# THE EFFECT OF LIGHT AND SHADOWS ON MASONRY

Illumination on a wall, whether from the sun or artificial light, may cause shadows that can be desirable when the architect intentionally designs for highlighting lines and textures or undesirable if it reveals the units have been laid with slight, but acceptable, imperfection. Often the units are placed well within published industry guidelines but the slightest shadows lead to the erroneous conclusion that the workmanship is substandard.

The use of light on walls and general criteria of shadows may play in the perceived acceptance or rejection of the wall.

Architects and owners evaluate walls in various lighting conditions and under certain circumstances. For visual acceptance of masonry walls, these conditions are standardized so that the acceptability is based on uniform lighting conditions and evaluated from a specified minimum distance.

## INTRODUCTION

Inspection of a masonry wall determines its acceptability or rejection. Too often masonry walls are inspected under lighting conditions that intentionally create magnified shadows, such as the sun positioned directly above the wall at midday. The shadows may be desirable or may be objectionable depending on the design intent and acceptable conditions.

Shadows can be intentionally created by patterned units, as shown in Figure 1, projecting units or tooled mortar joints.

*Field of wall showing pattern effect*

*Close view showing how block shape creates pattern*

**Figure 1** Patterned concrete masonry units create diagonal shadow lines on wall

Light and shadows can provide visual effect enhancing the appearance of individual masonry units (Figures 2 and 3).

**Figure 2** Split face or slumped concrete masonry units intentionally creating shadows and texture

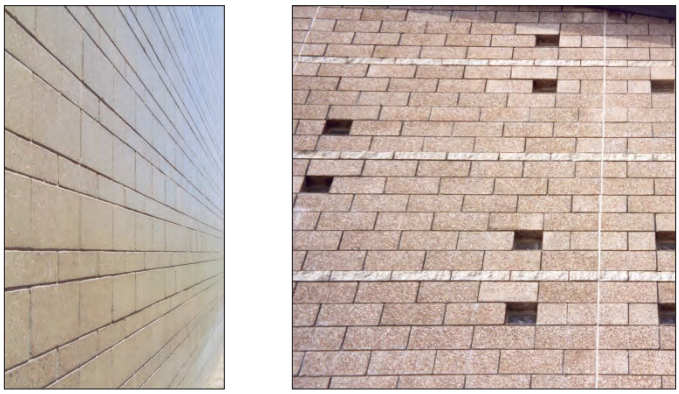

**Figure 3** Raked joints changes visualization of units (Rake joints not recommended for moisture resistance)

The effect is demonstrated by visiting the Grand Canyon in Arizona where the view of this natural wonder constantly changes throughout the day with the changing position of the sun. As the light and shadows cast in the Canyon constantly change, the visualization and beauty are continually altered. This phenomenon is also true of masonry walls and all structures in general.

Often, the designer seeks a flat smooth masonry wall with no special effects. Under these circumstances, visualization and inspection of the wall is critical. There are numerous conditions to assess so that proper evaluation can be made.

1. The time of viewing is critical since the angle of the sun on the wall can exasperate the placement of the units. Early morning with the sun from the east and low on the horizon may create shadows not seen otherwise. This is also true of an overhead sun at noon shining directly down the face of the wall. Setting sun may create long shadows on the wall and distort the effect of unit placement. Shadows travel with the angle of the sun and this must be considered in viewing a wall.

2. The nature of masonry walls makes them a custom product. Masonry walls are built in place from individual units produced offsite and transported to the jobsite. Masonry units are manufactured to specified ASTM tolerances and are subject to slight dimensional variation.

3. Concrete Masonry Units are specified by ASTM C90, *Standard Specification for Loadbearing Concrete Masonry Units*, with permissible variations in dimension tolerances stated in ASTM C90, Section 6 as follows.

**6. Permissible Variations in Dimensions**

6.1 *Standard Units*—For standard units, no overall dimension (width, height, and length) shall differ by more than ± 1/8 in. (3.2 mm) from the specified dimensions.
6.2 *Particular Feature Units*—For particular feature units, dimensions shall be in accordance with the following:
6.2.1 For molded face units, no overall dimension (width, height, and length) shall differ by more than ± 1/8 in. (3.2 mm) from the specified standard dimension. Dimensions of molded features shall be within ± 1/16 in. (1.6 mm) of the specified standard dimensions and shall be within ± 1/16 in. (1.6 mm) of the specified placement of the molded feature.
6.2.2 For split-faced units, all non-split overall dimensions shall differ by not more than ± 1/8 in. (3.2 mm) from the specified standard dimensions.
6.2.3 For slump units, no overall height dimension shall differ by more than ± 1/8 in. (3.2 mm) from the specified standard dimension.

