the calculated movements.

Building Movements

There are many different types of building movement. Movement caused by temperature, moisture movement, creep in concrete, and horizontal and vertical deflections are the most important to brick veneer. There are a number of other building movements, which are important, such as foundation settlement and seismic displacements, but not to the placement of control joints.

Brick walls move both horizontally and vertically due to changes in temperature and moisture content. When a brick wall is heated it gets larger and when it cools it gets smaller. When brick gets wet, it expands. Approximately 85% of its maximum expansion occurs in the first 18 months after firing. Sixty percent expansion occurs in the first 3 months. However, when brickwork dries it does not shrink completely to its original dimensions, due to the inherent nature of the brick.

For a straight wall sitting on a foundation, the brickwork expands vertically from zero at the base to a maximum at the top of the wall. It is believed that this vertical movement can be as much as 50% greater than the horizontal movement. As will be discussed later, the design of the adjacent building elements must take into consideration all such movements.

Horizontally, the veneer moves from the center of the wall out to the edges. The horizontal movement at the base of the wall is smaller than the horizontal movement at the top of the wall, since, at the bottom, the dead weight of the brick above reduces the horizontal movement.

The formula for estimating the thermal and moisture movements in brickwork is shown at the end of this technical note with sample calculations figuring the displacements along the outer free edges of the wall.

Free edges are those edges bordering control joints which are not restrained from movement.

There are a few factors to keep in mind when using the equation:

- First, brick get hotter than the ambient temperature due to solar radiation. Consequently, a dark brown brick may reach 130°F (55°C), a medium red brick may reach 120°F (50°C) and a buff brick may reach 110°F (45°C).
- Secondly, insulation between the brick and the backup changes the brick's average temperature. The more thermally isolated the brick, the greater the temperature swing in the brickwork.
- Thirdly, the actual control joint size may need to be two to four times the calculated movement due to the extensibility of the joint sealant. It is important that the sealant criteria be indicated in the construction specifications. Finally, the sealant type, the temperature at the time the sealant is installed, and the length of the wall will help determine the width of the control joint.

Another important building movement has to do with concrete structural frames. This movement is called creep. It is the permanent column shortening or beam deflection caused by sustained weight on the frame. With the frame shortening, there may be considerable differential movement between the brickwork and the concrete frame.

For example, a 3 story building with continuous brickwork from the foundation up the full 3 stories will have the most differential movement at the upper floor, particularly in the summer. The brick expands from the base to a maximum at the top of the wall while the concrete frame is shortening with the maximum movement also at the top of the frame. In order to compensate for these movements, window details may need to be reviewed as well as veneer anchors and coping design. If there is a horizontal shelf angle at every floor with a control joint, the space between the underside of the angle and the top of the brick veneer must be large enough to allow the brick to expand and the frame to shorten. If there is not sufficient space, then the veneer will be confined such that the wall may bow or develop vertical cracks.

When brickwork is supported by structural beams, excessive deflection of these members may develop vertical flexural cracks in the wall. To minimize this problem, the brick industry recommends that the deflection of the brick supporting angles not exceed L/600 or .3 inch (8 mm). If a wall is continuous past a column, the deflection in the beams between the columns may cause vertical cracks to occur at the column. The amount of vertical deflection of the beams or angles supporting the brick and the expansion in the walls should not exceed the space between the angles and the brickwork below the angles.

When the brickwork and the structural backup deflect due to wind pressure, horizontal cracks may develop in the veneer. This can be of particular concern if the backup is metal studs, since the design of the metal studs may not be sufficient to provide support against cracking. Judicious placement of control joints will not improve the inherent design problems.

If the backup for the brickwork is concrete block with continuous one piece ladder horizontal reinforcement, a strong wall will be created with minimum amount of deflection. The use of horizontal truss type reinforcement in a long wall with insulation in the cavity may cause bowing and possibly cracking and is not recommended.

There are a number of special building conditions that require additional control joint considerations. For example, parapet walls have both sides exposed to the sun, which means that one side of the wall may be expanding while the other side is shrinking. This causes increased differential movement between the back and the front walls.

A second special detail is when different materials, such as stone or block, are built into the brickwork. The differential movement due to the difference in temperature and moisture expansions for the different materials can cause horizontal mortar cracks. If stone or concrete copings are built on a brick wall which move more than the brick, these materials may bow up or horizontal mortar cracks may develop.

