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Ritchie, T.; Plewes, W. G.

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by

T. Ritchie and W. G. Plewes

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Design of Unit Masonry for Weather Resistance

T. Ritchie and W. G. Plewes

DECAY, DISINTEGRATION, OR OTHER SERIOUS DAMAGE has frequently occurred in unit masonry materials on their exposure to the weather, and has often resulted in considerable expense and inconvenience in attempts to remedy the trouble. In the design and construction of masonry buildings, therefore, consideration is necessary not only of structural strength and stability, but also of the durability and weather resistance of the masonry.

The task of the designer involves the important problem of selection of masonry units and mortar which, in themselves, will be durable under the conditions of their use, and which also in combination will produce masonry as durable and weather resistant as the components, for it has happened that very serious troubles have arisen in masonry constructed of units and mortars which individually were of high order of durability.

Certain features of the design of buildings, as well as the properties of the unit masonry materials used, can greatly influence the weather resistance and durability of the masonry.

Durability of Masonry Materials

Many studies have been made to determine the nature of the various processes which cause the decay and disintegration of masonry materials from their exposure to the weather. Almost invariably, the deterioration is associated with and dependent upon, moisture in the materials. This is well illustrated by the action of frost on a damp material, by which water in its pores is converted to ice, the resulting increase in volume of the ice often disrupting or weakening the material.

Many instances of severe decay have been attributed to frost action; therefore assessment of frost resistance is usually considered important in the selection of masonry materials. Resistance to damage from freezing forms the basis of durability requirements in Canadian and United States' specifications for clay and shale building bricks. In these specifications bricks are considered to be suitable for use under severe exposure conditions of dampness and frost if they can withstand, without appreciable change, 50 cycles of a freezing and thawing treatment while damp.

Certain properties of bricks are related to resistance to frost action. These are the properties of saturation coefficient (which is the ratio of easily filled to total pore volume), water absorption, and compressive strength. Correlation between these properties in combination, and the resistance of bricks to damage from freezing and thawing 50 times when damp has been established. Therefore in determining these properties a reasonably reliable indication of the resistance of the bricks to the freezing test may be obtained, and according to present specifications the bricks may be assessed on the basis of the freezing test or by the determination of the physical properties of saturation coefficient, water absorption, and compressive strength.

Existing specifications, which have as the basis of their durability requirements resistance to damage from frost, may be considered in the selection of bricks to give reasonable assurance of their durability for the conditions of use.

If bricks are selected solely on the basis of durability, preference will likely be given to those which are the most dense, the strongest, and the hardest-burned, since such bricks are usually most durable. However, as will be discussed later, such bricks may be lacking in properties which will give good bonding between brick and mortar and the durability of the brick and mortar assembly may be very low as a consequence.

The resistance of masonry mortars to damage from freezing and thawing when determined for the mortar alone depends greatly on the composition. Mortars are composed of a cementing material and sand. In modern masonry construction the cementing material is frequently a mixture of portland cement and lime. The resistance to frost damage of such mortars increases as the proportion of portland cement is increased. From the point of view of maximum frost resistance of mortar itself therefore, the cementing material of the mortar should contain a maximum of portland cement. However, other equally important properties in mortars set contrary requirements on mortar composition and it is usually necessary to set a limit on the proportion of portland cement in the mortar.

The selection of masonry materials requires not only that they be in themselves durable, but also that they can be combined to form a durable assembly. If an integral combination is not obtained rain may penetrate into it and the freezing of moisture in the masonry may disrupt it even if the masonry units and mortar individually are highly durable.

Rain Penetration of Unit Masonry

Second only to the problem of selecting masonry units and mortar which are durable in themselves, is that of achieving an assembly of them which is resistant to moisture penetration, and which therefore overcomes the major factor in decay. Rain leakage of unit masonry is also a problem that often causes much inconvenience from the undesirable conditions it creates inside the building.

Dampness in walls may be caused by ground moisture rising into the walls by capillary forces, or by condensation of water vapour inside the walls or on the wall surfaces. Not infrequently, however, dampness is caused by the penetration of rain through the masonry, and when rain falls on the surface of a wall, penetration to the inside may take place by movement of the water through the body of the masonry units or mortar, and by water movement through cracks or openings in the masonry.