Therefore, the thickness of a standard hollow concrete block unit may be ± 1/8 in., which means that an 8 in. nominally wide concrete masonry unit may range in thickness from 7 1/2 in. to 7 3/4 inches. This acceptable range is a result of the specified 7 5/8 in. dimension ± 1/8 in. manufacturing tolerance.

4. Hollow Clay Brick are specified by ASTM C652, *Standard Specification for Hollow Brick (Hollow Masonry Units Made From Clay or Shale)* with dimensional tolerances contained in ASTM C652, Table 3 as follows:

***ASTM C652, Table 3 Tolerances on Dimensions, in. (mm)***

| Specified Dimensions | Permissible Variation, max. | |
|---|---|---|
| | Type HBX | Type HBS and HBB |
| 3 (76) and under | ± 1/16 (1.58) | ± 3/32 (2.38) |
| Over 3 to 4 (102), incl. | ± 3/32 (2.38) | ± 1/8 (3.18) |
| Over 4 to 6 (152), incl. | ± 1/8 (3.18) | ± 3/16 (4.76) |
| Over 6 to 8 (204), incl. | ± 5/32 (3.97) | ± 1/4 (6.35) |
| Over 8 to 12 (306), incl. | ± 7/32 (5.56) | ± 5/16 (7.94) |
| Over 12 to 16 (408), incl. | ± 9/32 (7.14) | ± 3/8 (9.52) |

Therefore, for a 7 1/2 in. wide standard hollow clay brick unit (8 in. nominal), the variation in thickness could be ± 5/32 in. for Type HBX or ± 1/4 in. for Types HBS and HBB. Thus, the width of adjacent units could have a dimensional difference of as much as 5/16 in. to 1/2 in. depending on the type of unit.

5. Although extreme variations as listed above are rare, slight variation of 1/32 in., for example, would not be uncommon. This variation in thickness could result in an uneven surface appearance normally on one side of the wall. This is a result of the bricklayer aligning the units to a mason's line on one side of the wall. The side laid to the line will be relatively flat and even while the opposite side will reflect the unit thickness variation.

6. Variation of manufactured units may also be due to distortion or warpage of the units. ASTM C652, Section 7.2 contains the following for warpage:

*7.2 Warpage*—Tolerances for warpage of surfaces or edges intended to be exposed in use of individual hollow brick from a plane surface and from a straight line, respectively, shall not exceed the maximum for the type specified as prescribed in Table 4. Tolerances on warpage for Type HBA shall be as specified by the purchaser.

***ASTM C652, Table 4 Tolerances on Warpage, in. (mm)***

| Dimension, max. | Permissible Warpage, max. | |
|---|---|---|
| | Type HBX | Type HBS |
| 8 (204) and under | 1/16 (1.58) | 3/32 (2.38) |
| Over 8 to 12 (306), incl. | 3/32 (2.38) | 1/8 (3.18) |
| Over 12 to 16 (408), incl. | 1/8 (3.18) | 5/32 (3.97) |

Achieving a flat (planar) surface is more difficult when the units are warped and distorted.

## EVALUATION

When evaluating a Concrete Masonry Unit wall for acceptability, guidelines are set forth in ASTM C90. Section 7 contains specific requirements which include the minimum viewing distance and specific lighting conditions.

**7. Finish and Appearance**

7.1 Where units are to be used in exposed wall construction, the face or faces that are to be exposed shall not show chips or cracks, not otherwise permitted, or other imperfections when viewed from a distance of not less than 20 ft (6.1 m) under diffused lighting.

**Figure 4** Improper evaluation of CMU wall with the sun shining directly overhead

**Figure 5** Acceptable CMU wall viewed in diffused light from a minimum of 20 feet away as required by ASTM C90

The CMU wall in Figure 4 shows exaggerated shadows created by slight alignment imperfections that are caused by unit offsets within 1/8 in. of true plane of wall. This erroneous evaluation creates a perception that the installation quality is unacceptable. When the same wall is evaluated later in the day from the exact same position and viewed under diffused lighting (Figure 5) and at a distance required by ASTM C90 the wall is quite acceptable.

ASTM C216 for Facing Brick and ASTM C652 for Hollow Clay Brick specify viewing of the wall from 15 ft for Types FBX and HBX and from 20 ft for Types FBS, FBA and HBS and HBA. No statement is made concerning the lighting of wall but diffused lighting is implied and recommended by industry so that sunlight does not cause distorted shadows.