A third special condition occurs when a short brick wall is built continuously with a tall brick wall. Where the two walls meet, a vertical crack may develop since the short wall moves vertically at a faster rate than the tall wall which moves slower because of all the weight of the brickwork above.

A fourth special condition is when two walls meeting at a corner are designed so that one wall is load bearing and the adjacent wall is not. The non - load bearing wall will move more than the load bearing and may crack.
A final condition may develop where the building moves laterally due to the wind and potentially can develop high shear forces in the brickwork. This normally is not a problem since flexible anchors and control joints will allow sufficient movement between the brick and the frame to minimize stresses.

Control Joint Locations

The determination as to where to place control joints must take into account the various movements that have been discussed. An additional distinction that needs to be made has to do with the difference between a lintel and a shelf angle. A lintel is a loose angle that supports the brick over an opening and bears directly on the brickwork on each side of the opening. It moves with the brick. A shelf angle is a horizontal angle that is fastened to the structural frame. It moves with the frame. It is essential to keep this point in mind when locating control joints. The vertical control joints should not go through the lintel. Vertical control joints may go through the shelf angle. The brick that does sit on the shelf angle should be separated from brick that sits on the foundation.

Vertical Control Joint Spacing

The location of the control joints is based on where and why brickwork cracks. The joints create brick panels which are independent of each other. For vertical control joints, there are a number of conditions that need to be considered. First, vertical cracks may occur at the corners. When there are no vertical control joints near a corner, the brickwork on both walls meeting at the corner will want to expand or contract due to a change in the brick temperature and moisture. Since the brickwork is bonded together at the corner there is no place for the internal wall stresses to be relieved, therefore cracks develop. The way to prevent the cracks is to make the length of the walls meeting at the corner short by placing control joints near the corner. The normal “rule of thumb” is to place either one joint at the corner or to place two joints spaced no more than 20 to 25 ft. (6 - 8m) apart around the corner. For example, the distance on one corner wall from the control joint to the corner may be 8 ft. (2.5m), which would mean that the second adjacent wall would be 12 to 17 ft. (3.5 – 5m) long. Shorter walls are permissible.

A second area where vertical cracks may occur happens on short offset walls that adjoin two long perpendicular walls. When the ends of these long walls that adjoin the short wall expand, the ends move in opposite directions. These opposing movements generate high shear stresses in the short wall, causing the wall to crack. These cracks can be avoided by placing a control joint at the interior corner and a second control joint 20 ft. (6m) away going around the exterior corner. Another approach would be to place control joints 20 to 25 ft (6 - 8m) apart on the two long walls with the short wall between them.

For straight solid walls, the spacing between control joints is determined by the width of the control joints and the type of sealant; however the walls should not exceed 40 ft.(12m). If a 3/8" to 1/2" (10-12mm) wide joint is desired, then the spacing between joints is approximately 25 ft. (8m) which also corresponds to the column spacing. This is based on a sealant which has an extensibility of +/- 50%. If the walls are 40 ft.(12m) long, the control joint width may need to be 7/8 inch (22 mm).

If the solid wall has continuous strip windows above, the control joint spacing is the same as just mentioned. However, if the windows are discontinuous then there are several alternative methods for placing control joints. When the walls have punched out windows which are windows built with loose lintels, then the vertical control joints should be placed between the windows and not at the window jambs. For doors with lintels, the control joint should not be placed at the door jamb. The pier widths adjacent to the control joints should be at least 24 inches wide (600mm). If narrow piers are important, an alternative is to replace the lintels with a shelf angle over the tops of the windows. The vertical control joints can then be placed next to the window jamb. The use of shelf angles will permit vertical control joints to be placed anywhere in the panel no matter if there are continuous strip windows or piers between the windows.

The vertical control joints in parapet walls should not exceed 20 to 25 ft. (6-8m) This can create a problem if the control joints are spaced 40 ft. (12m) apart in the lower portion of the building. One approach is to make all the control joints 20 to 25 ft. (6 -8m) apart all the way to the top of the parapet. Otherwise a shelf angle provided at the roof line will enable vertical control joints to be placed at any spacing in the parapet, perhaps half the distance of the spacing in the lower portion of the building. Vertical control joint spacing requirements at the corners and short offsets also apply to parapets.

