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Please note

In many parts of Canada heavy wind-driven rains occur periodically and it is not uncommon in such storms for the rain to strike the wall of a building and pass through to the interior. This has happened in many buildings of unit masonry with walls of brick, stone, or block and the result bas been not only inconvenience to the occupant, but a condition that often is difficult and expensive to correct, and which may lead to premature decay of the materials.

The problem of rain penetration of unit masonry walls, like many other problems in building, has a long history. The architect-president of the United States, Thomas Jefferson, in his writings of 1782 mentioned the problem of damp walls resulting from condensation of water vapour on cool surfaces and also from rain penetration.* It is generally believed, however, that the problem has become more common in recent years (since about 1920) than it was before, probably as a result of changes in methods of construction and in the materials used. In many countries the wide-spread use of renderings such as stucco on unit masonry walls indicates that rain penetration is a problem. The widespread occurrence of the problem is also indicated by the number of countries in which it is being studied; these include the United States, Canada, Great Britain, France, the Scandinavian countries, Germany, and South Africa. Undoubtedly the most comprehensive investigations of the problem so far reported have been those of the U.S. National Bureau of Standards. Studies were started there in the 1930's and have revealed that of the many factors that affect the resistance of unit masonry to rain penetration the properties of the units and mortar are particularly important.

Several factors have a bearing on the problem: the degree of exposure of a building is important; low buildings or those in sheltered locations obviously are less likely to be affected than high buildings which are freely exposed to wind and rain; the properties of the masonry materials used and the care with which the masonry was designed and constructed also have an important influence on the resistance to moisture penetration.

Means of Entry of Rain

During a rain storm the air pressure at the outside surface of the rain-wetted wall is usually higher than that at the inside surface. The rain falling on a wall is forced through the wall by this pressure difference, provided that there are pathways within the units and mortar, or between

them, which the water can follow, and provided that the storm lasts long enough for the water to reach the inside of the wall. In low buildings (two stories or under) much protection from rain is derived from a wide overhanging roof; this is therefore a valuable feature. In higher buildings the amount of protection afforded by such a roof is less, and it probably should be expected that regardless of the type of roof some part of the wall of a high building will be wetted in a storm.

"Structural" cracks in masonry walls, caused by differential movements of parts of the building, are a means of entry of rain into the wall. Another means, which is frequently more important, is penetration through masonry which is free of structural cracks, but which contains unbonded areas between unit and mortar.

In most instances of rain penetration of brick walls leakage takes place between the brick and the mortar; only under unusual circumstances does rain pass through the brick or through the mortar. The same situation usually applies to stone masonry. In some other cases, however, units are used which are sufficiently permeable to moisture that when exposed in a wall to heavy rain, leakage takes place through the units. With such highly permeable units, therefore, it is customary to apply stucco or other rendering to ensure resistance to rain penetration.

Lack of Bond in Brick Masonry

Unbonded areas between brick and mortar, which usually are the cause of leakage in brick walls, may result from faulty construction techniques in which insufficient mortar is used to form the joint, or from an unsuitable combination of brick and mortar. In the latter case a "tight" bond between the brick and mortar is not obtained when they are brought together in the construction of the brickwork.

The bond that develops between brick and mortar depends on their properties, in particular the rate of water absorption (or "suction") of the brick and the water retention property of the mortar. When placed on a high-suction brick, mortar quickly loses its moisture to the brick and becomes stiff and non-plastic. This change in the mortar may take place before the next brick can be set in the mortar bed, in which case the mortar is not sufficiently plastic or "adhesive" to bond Well with the brick. Some mortars resist loss of moisture better than others. Such mortars may remain plastic long enough so that good bond is developed when the next brick is placed in the mortar.

The interaction of brick and mortar when they are brought together in the construction of the brickwork therefore determines the completeness of the bond between them. If the bond is incomplete, rain penetration through the unbonded areas is a possibility.