Even though almost all common masonry materials are porous and therefore water may find its way through them at some rate, there is general agreement among those who have studied the problem of rain penetration of unit masonry walls that leakage occurs almost always as a result of water travelling through cracks, separations, or other openings in the masonry, rather than by actual passage of water through the units or mortar. Observations of masonry walls of buildings during rain storms, simulated wind-driven rain tests on masonry panels, and examination of masonry dismantled after dyed water had penetrated it, have shown this.

These experiences of the occurrence of the problem have been summarized as follows, "Penetration of rain through brickwork nearly always occurs through fine cracks between the mortar and bricks and it is rare for the materials themselves to be so permeable that water can be blown directly through them. Resistance to penetration of rain depends therefore on getting tight joints and a good bond between the mortar and the building unit, whether it be brick, block or stone"[1].

In the case of brick masonry a common misconception is that by using very dense, impervious bricks and mortar the resulting masonry will also be impervious to rain. On the contrary, it has often been found that such brickwork may be seriously affected by leakage.

Cracks or openings may be the result of faulty or careless technique in the construction of the masonry, of settlement or other movement in a building, or the result of inability of masonry units and mortar to develop and retain bond or adhesion together.

In the case of brick masonry, two early investigators of the problem of leakage noted that, ". . . a poor extent of bond may be obtained with certain combinations of bricks and mortars simply because the two materials are not well suited to one another"[2].

Properties of Masonry Mortars

Cementing materials known as masonry cements are used also in making masonry mortar. These cements have no defined composition and are variable in properties. Because of this, and on account of the limited information available on the performance of masonry made of this type of mortar, only those mortars of the portland cement and lime types will be dealt with.

The properties of masonry mortars vary greatly with composition. Mortars of portland cement and sand, or containing in addition only a relatively small amount of lime, generally quickly develop, in themselves, considerable hardness and strength, while lime mortars are, in themselves, relatively much weaker and slower to develop strength.

Studies made at the Building Research Station of Great Britain[3], and elsewhere, have shown that mortars of portland cement and sand have crushing strengths of the order of 3,000 pounds per square inch. This diminishes as lime is added to mortar in replacement of the portland cement and the crushing strength of lime and sand mortars is only about 200 or 300 pounds per square inch.

The compressive strength of brickwork does not increase in direct proportion to the strength of the mortar used, so that in many cases little advantage in strength of brickwork results from the use of very strong mortar.

Studies have shown[3] that the crushing strength of brickwork piers of medium-strength bricks laid in very strong mortar (over 2,000 pounds per square inch compressive strength) is of the order of 2,000 pounds per square inch, while that of similar piers of the same bricks laid in a weak mortar (of compressive strength less than 500 pounds per square inch) is of the order of 1500 pounds per square inch. An increase in mortar strength greater than four-fold increased the brickwork strength by about one-third. In any event, the loading on brick walls in which even the weakest of masonry mortars is used, probably would approach the maximum compressive strength of the masonry only under exceptional circumstances.

The elastic properties of masonry mortars vary considerably with composition. The modulus of elasticity of portland cement and sand mortars is of the order of 3 to 4 million pounds per square inch, while that of lime and sand mortars is about 500,000 pounds per square inch. In accommodation of differential movements in the components of unit masonry walls, the elastic properties of the mortar are important.

The dimensional changes which mortars undergo as a result of their hardening and loss of water to an absorbent brick, and subsequently as a result of thermal change or change in moisture content, differ widely among various mortars and also between mortars and bricks. These differences may be such that large enough stresses between mortar and brick are set up to break the adhesion between them. The relatively high shrinkage of portland cement mortars when placed in contact with absorbent bricks and on subsequent hardening and drying was considered by many to be the cause of numerous fine cracks often observed between bricks and mortar, when such mortars were used.

To obtain integral brick masonry, therefore, sufficient adhesion between mortar and brick must be established to withstand the differential dimensional changes between them which tend to cause separations.

