Masonry Cracks: A Review of the Literature


ABSTRACT: Masonry surface cracks are objectionable because they are the primary source of water permeance and may be aesthetically displeasing or indicative of structural distress. Cracks are the most frequent cause for masonry's failure to perform as intended. The types, locations, patterns, sizes, and causes of cracks are discussed. Methods are described for their prevention and repair.

KEY WORDS: block (concrete), bricks, corrosion, cracks, expansion, failure, inspection, masonry, mortar, movement (structural), repair, sealants, shrinkage, strain

Cracking is probably the most frequent cause of masonry performance failure [30] and has been an engineering concern for at least the last 150 years [3, 7, 10, 26, 36, 54, 58, 70, 71, 88, 91, 92, 97, 111, 112]. More recently, cracked masonry has generated litigation [107-110]. Cracks are caused by movement (strain), which can not be prevented but can be accommodated. Thus, cracks can be eliminated or made so small as to be unobjectionable.

A crack is here defined as a break, split, fracture, fissure, separation, cleavage, or elongated narrow opening visible to the normal human eye and extending from the surface and into a masonry unit, mortar joint, interface between a masonry unit and adjacent mortar joint, or into the joint between masonry and an adjacent construction element.

Crack Classification

Masonry cracks may be classified by: (1) structure type; (2) masonry type; (3) location; (4) pattern; (5) width; and (6) cause. For a given type of structure and material, the location, pattern, and width often provide clues to the cause. Cracks result from strain which induces stress in excess of strength in compression, tension, or shear. Strain may be induced by the imposition of loads or by restraint of volume changes in the masonry materials. Volume changes include those induced by change in temperature, moisture, water or salt crystallization, or corrosion. Loads may be imposed by movements of foundations, structural frames, shelf angles, roof slabs, spreading of pitched roofs, wood expansion, or retaining wall deflection. Cracks may also be caused by vibration, blasting, and fire.

Types of masonry structures include: (1) arches and shells; (2) fireplaces and chimneys; (3) floors and pavements; (4) revetments and channels; (5) beams and slabs; (6) bearing walls and columns, and (7) nonbearing walls. Types of cracked masonry units include: (1) brick; (2) concrete masonry units (CMU); (3) stone; and (4) terra cotta. Cracks are located: (1) in masonry

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Cracking Strain

The theory of fracture mechanics has been applied to masonry by Shrive [94]. He observed that for a crack to be visible, the surfaces of the newly formed crack must separate, indicating the previous existence of tensile stresses. Thus, it is tension which causes cracks, whether the loads are compressive, shear, or tensile.

Compression induces tension transverse to the axial force, which may cause splitting (see Fig. 1). The strain required to cause brick masonry to crack in compression occurs at about half the ultimate strength [39]. Frequent application and withdrawal of load may cause fatigue and strength reduction and, therefore, increased cracking probability. As few as 40 cycles of compressive load is said to cause a 30% reduction in static strength [1].

Shear induces diagonal tension. The shear load at first visible crack in concrete masonry walls was measured at about 64% of failure load with a coefficient of variation of 25% for 15 walls [69,89,90]. Mayes et al. [63] found visible cracks in concrete masonry shear panels at stresses exceeding 50 psi (345 kPa). Schneider [87] found first crack at an average of 64% of the ultimate shear strength for 29 concrete-masonry piers. Meli [66] found the ratio of shear load at first crack to ultimate load on various types of masonry walls to be 0.83 with a coefficient of variation of 20% for 19 specimens.

The first crack in brick masonry in flexure occurs at about 80% of failure strength [46]. Lawrence and Morgan [59] found that the flexural stress in masonry at first crack may be estimated at 30% of the ultimate strength plus 29 psi (200 kPa). The tensile strain at rupture for concrete masonry walls is about 0.021% [67]. The effect of specimen size and test method on flexural strength is described in Ref 41.

