#603

MASONRY WALLS

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In the following discussion of masonry walls in relation to the air tightness of buildings, panel walls constructed of concrete blocks will mainly be considered. The primary function of such a wall is to close the space between the floors of a building in such a way that the desired and controlled environment on the inside is isolated from the natural environment on the outside by means of a barrier that will prevent the movement of air and whatever it contains. This can only be achieved if the panel wall is constructed of some material that is not permeable to air and if it is fitted into the space between the floors without leaving cracks or holes around the perimeter.

Most common building materials, including cast-in-place and precast concrete, gypsum board, plywood, sheet metal and glass are relatively impermeable to air. When joints between components made of these materials are adequately sealed an effective air stop or air barrier can be formed. In contrast, however, masonry walls, constructed of concrete blocks held together with mortar, are quite permeable to air for a number of reasons. Mortar shrinks about 10 times as much as concrete block and the differential movement produces numerous fine tension cracks in the mortar. In addition, when a block is laid in mortar there may be areas where bond does not develop between the bottom surface of the block and the top surface of the mortar. Another cause of the permeability of block walls is the incomplete filling of mortar joints, particularly the vertical ones.

Shrinkage of concrete blocks also plays a part in the problem of the permeability of such walls. Concrete blocks made with dense aggregate may shrink as much as 0.04 per cent after being placed, while lightweight blocks generally shrink twice as much. Autoclaved blocks shrink less than those cured at low pressure, but even so, their shrinkage is not generally less than 50 per cent of that of blocks not autoclaved. This amount of shrinkage means that for a 10-ft (3 m) high panel wall the vertical shrinkage amounts to between 1/20 and 1/10 in. (1.3 - 2.5 mm). Horizontal shrinkage also occurs but is usually somewhat less than the vertical because of the restraint caused by frictional resistance to movement along the base of the wall under its own dead weight.

It can be seen, therefore, that panel walls of concrete blocks placed within a rigid structural frame providing 20 ft (6 m) bays and 10 ft (3 m) spacing between floors, could produce, because of shrinkage, a continuous opening between each panel and the frame, at both sides and across the top, of 1/20 in. (1.3 mm) or more. The quantity of air flowing through this crack, at 1/10 in. (2.5 mm) water pressure difference,*

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* The pressure difference of 0.1 in. (2.5 mm) of water was selected for these examples because it is frequently encountered in all types of buildings. Pressure differences in high-rise buildings may be several times greater and the air leakage volumes would increase accordingly.

would be 120 cfm (3 m^3/min) or 7000 cu ft (190 m^3) per hour. This amount of air leakage when multiplied by the number of perimeter bays and floors in a building may represent a very large waste of energy.

In addition to perimeter air leakage there is leakage occurring through the panel itself. In brick walls, under a pressure difference of 1/10 in. (2.5 mm) of water, the air leakage may amount to 800 cu ft (22 m^3) per hour, for an area of 100 sq ft (9 m^2). Because of the fewer mortar joints in a given area of concrete block wall than in one of brick, it can be estimated that the air leakage rate will be between 250 and 400 cu ft (6.7 - 10.8 m^3) per hour, for an area of 100 sq ft (9 m^2). Fortunately, however, a masonry wall can be treated to perform as a suitable air barrier by applying to it a layer of mortar, plaster or some other material such as heavily textured paint or mastic which will seal the multitude of small openings in the units and the mortar joints. In this way air leakage can be reduced to as little as one-hundredth of that through the untreated wall; thus air leakage through 100 sq ft (9 m^2) of concrete block wall under a pressure difference of 1/10 in. (2.5 mm) water may be reduced to a value between 5 and 20 cu ft (0.1 - 0.6 m^3) per hour.

In this discussion of the effect on air tightness of the shrinkage of concrete panel walls, it has been assumed that the building structure is rigid, which in practice is not the case. Steel and reinforced concrete experience dimensional changes with changes of temperature when load is applied to them, and, in the case of concrete, when subjected to change in moisture content. In order to determine realistic values for the sizes of the cracks and holes that will develop at the joint between the structural frame and an infill panel, it is therefore necessary to know how much and in what direction the structure will deflect under its service conditions.

Under sustained compressive stresses, concrete suffers considerable deformation called "creep," which has been observed to continue for periods of up to ten years, although the most significant part of it generally occurs in from one to two years. Columns shorten and beams and floors continue to deflect until the deformations eventually become 2 to 5 times the initial or elastic deflections, but in most cases the ratio of creep to elastic deflection for structural concrete is 2 1/2 to 3. This means that if the design of a spandrel beam called for an elastic deflection of 1/480 of the span, for a column spacing of 20 ft (6 m) (which would be 0.5 in. (13 mm)) the creep deflection could be a further 1.5 in. (38 mm). (If the design deflection were limited to 1/1000 of the span the creep deflection could still be as much as 3/4 in. (19 mm).) In addition, a column that deflects 1/20 in. (1.3 mm) elastically may show creep shrinkage of a further 1/10 in. (2.5 mm) within the first two years after construction.