Certain mortar properties influence greatly the nature of the bond between brick and mortar, particularly the extent or completeness of the bond which is developed between the two. In this respect the mortar properties of workability and water-retaining capacity are particularly important.

The water-retaining capacity is the ability of the mortar to retain its moisture when placed in contact with an absorbent brick. A standard method of measuring this property is to compare the extent of flow or spread of the mortar when jarred on a flat table, before and after it has been subjected to a suction tending to withdraw moisture from it in the same manner as an absorptive brick.

The differences in the property of workability in mortars of various compositions are readily appreciated. There is as yet, however, no standard method of quantitative measurement.

Both these properties depend on the composition of the mortar, and it is found that mortars high in water retention are generally of good workability.

Mortar composed of portland cement and sand is characterized by harsh working properties and relatively low capacity to retain moisture against the suction of an absorbent brick. On the other hand, mortars composed of lime and sand are usually high in water-retaining capacity and have excellent working qualities. Therefore the properties of water retentiveness and workability are benefited by increasing the proportion of lime. The beneficial effects vary however, with the type of lime. Lime putty obtained from slaked quicklime contributes most to workability and water retention. Putty of soaked hydrated lime is generally less beneficial in this respect, and hydrated limes mixed dry into the mortar often contribute no more to the workability and water retention than portland cement.

Influence of Brick Properties on Bond

The properties of bricks, as well as those of the mortar, can influence the nature of the bond between them.

This is well illustrated by reference to the results of studies of the strength in tension of the bond between bricks and mortars. The first studies of this were probably made at the United States' National Bureau of Standards [2,4]. Although strength of bond is not a proper criterion of the suitability of a particular brick and mortar combination from the point of view of its rain resistance, studies of it have revealed the influence of certain properties of bricks, and mortar, on the nature of the bond.

The initial rate of water absorption or suction has been found to be an important property of bricks in relation to the nature of their bond with mortar. A standard method of measuring this property has been developed, by which the brick is placed in water to a depth of ⅛-inch for one minute, and the weight in grams of water absorbed, for a brick area of 30 square inches, is called the initial rate of water absorption or suction.

Fig. 1, taken from reports of studies at the United States' National Bureau of Standards[2], shows the effect of brick suction on strength of bond in tension between bricks and mortar for various mortar compositions. It is seen that in all cases, and other studies have given similar results, for increasing initial rate of absorption or suction of the bricks the strength of bond increases to a maximum and then decreases. The maximum occurs at initial rate of absorption of about 20 grams, that is, when bricks absorb about 20 grams of water when set in ⅛-inch of water for one minute.

The suction of bricks can be reduced by wetting them, and it can be seen in Fig. 1 that bricks of high suction when wetted a suitable amount can have a suction value imparted to them which will give maximum bond strength. Wetting can, in some cases, reduce the suction to a degree that lower strength of bond from that obtained with the dry brick is obtained. In any event it is a practice difficult to control accurately on the construction site to obtain uniform results.

Extent of Bond

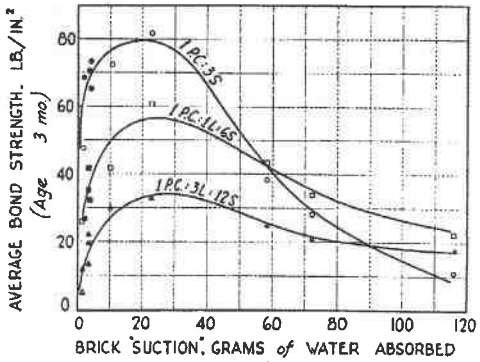
In regard to the rain resistance of brickwork, it has been found that completeness of the area of contact or adhesion between brick and mortar is an essential requirement.

That some combinations of bricks and mortars are much more suitable than others in the extent of bond developed, has been well demonstrated by a study made of the extent of cracking or lack of adhesion between brick and mortar at the exposed surface of brick walls of many buildings.