Cement Shrinkage

Mortar, grout, concrete masonry units, and reinforced concrete shrink upon drying. When excessive shrinkage is restrained, cracks result. Shrinkage of materials made with portland cement is caused by water loss and by carbonation. Water loss shrinkage is reversible. Carbonation shrinkage is not. As CMU dry, the recession of water in capillaries creates surface tension, which places the material in compression and thus reduces volume. Because sand and gravel are stiffer than lightweight aggregates, CMU made with such aggregates have greater shrinkage. Carbonation is primarily a reaction between calcium hydroxides [Ca(OH)₂], released by hydration of cement, and carbon dioxide (CO₂) from the air to produce calcium carbonate [CaCO₃].
FIG. 1—Restrained parapet: vertical bow or longitudinal split.

FIG. 2—Differential vertical movement at corners due to discontinuity of shelf angle.
and water [93]. Carbon dioxide may also react with other cement paste components. Lime also carbonates and therefore shrinks. The physiochemistry of carbonation is discussed by Kroone and Blakey [57], Powers [78], Verbeck [103], and Kamimura [51].

**Mortar Shrinkage**

Unrestrained, 28-day shrinkage of mortar specimens cast in metal molds is said to have a mean value of about $650 \times 10^{-4}\%$ with a standard deviation of $150 \times 10^{-4}\%$ [42]. The ultimate (23 year), unrestrained, mortar shrinkage is estimated to have a mean of $1800 \times 10^{-4}\%$ with a standard deviation of $420 \times 10^{-4}\%$ [40]. The horizontal shrinkage of mortar in bed joints in masonry is restrained by shear with the masonry units, which Ritchie [83] found reduces mortar shrinkage. From those data it is estimated that the mean effect of restraint is to reduce mortar shrinkage by about 30% with a standard deviation of 22%, when adjusted for sample size. Anderegg [5] found that mortar left in contact with brick had shrinkage about 50% less than that of mortar cast in metal molds. Mortar shrinkage is also discussed in Refs 44, 55, and 58.

Mortar shrinkage increases with water-cement ratio, which increases with lime content [28,33,49,65,73,83,106]. Voss [104] found that some mortars made with dolomitic hydrate shrink more than some made with high calcium putty. As mortar sand fineness increases, demand to provide workability increases and shrinkage increases [13]. Thus, Anderegg [6], Conner [18] found that mortar joint cracking increased with sand fineness. Masonry sands are also discussed in Ref 95. Increased air content also increases shrinkage [13].

The use of calcium chloride as a mortar additive can cause cracking by accelerating corrosion of metals in contact with mortar and by substantially increasing drying shrinkage of mortar [19]. Mortar cracks may also be due to weathering or sulfate attack [32,84]. McBurney [64] describes expansion due to delayed hydration of magnesium oxide in mortar as causing severe cracking of masonry.

**Shrinkage of Concrete Masonry Units**

Baker and Jessop [9] reviewed the literature on CMU shrinkage. Shrinkage of CMU increases as density is reduced and water absorption of the concrete is increased [50]. Shrinkage of low pressure cured CMU is about 85% greater than for high pressure cured units [16]. As with all products, availability of autoclaved CMU should be determined prior to specification. Table 1 provides statistical data on CMU shrinkage based on data given in Ref. 16.

When CMU, which had been previously dried to equilibrium with low humidity, were subsequently sprayed on one face for 2 h to simulate rain or painted with water cement paint, they reexpanded approximately one third of their original shrinkage from a saturated condition [86]. ASTM specifications provide for maximum moisture content of CMU ranging from 25 to

<table>
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<th>Statistic</th>
<th>Probability of Being Exceeded, %</th>
<th>Low Pressure</th>
<th>High Pressure</th>
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<tr>
<td></td>
<td>All CMU</td>
<td>Sand &amp; Gravel</td>
<td>Light Weight</td>
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<td></td>
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<td>130</td>
<td>162</td>
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45% depending on CMU shrinkage and average annual relative humidity at the construction site [8].

Concrete Masonry Wall Shrinkage

Total prevention of cracks in concrete masonry is said to be technically and economically unfeasible [20]. Shrinkage of mortar and of concrete masonry units in concrete masonry walls results in wall shrinkage which is greater than CMU shrinkage, perhaps 30% greater [86]. Total concrete masonry wall shrinkage may range from 0.01% to 0.1% [14]. More precise data is given in Table 2.