*ASTM C216 Standard Specification for Facing Brick (Solid Masonry Units Made from Clay or Shale)*

**8. Material and Finish**

8.4.1 Other than chips, the face or faces shall be free of cracks or other imperfections detracting from the appearance of the designated sample when viewed from a distance of 15 ft (4.6 m) for Type FBX and a distance of 20 ft (6.1 m) for Types FBS and FBA.

*ASTM C652 Standard Specification for Hollow Brick (Hollow Masonry Units Made From Clay or Shale)*

**8. Workmanship, Finish and Appearance**

8.2 Other than chips, the face or faces shall be free of cracks or other imperfections detracting from the appearance of the designated sample when viewed from a distance of 15 ft (4.6 m) for Type HBX and a distance of 20 ft (6.1 m) for Types HBS and HBA.

Specification for Masonry Structures (TMS 602-11/ACI 530.1-11/ASCE 6-11) contains parameters for construction tolerances. These tolerances are fundamentally based on eccentricities or structural requirements, but may quantitatively be applied for aesthetics.

**3.3 F.** *Site tolerances* – Erect masonry within the following tolerances from the specified dimensions.

1. Dimension of elements
   a. In cross section or elevation
      .....- ¼ in. (6.4 mm), + ½ in (12.7 mm)
   b. Mortar joint thickness
      bed.....± ⅛ in. (3.2 mm)
      head.....- ¼ in. (6.4 mm), + ⅜ in. (9.5 mm)
      collar.....- ¼ in. (6.4 mm), + ⅜ in. (9.5 mm)
   c. Grout space or cavity width, except for masonry walls passing framed construction
      .....- ¼ in. (6.4 mm), + ⅜ in. (9.5 mm)

2. Elements
   a. Variation from level:
      bed joints
      .....± ¼ in. (6.4 mm) in 10 ft (3.05 m)
      .....± ½ in. (12.7 mm) maximum
      top surface of bearing walls
      .....± ¼ in. (6.4 mm) in 10 ft (3.05 m)
      .....± ½ in. (12.7 mm) maximum
   b. Variation from plumb
      .....± ¼ in. (6.4 mm) in 10 ft (3.05 m)
      .....± ⅜ in. (9.5 mm) in 20 ft (6.10 m)
      .....± ½ in. (12.7 mm) maximum
   c. True to a line
      .....± ¼ in. (6.4 mm) in 10 ft (3.05 m)
      .....± ⅜ in. (9.5 mm) in 20 ft (6.10 m)
      .....± ½ in. (12.7 mm) maximum
   d. Alignment of columns and walls (bottom versus top)
      .....± ½ in. (12.7 mm) for bearing walls and columns
      .....± ¾ in. (19.1 mm) for nonbearing walls

3. Location of elements
   a. Indicated in plan
      .....± ½ in. (12.7 mm) in 20 ft (6.10 m)
      .....± ¾ in. (19.1 mm) maximum
   b. Indicated in elevation
      .....± ¼ in. (6.4 mm) in story height
      .....± ¾ in. (19.1 mm) maximum

4. If the above conditions cannot be met due to previous construction, notify the Architect/Engineer.

## CONSTRUCTION REQUIREMENTS

During construction of a masonry wall, the units, either through-the-wall units such as concrete or clay block or solid units, such as brick, are laid to a mason's line. The mason's line is tightly stretched between plumb corners or leads and masonry units are laid between leads using the line as a guide. The run between plumb corners is called the range and defines the plane of the wall.

The units are laid slightly away (about 1/16 in.) from the line (Figure 6) that is stretched between the leads. There is no tolerance to this clearance. If units are laid right to the line, the line may be pushed away from the plane of the wall affecting the quality of the installation.

**Figure 6** Masons laying to line

In the case of a banana or dished brick unit, the crown is typically laid away from the line with the end points or corners laid to the line.

Distorted clay brick units may create shadows but this is due to the manufacture of the unit and not the manner in which the units are installed.

Skilled craftworkers should be trained in an approved apprenticeship program to properly lay units to line without canting, twisting or cocking of the units. When units are properly laid to line the flat plane of the wall is well-defined.

## CONCLUSION

Project specifications should state the side of the wall that is to be evaluated so that the contractor can be aware of the lay up and inspection evaluations. Splitting the variation in thickness between the two faces is not practical since each face will then show imperfections.

Textured units, patterned units, split faced units and other custom units must be evaluated to determine the proper lay up so that visualization of the wall is acceptable to the architect and owner.