This study by C. C. Connor[5], an early investigator in the United States of the problem of rain penetration of brick walls, involved measurements of the total linear amount of visible cracks or separations in areas of the brickwork of the buildings, and the amounts were expressed as a percentage of the total mortar joint length in the area examined. In this study it was found that "the amount of visible separation cracking in brick panels at each building was measured and was found to vary between 2.5 and 68.3 per cent with an average of 31.1 per cent", and it was further noted that "if this average of cracking existed throughout the walls of a moderate-sized two-storey brick building having 10,000 sq. ft. of exposed brick walls, there would be about three miles of cracks".

The rate of water absorption of the bricks used and the composition of the mortar were indicated in this study to be related to the extent of adhesion developed between brick and mortar. With all types of bricks the extent of adhesion was better when mortars high in lime content were used. The lack of adhesion between brick and mortar was less extensive also when bricks low or moderate in rate of absorption were used and increased in amount when bricks very low, high, and very high in rate of absorption were used. This lack of adhesion between brick and mortar was consistently least when combinations of bricks of low or moderate rate of absorption and mortars high in lime content were used.

In a later study of these buildings and others from the



RELATION BETWEEN BRICK SUCTION & STRENGTH OF BOND IN TENSION

Fig. 1

point of view of resistance to rain penetration (they were situated in an area of the United States in which this was considered a serious problem), it was found that the properties of bricks and mortars similarly influenced the resistance of the buildings to rain penetration.

The use of bricks of moderate rate of water absorption (between 5 and 25 grams when the brick was placed in ⅛-inch of water for one minute) and the use of mortars of lime content at least equal to one-half the volume of portland cement, were found to be factors highly favourable in the rain resistance of the brickwork.

If bricks of other rates of absorption and mortars higher in content of portland cement were used, it was considered that detrimental factors were introduced in the resistance of the brickwork to rain penetration.

Construction and Design Details

No unit masonry can be expected to withstand repeated and severe saturation from water directed on to it in concentrated amounts. It is common to find deterioration where copings and sills or other details of faulty design have drained water on to the masonry instead of performing their function of directing it away from the wall. Localized areas thus saturated are highly susceptible to frost deterioration, chemical deterioration, or efflorescence.

The type of wall construction used and certain details of the type of workmanship specified are also important factors in the weather resistance of masonry. Even good materials cannot perform well if the wall construction is at fault.

Joint Filling

Considering first of all the details of the brickwork itself, there is general agreement among authorities that the most important factor in the water resistance of masonry walls is the filling of the joints. It is evident that lack of care in filling the joints leads to voids and through channels in the brickwork through which water may flow. The durability may also be affected. If water collected in such voids freezes the wall will be liable to disruption regardless of the durability of the materials tested individually.

Tests have shown excessive leakage where the type of construction sometimes used by speculative builders is employed. In this method the mortar is used sparingly, the bed joints are deeply furrowed and the head joints are but lightly buttered at the outside corners with only enough mortar to maintain the outside appearance of the building. The interior vertical joints in this type of wall are left unfilled. Such brick walls are highly permeable for all types of bricks, mortars and wall thicknesses.

There are several methods of constructing solidly filled joints which produce satisfactory results. In one such method the mortar for the bed joint is spread to a uniform thickness or only lightly furrowed. The head joints are formed by heavily buttering the ends of stretcher bricks and the edges of header bricks before they are placed. The filling of the collar joints is completed by slushing the mortar in from above. Other methods of filling the joints are by pouring in grout or by shoving the brick with a sideways motion into a heap of mortar placed on the bed (pick-and-dip method). Grouting appears to be the least reliable of the three.

Wall Thickness

Wall thickness is of course an important factor as well. It has been found that where a wall is composed of two or more thicknesses of units the intervening mortar joint acts as a barrier to the penetration of water. For instance water penetrates the continuous paths through header bricks many times as quickly as it takes to pass through two stretches and a mortar joint. This does not necessarily mean that the mortar is less permeable than the brick. It means that the penetration time of the two materials in combination is not an additive function of the times taken to penetrate them separately.

Wall thickness is also effective in other ways. Porous materials will absorb water when wetted by rain and will evaporate it in dry weather. Penetration will occur when the wall is saturated so that the permeability of a wall depends to some extent on its capacity to act as a reservoir, which is a function of its thickness as well as its porosity. Wall thickness also delays penetration by reducing the probabilities of cracks or openings being continuous through the wall.