A rationale for recommending a maximum ratio of wall length to height was provided by Copeland [21]. Wall shrinkage is restrained at the wall base by bond and friction but may not be restrained at the top of the wall. For walls of excessive length to height ratio, this phenomenon results in a vertical crack near the center of the wall. Such cracks are wider at the top and tapered in width toward the wall base. Depending on the relative tensile strength of CMU and mortar, the vertical crack may be coggled or relatively straight.

In the absence of excessive wall height, shrinkage cracks are of even width and occur at the weakest part of the wall. With long walls, vertical cracks occur at the midpoint or at rather even intervals. Cracks may be vertical or coggled and sometimes stepped, especially near wall ends. Vertical shrinkage cracks are common at reentrant corners [22,25,96,100].

Rainer [81] reports that wall cracks are most likely to occur at changes in wall dimension; at corners, openings, pilasters, or other wall stiffeners; and in areas of greater exposure as in parapets, wing walls, or fences.

The shrinkage cracking of concrete masonry walls is reduced by using two-core rather than three-core CMU and the use of mortars having higher bond strength [67]. An increase of 10% in crack resistance is reported. Concrete masonry units should be kept covered and dry during transportation and job site storage until installed in the wall to minimize in-the-wall shrinkage [79]. Weaker mortars, because of their greater extensibility (lower modulus of elasticity and greater creep in tension), accommodate CMU shrinkage to a greater extent than stronger mortars [86]. Expansion joints are usually not required in CMU walls because shrinkage normally exceeds expansion (see Ref 2).

Sealant Joints

Sealant joints are sometimes called "movement joints." Three types of such joints are used for crack control in masonry: expansion joints close to accommodate expansion of brick or stone masonry; control joints open to accommodate shrinkage of concrete masonry; construction joints seal the crack between masonry and other materials, such as windows and doors. To avoid considerable confusion, the terms expansion joint, control joint, and construction joint

<table>
<thead>
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<th>TABLE 2—Unrestrained shrinkage of concrete masonry, 10^-4%.</th>
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<tr>
<td>Aggregate Type</td>
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<td>--------------------</td>
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<tr>
<td>Sand and gravel</td>
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<tr>
<td>Cinders</td>
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<td>Expanded slag</td>
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<td>Expanded shale</td>
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FIG. 3—Slab curl on right; wall expansion on left.

Concrete Slab Up Lift at Corner

Deflection

Wall Expansion

Roof Slab

Roof Line

Horizontal Tensile Crack

Walls

Foundation

Displaced Wall

Horizontal Shear Crack

Stepped Shear Crack

Floor Line

Grade
should not be used interchangeably. Some types of control joints are filled with mortar, cannot close, and cannot be substituted for expansion joints without causing significant cracking. The design of sealant joints is discussed in Ref 61 and 75.

**Crack Control in CMU Walls**

Methods for controlling cracks in concrete masonry walls include: (1) limitation on length to height ratio of walls; (2) limitations on horizontal distance between vertical control joints; (3) installation of bed joint reinforcement or bond beams; (4) location of control joints at points of stress concentration; (5) control of moisture content in CMU at time of construction; and (6) installation of slip joints [29, 62].

The maximum spacing of vertical control joints is a function of type of CMU, wall height, and spacing of bed joint reinforcement. The following recommendations for control joint spacings [62] apply to walls built of ASTM Specification for Hollow Load-Bearing Concrete Masonry Units (C 90), Type I (moisture controlled) CMU [8]. Bed joint reinforcement is two No. 9 cold drawn, steel wires, one in each shell bed. With no bed joint reinforcement, the maximum control joint spacing is 18 ft (5.5 m) in exterior walls in climates where the average annual relative humidity is between 50 and 75%. That control joint spacing is increased 33% to 24 ft (7.3 m) for 5-in. (400-mm) spacing of bed joint reinforcement and increased 67% to 30 ft (9.1 m) for 8-in. (200-mm) spacing of bed joint reinforcement. Those control joint spacings are increased 25% for interior walls. All of those control joint spacings are increased 6 ft (1.8 m) in dry climates, where average annual relative humidity is less than 50% and reduced by 6 ft (1.8 m) in humid climates, where average annual relative humidity exceeds 75%.