Improvement of Bond

Since the bond between brick and mortar is so important to the "tightness" of the wall, everything possible should be done in the construction of brickwork to obtain an intimate contact between brick and mortar, with no unbonded areas at the interface. If, for example, bricks with a high suction value are to be used (by the standard test, more than 25 grams of water absorbed when the brick's bedding surface is dipped in water for one minute), the bricks should be wetted before they are laid. This reduces the suction and so produces a better condition for bonding with mortar. Similarly, with high-suction bricks, it is best to use a mortar of high water-retention value, i.e., of high capacity to resist loss of moisture to an absorbent brick. To achieve as good a bond as possible, any mortar should be used as wet as possible; mortar of stiff consistency when laid produces a poor bond with the brick.

The bricklayer's method of constructing brickwork also affects the bond; better bond between brick and mortar is obtained when a short, rather than a long, mortar bed is laid out in advance of the work. In this way, by the time the last brick has been placed, the mortar is still plastic and has good bonding properties, whereas a long mortar bed would have lost its plasticity and the last bricks set in it would be poorly bonded. The bricklayer should not move or shift bricks after they have been set in the mortar since the movement will break the bond between brick and mortar and produce a crack at the interface. Full mortar joints are necessary; incompletely filled joints allow easy penetration of rain.

The resistance of brick masonry walls to rain penetration is improved if the mortar joints of the newly built masonry are tooled to form a concave surface. Other types of mortar joint tooling, or joints which are raked-out or flush-cut, do not provide as much resistance to entry of moisture as that given by concave tooling.

Influence of Building Design

Failure in the design of a building to provide for the accommodation of differential movements between its parts may lead to cracking of the masonry. Rain may then enter where the masonry has "opened up" as a result of the stresses placed on it. The cracking of masonry walls in which concrete floor and roof slabs are embedded, for example, has been attributed in many instances to "working" of the concrete (caused by its initial shrinkage or later movements due to changes in temperature and moisture content), which stresses the adjoining masonry to failure by cracking.

Expansion or contraction of walls may also be a cause of cracking. In the latter case, a familiar example is that of cracking from "drying shrinkage" of the units. Certain types of masonry units shrink an appreciable amount on drying, and if this shrinkage is restrained, severe stresses which lead to cracking may be set up in the wall. The provision of "control" joints may therefore be necessary to accommodate the movements safely.

The combination of unit masonry and the structural frame of a building sets up a difficult situation with regard to the prevention of rain penetration. The thickness of the masonry at columns and spandrel beams is usually reduced and thus is more vulnerable to moisture penetration than the remainder of the wall. In addition, differential movements between frame and masonry are a possible source of cracks in the masonry. A flashing in the wall at spandrel beams, for example, has sometimes provided a "cleavage plane" for the relief of stresses in the masonry resulting in cracking of the wall.

Parapet walls are frequently a source of entry of rain when they have not been isolated from the wall below by proper flashings. If such "damp-proofing" is omitted, rain may permeate the parapet wall and then pass downward into the masonry below. On this account, carefully installed flashings at the base of the parapet are necessary. In addition, due to the severe weathering conditions to which the parapet wall is exposed, its top and back surfaces should be protected by suitable coverings.

Common sources of leakage can be avoided by providing drains of adequate capacity and by eliminating surfaces adjacent to masonry which run water onto the masonry. Carefully applied and complete caulking around windows and doors is also necessary for protection against rain penetration. In short, careful design of the building and the installation of proper flashings and caulking are required to ensure satisfactory performance when wind-driven rain strikes.

Cavity Walls

A special type of masonry wall construction, called "cavity wall", designed to prevent moisture penetration has been used extensively in some countries, particularly in Great Britain where severe exposure of buildings to rain is common. In recent years many buildings have been constructed in the United States of this type of wall and they have performed well against heavy rain. A cavity wall consists of two walls which are separated by a continuous vertical air space, but which are bonded together by metal ties. The principle of operation of a cavity wall is that in a storm rain may penetrate the outer part of the wall but it will then flow down its inside face without being able to cross the cavity to reach the inner wall.