Light and shadows create the interest and expression in masonry. Light and shadows are always present and they should be used advantageously.

## REFERENCES


*ASTM C90-11 Standard Specification for Loadbearing Concrete Masonry Units*

*ASTM C216-10 Standard Specification for Facing Brick (Solid Masonry Units Made from Clay or Shale)*

*ASTM C652-10 Standard Specification for Hollow Brick (Hollow Masonry Units Made From Clay or Shale)*

*Building Code Requirements and Commentary for Masonry Structures (TMS 402-11/ACI 530-11/ASCE 5-11), The Masonry Society, Boulder, CO*

*Chrysler, J., Reinforced Concrete Masonry Construction Inspector's Handbook, 7th Edition, Masonry Institute of America, Torrance, CA*

*International Building Code, 2009 Edition, International Code Council, Washington DC.*

*Specification and Commentary for Masonry Structures (TMS 602-11/ACI 530.1-11/ASCE 6-11), The Masonry Society, Boulder, CO*


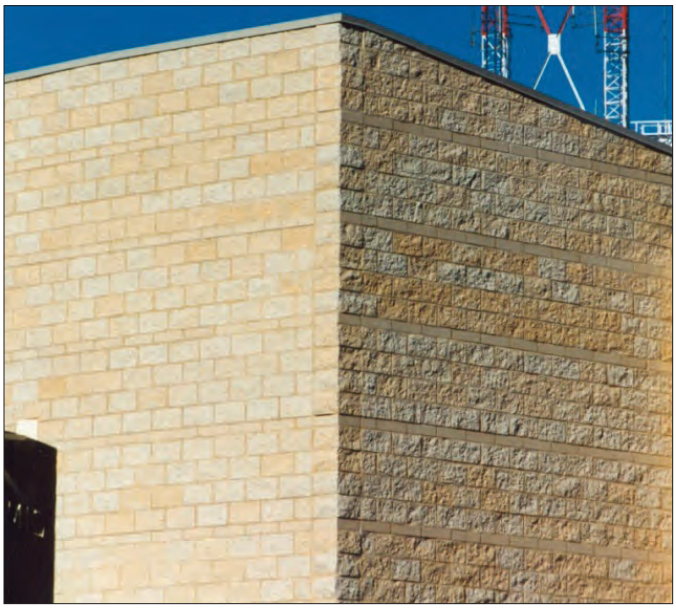

**Figure 7** Contrast of same wall color and finish under different lighting conditions

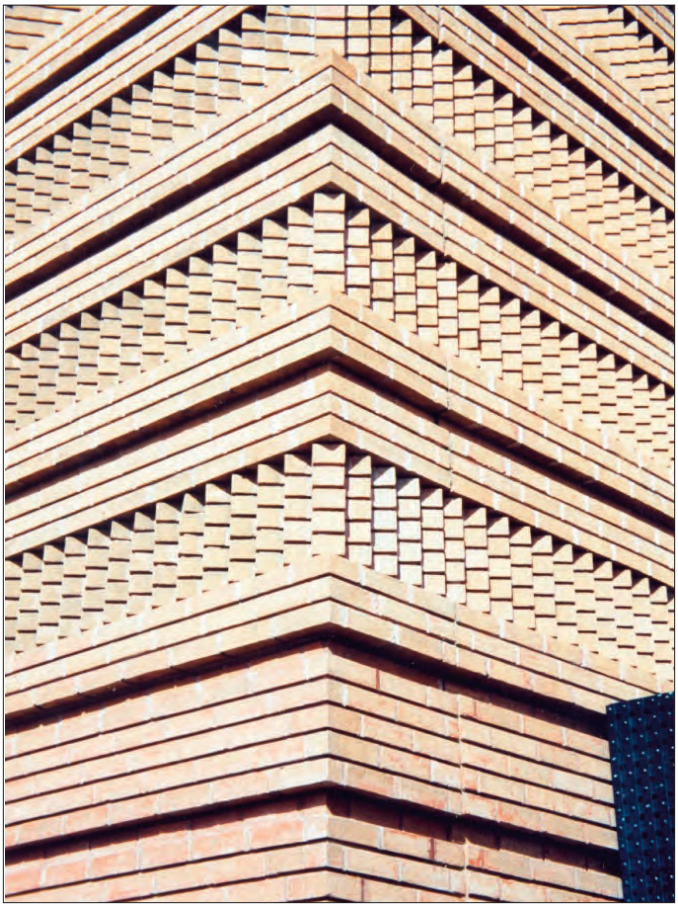

**Figure 8** Blend of unit orientation, offset and shadows