Horizontal Control Joint Spacing

The location of horizontal control joints is not as involved as the vertical joints. The building code limits brick veneer/stud construction to a height of 30' above the foundation. Above this height, brick veneer should be supported on shelf angle at each floor. As the wall gets taller without control joints, special considerations need to be taken such as the coping detail, the space between the windows, and the brickwork at the upper floors and the type of adjustable anchors for the brick.

The control joint is created by providing a horizontal shelf angle with sufficient space between the underside of the angle and the top of the brickwork below the angle to accommodate all the building and brick movements. The joint is made watertight with a backer rod and a commercial sealant.

Normally, horizontal control joints are placed every floor over the windows. However, they could also be placed at every floor line with loose lintels over the windows. The control joint could be spaced every two floors, however, the size of the shelf angle and the width of the joint would have to be larger. A 3/8 to 1/2 inch (10-12mm) wide joint is satisfactory for control joints every 10 ft. (3m) for a steel frame. A concrete frame requires a wider joint. If the horizontal joint stops at a wall, the shelf angle must also stop at the wall without continuing through the vertical control joint. Similarly no horizontal reinforcing should go through the vertical control joint. When the control joint is continuous around the building perimeter, the angle does not interfere with the vertical control joints.

A special condition occurs when there is brickwork surrounding a large opening in the building facade. There must be a shelf angle over the opening to support the brick. One approach for placing control joints is to provide a shelf angle only long enough for the opening and then install vertical control joints that line up with the ends of the opening in the panel above the opening. Another approach is to extend the shelf angle over the opening either to the next vertical control joint or all around the building perimeter. Then vertical control joints can be placed anywhere in the panel above the opening.

Another special condition develops with the coping design on top of the parapet wall. If there were no horizontal control joints, the vertical movement at the top of the brickwork may be sufficient to push the coping. Therefore, either there must be a space between the top of the brick and the underside of the coping blocking, or a horizontal control joint is placed near the roof line to minimize the vertical movement in the brickwork.

In summary, the approach for locating vertical control joints can be delineated as follows. Normally, wall elevations are sufficient to determine joint placement. However, sometimes floor plans are also necessary for complicated buildings.

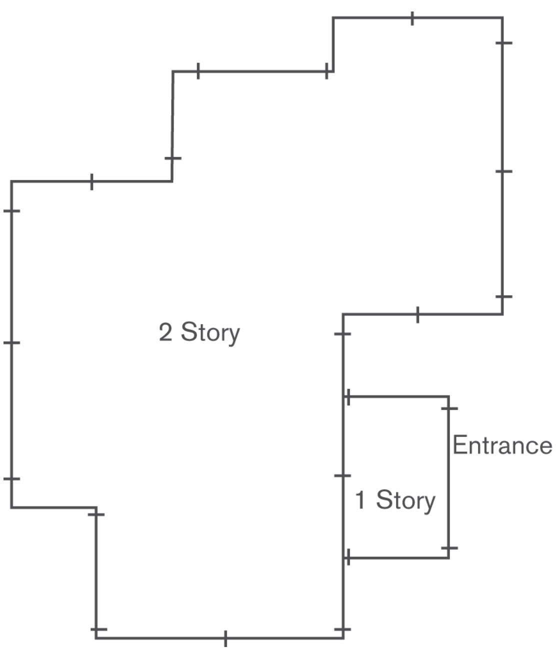
1. Start with an exterior corner, place control joints so that the distance between joints around the corner is less than 25 ft. (8m).

2. Proceed along one of the two walls, placing control joints on the straight portion 25 to 30 ft. (8 – 9m) apart or at the column lines or in the middle of window piers or along the edge of the window jamb if there is a horizontal control joint over the window.

3. When you get to an offset in the wall, place a control joint either at an interior corner or two control joints 20 to 25 ft. (6 – 8m) apart.

4. Continue all around the building until vertical control joints have been placed on every wall, bearing in mind special circumstances such as different height walls, parapets, wide facade openings, set back walls, different exterior materials and column locations.

The elevation sketch on the first page illustrates one possible choice for control joint locations on one wall. There are many different options. The plan view below illustrates one possible set of control joint locations all around the building. (- line indicates control joint)



Determining Control Joint Widths

The determination of control joint widths is based on many factors, such as the color of the brick, the temperature variation in the brick over a year's time, the length of the wall, the temperature of the brick when the sealant is installed and the sealant extensibility.