In addition, control joints are required at critical points of high stress concentration, that is, at changes in wall height or thickness, above joints in floors or foundations, and below joints in slab roofs bearing on the wall, at one or both sides of wall openings, at a distance from wall intersections or corners not greater than one half the allowable spacing of control joints, and in composite walls at the same location as expansion joints in the brick masonry. In lieu of a control joint at each jamb of a wall opening, bed joint reinforcement may be placed in the first and second joints immediately above and below wall openings, extending at least 2 ft beyond the opening.

In large wall expanses, bond beams may be used in lieu of bed joint reinforcement. Trough or U-shaped CMU are used in a continuous horizontal course, which is filled with concrete and in which one or more reinforcing bars are placed. For two No. 9 bars the vertical spacing of bond beams is four times the spacing of the replaced bed joint reinforcement. If used, bond beams should be placed at the base and top of a wall and below windows [62].

Slip joints are horizontal planes of weakness formed by breaking the bond of mortar bed joints with the CMU. Slip joints are placed at the top exterior corners of walls that support cast-in-place concrete roofs or floor slabs and at CMU lintel bearings, where a control joint is located above the jamb at a wall opening.

**Cracks in Brick**

The plane of cracks in the face of unglazed, extruded brick may be perpendicular to the face and parallel to the direction of extrusion (for example, vertical for brick laid as a stretcher) and are usually located at a core in the brick. They may penetrate only slightly or may extend to the core. Such cracks are typically 2 mm (0.08 or 5/64 in.) or less in width. They are caused by inadequate quality control in the brick manufacture process. ASTM Specification for Facing Brick (Solid Masonry Units Made from Clay or Shale) (C 216) limits facial cracks in face brick those which may be seen at a distance of 15 ft (4.6 m) or 20 ft (6.1 m), that is, crack widths of about 1.5 mm (0.06 in.). Cracks in brick that are parallel to the face and to the direction of
extrusion are called laminations and are not visible on the surface. All extruded brick are laminated to some extent or other. Although laminations are of some concern to ceramic engineers, there is no evidence that they affect brick performance [85]. Weathering or excessive compressive stress applied at the face of brick may cause it to spall [40] (see Fig. 4).

**Brick-Mortar Compatibility**

Cracks in mortar may be due to differential movement between brick and mortar. For example, if the coefficient of thermal expansion of brick is greater than that of mortar, vertical cracks may occur in horizontal bed joints.

FIG. 4—Nonbearing wall.
Hedstrom et al. [45] measured the modulus of elasticity of several mortars at 90% of tensile strength. The mean value was $2.87 \times 10^6$ psi. If the tensile bond strength of mortar to brick is about 75 psi, the maximum unit strain in the mortar is $75/2.87 \times 10^6$ or $26 \times 10^{-4}$%, which is about one eighth of that found by Menzel [67]. In any event, if the 28-day shrinkage of restrained mortar is $230 \times 10^{-4}$%, to avoid a cracked head joint the differential strain must be compensated for by brick expansion. Irreversible moisture expansion of brick at 28 days has a mean value of $63 \times 10^{-4}$% [42]. A 7.63-in. (190-mm)-long brick expanding at that rate would produce a strain in a 3/8-in. (10-mm) mortar head joint of $1280 \times 10^{-4}$%, that is, some 5.6 times greater than that required to compensate for mortar shrinkage.

Since the most likely brick moisture expansion, a shrinkage crack in the mortar head joint most likely will not occur in brick masonry. Palmer and Parsons [74] found no evidence that volume changes in mortar subsequent to hardening destroyed or weakened mortar bond when extent of bond was good. When water retentivity of mortar was not compatible with the suction rate of brick, mortar volume change was disruptive. High shrinkage mortar could be combined with low moisture expansion brick, in which case the bond strength and extensibility of the mortar becomes important to crack avoidance.