A wall of dense, impervious units and mortar will absorb very little water from a rain. Owing to the nonabsorptive properties of the material, however, water may penetrate any cracks or openings in the wall practically unhindered. Watertightness depends on tight bond and meticulous workmanship to eliminate cracks and openings through which water may pass. The thickness of the wall is again an important factor in reducing the number of opportunities for water penetration.

These are some of the essential factors in the rain resistance of masonry walls but there are as yet no guides by which a designer can use them directly to choose a wall thickness. Numerous tests have, however, been carried out to determine by test the effect of thickness on the permeability of masonry test panels. The most extensive of these were carried out at the U.S. Bureau of Standards[6,7] and some of their conclusions were as follows:

(1) If the interior joints of the brickwork are left open, both 8- and 12-inch integral walls are highly permeable to driving rain and there is no consistent correlation between leakage and the absorptive properties of the bricks;

(2) Where the workmanship is poor there is little advantage in a 12-inch wall over an 8-inch wall;

(3) *By a suitable selection of brick and mortar properties* an 8-inch wall may be adequate.

It is fair to say that the above conclusions were arrived at from laboratory tests on relatively small test panels. C. C. Connor of the New Jersey Bell Telephone Co.[8], made a survey of 93 brick buildings under his supervision and concluded that if other factors were favourable a 12-inch thickness of wall is necessary to provide sufficient rain resistance under severe conditions. It may well be that under job conditions some accidents of workmanship are unavoidable and even when the materials are selected with care a 12-inch wall is desirable. The same observer reported that where conditions such as brick properties and workmanship were not favourable, walls up to 20 inches in thickness had leaked.

Effect of Header Bricks

Where bricks are very porous, header bricks tend to increase the permeability of 8-inch walls by providing a direct connection between the inner and outer faces of the wall. This normally occurs only when the rain is unusually heavy or persistent but it may sometimes be observed in new walls when rain falls on brickwork that already contains considerable moisture from construction.

Tests have been made in which two wythes were bonded together with metal ties instead of headers. It was found that there was little difference in the methods of bonding with low or medium absorption bricks but for walls made of high absorption bricks the permeabilities were less.

Effect of Back-up Material

Walls built with low absorptive facing wythes and highly absorptive back-up wythes have also been tested[6]. Results indicate that when all the joints are filled with mortar such walls are less permeable than those with all-high or all-low absorption bricks. The effect appears to be that an impervious facing reduces the amount of water penetrating to the wall interior and the porous back-up tends to delay any water that penetrates the exterior facing in its passage to the back face of the wall. Where the workmanship was characterized by unfilled interior joints the absorbent backing was effective in reducing wall permeability only when the test conditions were not severe. Some authorities[9,10] are of the opinion that if the facing wythe is made of materials that are too impermeable, any water getting into the wall may be trapped and increase the danger of damage by frost action.

It was found by some that there was no evidence that walls of brick backed with hollow tile or concrete block were inferior to solid brick walls with regard to rain resistance[8,11]. Others have found that solid brick walls give slightly more consistent performance than walls with backings of hollow units, but that with filled interior joints and a relatively high rain resistance to the facing the difference is not likely to be great[6]. There is reason to believe however, that these findings should be accepted with reservations in parts of Canada where wet weather is often followed by severe freezing. Water has been known to accumulate in the cavities of hollow units causing disruption of the wall when freezing occurred.

Joint Tooling

A method of joint tooling is frequently chosen for the appearance it gives to the brickwork but from the standpoint of rain penetration concave tooled joints give the greatest resistance. Cut-flush, struck or raked joints, although they have their place, should not be used for buildings subject to wind-driven rain. Forming such joints tends to draw the mortar away from the units, whereas in forming concave joints the mortar is compressed and a firm bond created between the unit and the mortar at the face of the wall. The surface is also excellent for the shedding of water. Joint tooling is not, however, so important as the workmanship inside the wall.

Parging and Stucco

The U.S. Bureau of Standards conducted tests on brick and hollow masonry walls in which stucco or parging was used in the construction in various ways[6,7,12].