Steel, unlike concrete, does not develop creep strains. It is a more nearly elastic material in the range of stresses normally imposed on it in building construction. Therefore, its deformations are proportional to the load and are more predictable than for concrete.

For the development of the details used in this and the following discussions, the general approach was adopted that the insulation be placed outward of the structure and its panel walls to take advantage of the increased dimensional stability that results when the temperature variations they experience are minimized. The insulation, placed immediately to the cold side of the air barrier, is protected by a rainscreen on the outside, which shields it from the weathering effects of sun, wind and rain.

A design approach to the foundation wall/ground floor junction is illustrated in Figure 2. The outer face of the concrete block panel wall, placed flush with the foundation wall, supports the air barrier that is formed by the application of a suitably textured mastic. Besides sealing the cracks in the block faces and mortar joints, the mastic may also serve as an adhesive for fixing semi-rigid glass-fibre insulation to the wall. This configuration places the wall and foundation insulation in the same plane, making it easy to form an unbroken cover and thus avoid a thermal bridge at the edge of the floor slab. It also allows the cutting of service chases in the inner face of the block without interrupting the air barrier.

The insulation over the basement wall may be foam plastic or a rigid glass-fibre insulation; the latter would serve the added purpose of providing adequate drainage through the soil to the perimeter tile thus avoiding the cost of hauling in granular material for backfill. If foam plastic insulation is used, it needs to be protected against the effects of ultraviolet radiation and both types of insulation would need protection against mechanical damage at this level, which may be provided by an asbestos-concrete board, or by parging.

The brick rainscreen is supported by a normal-size shelf angle from a wedge insert in the edge of the floor slab, and a spacer fabricated from a hollow rectangular structural section. Adjustment in three directions of the position of the shelf-angle is permitted by a horizontal slot in the shelf angle, a vertical slot in the wedge insert and a selection of sizes of sections for the spacer. This type of support was chosen in preference to an angle with longer legs fastened directly to the edge of the slab mainly because the heavier section required would be much more difficult for the masons to handle. Where steel reinforcement of the masonry wall is required to resist earthquake loads the block and brick wythes must be reinforced and tied together and to the structure.

Windows usually account for large heat losses, because of air leakage through both the window sash and frame and through the space between the frame and the opening in the wall into which it is fitted. Good window design takes care of the first; the second is a construction problem that arises from the common practice of fixing windows by wedging the frame into the opening and securing it to the wall with mechanical fasteners. This generally leaves a gap of at least 1/2 in. (12 mm) wide around the frame and, even though the finish materials on the inside may hide it, the gap remains and air finds its way through.

A design approach to window openings is shown in Figure 3, where in order to make the air barrier continuous, it is turned back over a wood frame built into the wall opening as indicated (broken line). It may also be turned back directly over the upper face of the top course of concrete block, which for this purpose should be solid.

Wood may shrink as much as one per cent across the grain, and it may warp, causing the joint between it and the concrete block to open up. Accordingly, if mastic were used it is possible that a break in the air barrier would occur at the interface. To prevent an air leak from developing here, a flexible membrane such as butyl rubber may be adhered to the mastic coat on the outer face of the wall and turned over the top of the wood frame, with the continuity of the air barrier maintained by the application of a flexible sealant to the opening between the membrane and the window frame. The frame itself, the inner glazing seal and the inner pane of glass of the sealed glazing unit then form a continuation of the air barrier.

Figure 4 provides details of a window jamb, which are essentially the same as to those of the sill. The air stop is taken to the inside of the window frame so that it can be repaired more easily than if it were on the outer surface, especially where sealed glazing units are used. In addition, the edges of concrete blocks are often roughly cast or damaged during handling, making it difficult to achieve a good seal at the outer corner.

The proper functioning of a window of this type in cold weather depends upon the inner part of the window frame (the aluminum box section) being maintained at a temperature above the dew point, otherwise condensation will occur. In addition, because the tensile stresses at the edges of the inner pane of glass of a sealed glazing unit increase as the edge temperature decreases, the possibility of fracture is heightened. It is important therefore that cold air be prevented from circulating freely in the spaces between the wedges. This is accomplished by installing an outer caulking of compressible foam plastic rope which is secured between the concrete block, the window frame and a metal finish plate at the jambs and head, and at the metal sill as shown in Figure 3.

An approach to the design of the window head and floor/wall junction is given in Figure 5. The arrangement shown allows the insulation blanket to continue past the edge of the slab, broken only by the shelf angle supports, spaced at intervals of 5 or 6 ft (1.5 - 1.8 m), thus avoiding the massive thermal bridge that occurs when the edge of the floor slab interrupts the insulation blanket.