Mortar shrinkage and brick expansion are additive in bed joints. If that differential strain is $290 \times 10^{-4}$% and the mortar modulus of rigidity is $0.4 \times 2.87 \times 10^6$ psi, the estimated shear stress is 332 psi. For ASTM C 270 Type N mortars, Nuss, Noland, and Chinn [72] found a mean 28-day shear strength of brick masonry to be 394 psi. When the IRA of brick was reduced by wetting, shear strengths were much higher. It was also higher when Types M and S mortar were used. Mortar shrinkage should not cause cracking of well-bonded mortar bed joints in brick masonry.

**Facial Separation Cracks**

Facial separation cracks are openings in the wall face between brick and mortar, usually 1 mm (0.04 in.) or less in width. They are most frequently caused by inadequate tooling of mortar joints during construction but may also be caused by thermal contraction of masonry units and mortar and less frequently by mortar shrinkage. The effect of facial separation cracks was discussed by Conner [17]. He found that the average cracking in the brick masonry wall of 44 buildings which had no wall leaks was 14.7% (that is, 14.7 ft of crack/100 ft of mortar joint), which compared with 36.3% in 34 buildings which did leak.

Flexure induces cracks between brick and mortar rather than in mortar, because bond strength is inevitably lower than the tensile strength of mortar. Horizontal cracks between brick and mortar bed joints may be induced by shear (Figs. 3 and 5) or flexure (Fig. 4).

**Brick Masonry Expansion**

Expansion of masonry may be caused by heat, moisture, or freezing. Such elongation may cause oversailing of upper portions of a wall over lower portions (see Fig. 5), diagonal shear cracks (see Figs. 3 and 8), bowing of walls (See Fig. 1, 4, 9, and 13), and flexural cracking at corners in a vertical straight or coggled pattern (Fig. 11). Restrained longitudinal expansion may cause delamination and buckling of pavements and bowing of parapets (Figs. 1 and 13).

Cracking due to expansion can be controlled in curtain walls by placing horizontal expansion joints under shelf angles and vertically at appropriate horizontal intervals. For 3/8-in. (10-mm)-wide joints and sealants having 50% compressibility, expansion joints in brick masonry should be spaced at horizontal intervals of about 20 ft (6.1 m) [42]. In addition, expansion joints should be located at the same critical points of high stress concentration as in CMU walls. Expansion joints in parapets should occur twice as frequently as those in enclosing walls, unless the parapet is reinforced [30].
A wall above grade is more prone to volume change than a foundation wall. If the two are rigidly anchored together, the restraint often induces cracks (Fig. 5).

Differential movement will also occur between dissimilar materials in a wall, for example, face brick bonded to CMU in a composite wall [35]. If the brick expansion is 0.03% and the concrete masonry contraction 0.03%, the differential is 0.06%. If the modulus of rigidity of the masonry is 500,000 psi, the first approximation of the shear stress in the masonry is 300 psi. Differential vertical movement between dissimilar materials can cause parapets to lean in (see Fig. 12).
FIG. 8—Shear crack.

FIG. 9—Buckled or bowed wall.
FIG. 10—Flexural crack at pier head and base.

FIG. 11—Flexural crack at corner.
Cracks can occur in bearing wall structures due to differential strain at the intersection of bearing and nonbearing walls. Horizontal cracks at wall midheight may be due to flexure caused by excessive deflection or bowing due to unaccommodated, differential, vertical movement (Fig. 4). Such cracks are also caused by excessive deflection of masonry veneer over flexible steel studs designed for a maximum deflection of L/360 or L/600. A single wythe of brick masonry cracks at a flexural deflection of about L/2000 [15]. The horizontal expansions of wood floors has caused bulging and cracks in brick veneer on wood frame buildings.