Masonry test walls of hollow tile with stucco facings were found to be superior to brick-faced walls when new, but after three years outdoor exposure cracking of the stucco reduced their effectiveness to about that of an 8-inch brick wall.

Four-inch test walls with ½ inch of mortar parging on the back were about equal to 8-inch solid walls with solidly filled joints when new. After a few years of outdoor exposure, however, cracking of the parging caused them to leak excessively.

A third series of tests was made to study walls in which a parge coat was applied to the back of the facing wythe or to the back-up wythe to act as a dam in preventing the passage of water through the wall. An ⅛-inch space was left between the parging and the opposite wythe. This type of construction might have particular application where there is not likely to be sufficient building inspection on the job to ensure filled joints. It is frequently used where hollow tile is the back-up material. Such a parge coat is discontinuous at the header courses and it was found that, unless the joints at the headers were completely filled with mortar, the passage of water through the walls was not effectively stopped. When this was done the results were quite satisfactory. No data are yet available to indicate what the performance of such walls is likely to be, if, after a few years of exposure, cracks occur in the parging.

Protection of Brickwork

The degree of protection that can often be afforded masonry structures by flashing, weathering and caulking can well be emphasized.

It is generally agreed that all horizontal surfaces where water is likely to accumulate should be weathered and preferably flashed as well. The concentration of water where a nonabsorbent surface drains onto brickwork is likely to cause leakage, deterioration, or staining. For this reason sills and copings are usually projected from the wall and provided with adequate drips. If such sills and copings are not all of one piece or are of porous material they should be provided with through flashings which cut them off completely from the wall. Belt courses, window and door heads, expansion joints and the junction of roofs with masonry walls are other typical places that require flashing.

The top of a parapet is one of the most vulnerable points in a building for the entry of water into a wall. It is necessary to provide either a continuous, overhanging, impermeable coping, or, if the parapet has joints or is of porous material a through flashing should be provided below it. If possible, through flashings should project beyond the face of the wall and be turned downwards to form a drip.

The parapet may still be frequently saturated by rain from the sides and the water may percolate downwards into the building. To prevent this it is recommended that a through flashing be placed near the roofline also. This is usually a continuation of the counter flashing to the roofing material which is carried up the parapet wall high enough to retain any water impounded on the roof. The brickwork on the back of a parapet should be equally as durable and watertight as that used on the face and should not be made of inferior material as is sometimes the case.

At least one authority[8] has stated that it is good practice to cover the back of a parapet with a felt or metal covering. Others[13,14,17] claim that if the rear side is covered water can still enter on the other and because of the covering on one side the parapet may not dry out readily and thus becomes subject to frost action. The weight of opinion seems to be against such a covering but the matter warrants further study.

Since parapets are severely exposed and are often saturated, they are sometimes made hollow with weepholes draining to the roof just above a flashing at its base[9]. This is believed to keep the parapet drier and less liable to deterioration. The idea seems to have some merit.

It is commonly recommended practice to install an asphalt membrane covering at spandrel beams to form a cut-off through the walls at floor and roof levels. This is put in because the brickwork is thinner at the beams than in the rest of the wall and to prevent water from entering at these points where cracking is likely to occur due to shrinkage of the brickwork or movements of the structural frame.

In Connor's[8] investigation of leakage in nearly 100 buildings it was found that such waterproofing actually promoted cracking by providing a cleavage plane where the membrane turned out to the face of the wall. At the roof spandrel, parapet movements were found to take place along this cleavage plane whereas in buildings without spandrel beam waterproofing, little evidence was seen of parapet movements. Fifty-three of 76 buildings were moisture proof when spandrel waterproofing was not used but only 1 out of 24 when the spandrels were waterproofed. It was the investigator's opinion that spandrel beam waterproofing was a detrimental factor toward obtaining leakproof walls.

F. O. Anderegg[15], one of the earliest investigators of masonry leakage, also acknowledged that sometimes a problem does exist when he stated that shrinkage of masonry wall panels often results in a fine crack just below the spandrel beams. It was his suggestion that a flexible joint might be made at this point out of bituminous material.