The joint beneath the edge of the floor slab at the top of the wall will experience a reversal of movements. With drying shrinkage of the panel-wall, the joint will first of all open fairly uniformly, followed by a closing which will be greatest at mid-span as the panel wall above is being constructed. A further closing, again greatest at mid-span, will occur as creep-shortening of the columns and creep deflections of the edges of the slab continue. Because the combined elastic and creep deflections of the edge of the slab will normally be greater than that due to drying shrinkage of the wall, the total effect of these movements will be to close the joint. Consequently, unless sufficient space is provided, the slab will eventually rest on the top of the wall and begin to transfer loads to it, which could lead to buckling and collapse.

In a high-rise building with identical floor layouts above the first floor or two, the floors and beams are usually of the same structural design because they carry similar loads. Under these conditions the edges of the slabs deflect about the same amount with the result that the vertical distance between floors is likely to be fairly uniform across the span. Only the creep shortening of the columns will be significantly different from storey to storey because the actual amount varies with the level of stress and with the ratio of the area of steel reinforcing to that of the concrete.

Nevertheless there will be some variations in the movements of the slabs and infill walls, therefore the materials used to block these potential air-leakage paths must be sufficiently flexible to accommodate the opening and closing of the joints. In addition, the differential movements between the edge of the slab and top of the panel wall have implications for the details of the brick veneer. Sufficient space, filled with a suitably flexible sealant to exclude the rain, must be provided beneath the structurally supported shelf-angle to avoid transferring compression stresses from the structure to the brick cladding.

Design details in the horizontal section of a column and window jamb are shown in Figure 6. The wall insulation is brought as close to the window frame as the construction will allow, but finishing the window surround with brick means that the wall insulation stops some 5 or 6 in. (128 - 153 mm) away from the jamb. The resultant thermal bridging means that the window jambs will be colder than the head and sill. At the columns, the outer surface of the wall is in the same plane as the column face, simplifying the application of the mastic and insulation blanket. The two joints between the panel walls and the column may be left without mortar, but at the outer face the space should be bridged by a sealant bead of the proper geometry to permit extension of the joints as the wall shrinks, without excessive strain in the sealant material.

At each floor, and at the roof line as detailed in Figure 7, the joint between the top of the panel wall and the underside of the concrete slab will present the same problem. The air stops must be flexible, durable and sufficiently tight that they cannot be dislodged by the highest pressure difference to which they will be subjected.

The provision of a continuous air boundary in a steel frame building with concrete block panel walls can be very difficult if the designer attempts to place them in the same plane in the building envelope. However, a relatively simple alternative is suggested in Figure 8; that of extending the floor slabs beyond the outer surfaces of the structural steel by an amount sufficiently wide to allow the laying of uninterrupted concrete block walls. The outside surface can be treated to form the air barrier and the insulation installed in the same manner as was used for the concrete structure.

If the floor slab is not extended as shown in Figure 8, support of the shelf angles for brick veneer may require complicated appendages to the structure protruding through the panel walls and promoting air leakage. When necessary, shelf angles can be supported as they are at the edge of the slab of a reinforced concrete structure, but an easier solution for a building of only two or three storeys is to support brick cladding at foundation level and carry it up to the roof line.

Details of a horizontal section through a steel column and window jamb, essentially the same as that for the concrete structure except that the column is now completely inside the panel wall, are given in Figure 9. Here the vertical joint becomes a shrinkage control joint in the block wall.

It is sometimes desirable that steel columns be recessed into the walls, for example, in a school gymnasium. A solution for such a situation, which follows the approach of applying both air-barrier and insulation to continuous plane surfaces, is presented in Figure 10. The outer surface of the block wall is bridged by a strip of sheet steel attached to the flanges of the column before the masonry work is started. Shrinkage of the wall will cause cracks to open between the wall and the flange faces, but these potential leakage paths are stopped with back-up caulking and sealant as indicated. At the base of the column care is needed to ensure that infiltration and circulation of cold air does not occur, because this would nullify the purpose of the insulation and lead to condensation on the interior surfaces of the column.

Resistance to lateral movement is provided by clips attached to the bottom flange of the spandrel beam, shown in Figure 11. They make it impossible to use caulking and a sealant bead as a continuous air stop at this joint. Continuity of the plane exterior surface is maintained by placing gypsum board or plywood sheets to cover the spandrel beam but flush with the outer face of the concrete block wall. Differential movements will take place between the wall and the roof structure, therefore a flexible seal, such as a butyl-rubber membrane, should be used to span the joint at the top of the wall.

In summary, because of the differential movements of the various materials and components of a panel wall structure the joints between them must be sealed to prevent air and moisture leakage through the wall. It is critical to the continued satisfactory and economical performance of a building that such seals and air stops be properly designed, properly installed, and of suitable materials.

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Construction Details for Air Tightness

Record of the DBR Seminar/Workshop
October, November 1977 and January 1978

Proceedings No. 3

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