The metal ties are usually designed with a "V" crimp in the middle so that water cannot pass along them to the interior. Water which flows down the cavity strikes a metal flashing at the base and is directed out of the wall through drains. In cavity wall construction, therefore, the brickwork of the outer "skin" of the wall is not relied upon to prevent moisture penetration. The rain which is expected to penetrate the wall is controlled in its movement and is directed out of the wall at the base. Careful construction of a cavity wall to avoid "bridging" of the cavity by mortar or other material which can transmit moisture, obviously is necessary for it to perform

satisfactorily. Properly designed flashings over wall openings must be provided, as well as vertical diverter strips in the cavity at door and window jambs.

Treatment of Damp Walls

Direct penetration of rain through masonry is only one cause of dampness on the inner surface of a wall. Other causes of dampness are: condensation of water vapour on a cool surface, defective drains or pipes within or near a wall, defective flashings, lack of caulking around wall openings, and the rise of ground moisture into the wall from "wicking" action. The possibility of other causes should therefore be investigated before attempting to correct an existing problem of dampness.

Most of the rain which penetrates unit masonry passes through unbonded areas between unit and mortar. These usually cannot be seen and the wall appears perfectly sound. Some penetration may also occur through the units if they are sufficiently permeable, but the amount is usually small in comparison with the leakage through the interface. To overcome leakage between unit and mortar it is necessary to "plug up" the openings. This may be done by brushing a paste of portland cement and fine sand into the mortar joints; some of the paste is carried into the openings and closes them. Another method is repointing which requires that the mortar be removed to a depth of about ½ inch from the joints and replaced with fresh mortar tightly packed in the opening so that it bonds well with the units and the original mortar.

Walls of permeable units require treatment additional to that of the mortar joints. The treatment required depends on the permeability of the unit and on the severity of exposure. For units that are highly permeable and in a severe exposure condition stucco may be the only treatment that will overcome rain penetration. In other cases, painting the wall or applying a colourless "waterproofer", such as a silicone material, may prevent penetration. These treatments will have to be renewed periodically.

It should be emphasized that an essential part of the treatment for damp walls is the filling of structural cracks, renewal of caulking around windows, and the repair and correction of faulty drains and flashings.

Summary

Rain penetration of walls of unit masonry is a common problem, which may arise for several reasons. When units and mortar are not completely bonded together penetration may occur at the interface. In addition, when permeable units are used, leakage may take place through them. Structural cracks form yet another path for rain penetration.

In the design of a building consideration should be given to the possibility of stresses being set up in the masonry from differential movements of various parts of the building. When possible, the movements should be accommodated without stressing the masonry, in order to avoid cracking. Suitable design of a building for rain resistance also calls for the provision of adequate flashings and of complete caulking at wall openings. In construction of the masonry, particularly brick masonry, steps can be taken to obtain complete bonding between unit and mortar and thus prevent interface leakage.

Cavity wall construction affords a means of obtaining resistance to rain penetration and walls of this type have come into extensive use where severe exposure to rain has caused leakage problems in solid walls.

Treatment of a masonry wall affected by rain penetration requires "plugging" of the openings between mortar and unit, and in addition, often a treatment of the face of the unit. For very permeable units it may be necessary to apply stucco; in other cases paint or colourless water-repellent coatings may be sufficient. Filling of structural cracks, renewal of caulking, and repair of defective drains and flashings are a neccessary part of the treatment of damp walls.

* "...with us it is only through the northern and eastern walls of the house, after a north-easterly storm, this being the only one which continues long enough to force through the walls... In a house, the walls of which are of well-burnt brick and good mortar, I have seen the rain penetrate through but twice in a dozen or fifteen years."