Masonry having a lower modulus of elasticity has higher strain capacity and is, therefore, less likely to crack. Therefore, the lowest adequate strength of masonry should be used. The use of strength mortar which is strong enough should always be used.
Foundations

Foundation movement may be caused by uneven settlement, moisture movement in plastic soils, or downhill creep of surface layers. Settlement is caused by soil consolidation, shear failure, and variable soil types. Clays and silts increase in volume with increased moisture content and decrease in volume with reduced moisture. Water content of soil changes with season, trees and shrubs, localized watering and heat, and moisture migration. When ground water reduces the shear strength of sloped soil, downward slides can result [96]. Masonry pavements on chalky or fine sandy soils may be subject to upheaval due to ice lensing during severe winters [23]. Building on permafrost is a special case with peculiar problems. In coal mining regions ground subsidence may cause a surface wave 2 or 3 ft (0.61 or 0.91 m) high to pass slowly through entire communities [27,76]. The influence of trees on house foundations in clay soils is discussed in a publication of the British Building Research Station [101]. The settlement of foundation for masonry walls is discussed by Komornik and Mayurik [56].

Cracks that result from uneven settlement of foundations may take any form, but they are most often diagonal or vertical and are usually tapered [96] (see Figures 6, 7, 14, 15, 16, and

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FIG. 13—Restrained parapet buckled laterally.
FIG. 14—Deep beam flexure—corner settlement and/or midwall heave.

FIG. 15—Deep beam flexure with wall openings—corner heave and/or midwall settlement or support beam deflection.
17). Vertical cracks wider at the top than at the base indicate flexure, sometimes due to foundation movement (see Fig. 14).

Frame Movement

Wind loads [4] cause structural frames to sway. Frame drift may induce racking of masonry walls supported on frames (Fig. 18). Concrete columns are subject to thermal, creep, shrinkage, and elastic deformations, which usually are different for each column in the same building. The average contractions of concrete columns in highrise buildings is reported by the Portland Cement Association to be about 0.032% for shrinkage, 0.04% for creep, and 0.042% for elastic deformation, but extreme values may be 65% greater [14]. Unaccommodated differential
movement between adjacent columns will crack masonry walls attached to the frame (see Fig. 16). Thompson and Johnson [102] report differential vertical movements of 1/2 in. in 15 ft of wall length as insufficient to cause cracking (0.0028L), but others have suggested limiting such movement to 0.0014L. Such movement, when excessive, often causes diagonal cracks extending to and from the corners of wall openings [88].

Horizontal cracks near floor level may indicate excessive floor, beam, or slab deflection. Walls supported on beams having excessive deflection may crack horizontally anywhere, vertically near midspan, and diagonally near span third points [14,96]. Masonry supported on a steel spandrel beam may crack due to torsional rotation of the spandrel beam [52].

The net expansion of brick masonry due to freezing, moisture, and heat, less restraint and mortar shrinkage, is estimated to have a mean value of about 0.03% but one chance in 20 of being as much as about 0.07% [42]. When brick masonry is anchored to a concrete frame, the differential vertical movement may average 0.14% and could be as much as 0.26%, that is, 3.12 in. (79 mm) in 100 ft. (30.5 m). If that magnitude of differential vertical movement is not accommodated by horizontal expansion joints between the masonry and the frame, cracking will result. A restrained movement of only 0.01 in. (0.25 mm) in 20 ft (6.1 m) can produce a bulge of 1 in. (25 mm) [22].

Cracks at Shelf Angles

In the absence of a horizontal expansion joint under the shelf angle, which supports masonry on a structural frame, differential vertical movement between the masonry and the frame produces a load on the shelf angle, which may be sufficient to lift the angle from its wedge insert anchor, to yield the angle [43], or to cause spalling of brick [77,98,99]. Mortar in the joint at the toe of a shelf angle can cause spalling of brick at the shelf angle [77,98,99] (see Fig. 4). The deflection of shelf angles should be carefully controlled to ensure that the expansion joint under the shelf angle does not close excessively [43]. Total shelf angle deflection should not exceed 1/4 in. [30].

Vertical cracks frequently occur at corners of walls supported on shelf angles, when the...
angle is not continuous around the corner, leaving the masonry at the corner continuous vertically past the shelf angle (see Fig. 2).

Cracks at Roofs

Horizontal cracks at corners near concrete roof slabs may be due to slab curl caused by differential shrinkage between the top and bottom of the slab [24, 48] (see Fig. 3). Roof movement can cause diagonal cracks in masonry walls parallel to the roof movement (see Fig. 5) and horizontal cracks in masonry perpendicular to the roof movement [96]. Roof movement may be due to concrete shrinkage or thermal movement in steel roofs. Horizontal cracks near eaves may indicate lateral movement of pitched roofs, vaults, or shells. Dimensional change of wood plates rigidly anchored to masonry walls may cause masonry cracks. The holes in such plates through which the anchor bolts pass should be larger than the bolts, and the anchor nut should be tightened only by hand.