This is not sufficient evidence on which to abandon spandrel beam waterproofing in view of the high regard with which it is held by most authorities but it does show that further investigation is needed.

The amount of protection afforded brickwork by an overhanging roof is not always appreciated. Roof overhang is a positive barrier against the entry of water at the top of a wall. In addition, rain very often falls vertically or at only a slight angle and when this is the case large areas of the wall receive very little water if they are protected by eaves. It is particularly important that the eavestroughs and downspouts be adequate to handle the flow from the roof. They must also be kept unobstructed and in good repair. A large amount of disintegration, efflorescence and staining is caused by water from faulty gutters.

Wall Furring

There is no conclusive evidence that furring is necessary on all masonry walls. Authorities practically all agree, however, that it is highly desirable practice in a generally cold climate such as we have in Canada or in areas subject to wind-driven rain. While furring does not prevent leaks in the masonry it does reduce the extent of damage to the plaster when walls are penetrated by moisture. It is true that many walls have been successfully plastered directly on the masonry but the method provides no insurance against any defects in the wall construction.

Cavity Walls

Nothing has heretofore been said about the true cavity wall. In Britain, the British Standard Code of Practice for Brickwork[16] considers this type of wall the only one that will provide reliable rain resistance. Solid walls are not recommended under severe exposure conditions. The following table is taken from the above-mentioned Code.

SUITABILITY OF WALLS FOR VARIOUS EXPOSURES

R — Recommended N — Not Recommended

Construction	Exposure Sheltered	Exposure Moderate	Exposure Severe
4½ inch wall	N	N	N
9 inch solid wall	R	N	N
13½ inch solid wall	R	R	N
Rendered solid wall	R	R	N
Cavity wall	R	R	R

Exposure conditions were rated as follows:

Sheltered — Sheltered conditions obtain, for example, in districts of moderately low rainfall where brickwork is protected from the weather by the proximity of buildings of similar or greater height. The first two storeys above ground of buildings in the interior of towns come within this group.

Moderate — Moderate conditions obtain where the exposure is neither sheltered nor severe.

Severe — Severe conditions obtain where brickwork is liable to exposure to a moderate gale of wind accompanied by persistent rain. Brickwork that projects well above surrounding buildings may be severely exposed even if it is not on a hill site or near the coast.

The thinking behind these provisions seems to be that because of the variability of available masonry materials and the difficulty in always obtaining the meticulous care required to build leakproof solid walls, they cannot be depended upon to resist the most severe conditions. In a rain of sufficient duration a solid wall may leak. A cavity wall if properly built, they contend, will provide a positive barrier to rain.

In America, field studies[8] and laboratory tests[7] show that excellent results can be obtained with the cavity wall.

All observers emphasize the need for weepholes and that the cavity should not be bridged across by mortar droppings falling to the bottom or onto the wall ties. Flashings and weepholes are required over all openings which will positively divert water to the outside.

Cavity wall construction cannot be recommended for

Canada without reservations until at least two possibilities have been investigated further. Firstly, in parts of the country very low outdoor temperatures and efficient heating systems set up large temperature differences between the inside and outside of walls. There is evidence that this may result in large differential movements between the inner and outer wythes of a cavity wall. Secondly, the outer wythe of a cavity wall is severely exposed to moisture saturation and possible freezing. In our climate the durability requirements may be so severe as to be not always easily met.

Summary

The design of unit masonry for weather resistance requires consideration of many factors. The materials to be used must be selected from the point of view of their individual durability, and also of obtaining an integral combination, for if this is not achieved serious deterioration can occur in the masonry even if the materials in themselves are highly durable. The design of the building and the masonry also exert considerable influence on its weather resistance.

Under conditions which are severe a high degree of protection against excessive wetting of the masonry may have to be afforded in the design of the building exterior in order to obtain satisfactory service. Weather-resistant walls are not ensured by any single factor. They result from the presence of a combination of favourable factors and the exclusion of those that are unfavourable.

The above was a paper read at the Annual Assembly of the Royal Architectural Institute of Canada in June, 1955.

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