Since it is not possible to determine the temperature when the sealant is installed, the yearly temperature variation is assumed to be the worst case. If the sealant extensibility is +/- 50%, then the required as-built control joint width needs to be 2 times the calculated movement at the control joint. If the sealant extensibility is +/- 25%, the required as-built control joint width needs to be 4 times the calculated movement at the control joint.

The following equation is the BIA's recommendation for calculating the movement along a free edge.

$$w = (.0005 + .000004\,(rT))L$$

w = movement along a free edge

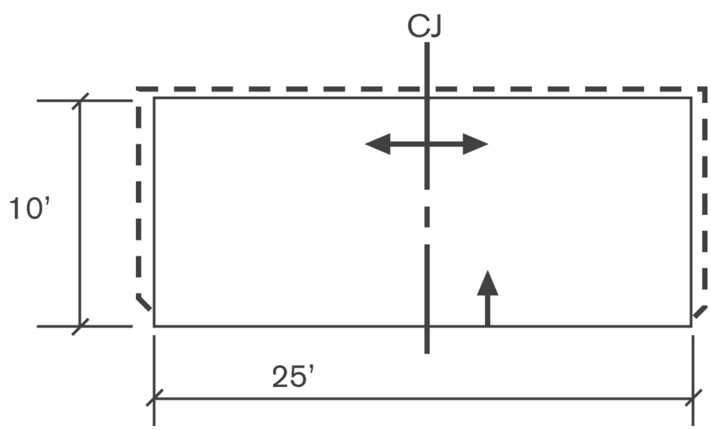
.0005 = coefficient of moisture expansion

.000004 = coefficient of thermal expansion

(rT) = maximum yearly temperature change

L = distance from point where there is no wall movement to the point on the wall where the maximum movement occurs. Horizontally, L is half the length of the wall. However normally there are two walls meeting at one joint, consequently the calculated movement occurring at the joint must be twice the calculated number for one panel. Vertically, L is the height of the panel.

Sample Calculations



A. Assume:

maximum brick temperature = 120˚F

minimum brick temperature = 40˚F

sealant extensibility = +/-50

Movement along the top edge of the panel

w = (.0005 + .000004 (80)) 10’ x 12 =.10”
sealant factor = 2
CJ width = 2 x (.10) = .20” < 3/8”

Movement along the vertical edge of the panel

w = (.0005 + .000004 (80)) 12.5’ x 12 =.123”

Since 2 panels meet at same CJ

Actual w = 2 x .123” = .246”

Sealant factor = 2

CJ Width = 2 x .246” = .49”

If extensibility of the sealant is 25%, then the sealant factor is 4. The CJ width along the top of the panel is .10” x 4 = .40” and the CJ width along the vertical control joint is .246” x 4 = .98”.

B. If the brick has been out of the kiln for 3 months, the coefficient of moisture expansion would be approximately .0002 instead of .0005. This changes the size of the required CJ widths.

Movement along the top edge of the panel

w = (.0002 = .000004 (80)) 10’ x 12 = .06”

CJ Width = 2 x .06” = .12”

Movement along the vertical edge of the panel

w = (.0002 + .000004 (80)) 12.5’ x 12 = .08

CJ Width = 2x 2x .08 = .32”

Waiting for the brick to expand due to moisture, will reduce the size of the CJ.

For calculating movement of clay brick masonry on buildings in Canada, the following coefficients should be used, taken from Table 1, Masonry Dimensional Properties, of CSA S304.1-94 Masonry Design for Buildings (Limit State Design)

Thermal movement
horizontal (mm/m/100˚C) 0.5 – 0.6

Thermal movement
vertical (mm/m/100˚C) 0.7 – 0.9

Moisture movement
reversible (mm/m) 0.2

Moisture movement
permanent shrinkage (mm/m) 0.2 – 0.7

Load movement
Initial elastic modulus (GPa) 4 - 26

Load movement
Long term strain/initial strain 2 - 4

Additional Reading Material:

1. BIA, Technical Notes 18 and 18A

2. Grimm, C.T., Masonry Cracks: A Review of the Literature, Masonry: Materials, Design, Construction and Maintenance, ASTM STP 992, 1988, pp. 257-280