Vibration-Induced Cracks

Most building vibrations generated internally are caused by machines (cranes, elevators, fans, pumps, and punching presses) or by people (walking, jumping, running, dancing). Externally generated vibrations are commonly caused by road or rail traffic, subways, sonic booms, strong wind, earthquake, blasting, excavation, soil compaction, or pile driving [80]. Relatively small vibration may add to built-up stress concentrations and lead to unexpected masonry cracks even when vibration levels are within recommended limits [80]. In tall buildings wind-induced vibrations can lead to cladding cracks. Dowding and Corser [31] describe cracks caused by blasting due to: (1) vibration of the structure or its foundation; (2) impact of flying rock; (3) permanent ground distortion; and (4) air blast [31].

Other Crack Causes

Cracks in chimneys may be caused by sudden and wide temperature changes or by the freezing of condensate from the combination of natural gas. Severe fire causes cracking and bulging of masonry as well as surface spalling or possibly vitrification of clay brick. Although severe damage to masonry may be caused by earthquakes, well designed and built masonry may be crack free after imposition of significant seismic loads.

When steel corrodes, the ferric oxide occupies more than twice the volume of steel from which it was formed [43]. Corrosion of imbedded reinforcing steel may cause a crack at the wall surface along the length of the steel. In walls, horizontal cracks at regularly spaced vertical intervals may be due to corrosion of bed joint reinforcement or wall ties.

Crack Inspection

Although no absolute determination as to the cause of masonry cracking can be made solely on the basis of visual observation, cause clues are readily obtained. What to notice about cracks [32]: (1) direction (pattern); (2) extent (where it begins and ends); (3) width (uniform or tapered and if so how); (4) depth (through the paint, the plaster, and the wall); (5) alignment (in plane or laterally offset); (6) edge sharpness (rough, rounded, or broken edges may be indicative of compression failure); (7) cleanliness (new cracks have clean sides, not coated with paint, dirt, or algae); and (8) crack dynamics (static or changing in size, shape, or direction).

Information on the date of crack occurrence is suspect because a crack is very seldom noticed first unless its formation is accompanied by a loud noise. Hearing a noise and then finding a
crack is not uncommon, but a cause-effect relationship is seldom justified [32]. Crack width may be gauged by use of the Avongard Calibrated Crack Monitor (2836 Osage, Waukegan, Ill).

Under about 15 foot candles of illumination visual acuity is about 0.5 min of arc, that is, under that illumination, a crack can be seen at a distance up to about 6900 times its width [47], for example, a crack width of 0.1 mm can be seen at a distance of about 2 ft-3 in. (960 mm).

The frequency with which masonry should be inspected for cracks varies from one to five years [105]. The legal liability assumed by architects and engineers who inspect building facades has caused considerable concern [60].

Repair

Tests made at the Building Research Station in England have shown that the capacity of 9-in. (229-mm)-thick brick walls to carry vertical loads is reduced no more than 30% by a stepped or slanted crack up to 1 in. (25 mm) wide, provided that the damage is not accompanied by considerable transverse movement [82]. If a wall is out of plumb not more than 1 in. (25 mm) or bulges no more than 1/2 in. (12 mm) in a normal story height, no repair would usually be needed on structural grounds alone [82].

Crack repair methods may be classified as those which do not significantly change wall appearance and those which do. Fine cracks [less than 1/16 in. (1.5 mm)] are not very conspicuous and in brick masonry would often be made more unsightly by repointing [82]. Such cracks can be filled by surface grouting, which will prevent objectionable water permeance and not greatly change wall appearance, if the masonry surface texture is relatively smooth. Clear coatings for masonry typically do not bridge cracks and, therefore, do not prevent water permeance. Crack repair methods for masonry are discussed in Ref. 34, 37, and 38.

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