CANADA

BUILDING NOTE

EFFLORESCENCE ON THE EXTERIOR SURFACE OF MASONRY WALLS

(A review of the literature)

by

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Abstract

The two general conditions necessary to produce efflorescence in masonry walls are (a) presence of soluble salts in the wall materials and (b) moisture to carry these salts towards or onto the surface of the wall.

No simple method, capable of general application, has been devised to limit the soluble salt content in masonry materials. Hardly any masonry material is exempt from the possibility of containing sufficient soluble salts to contribute to the development of noticeable efflorescence if moisture should penetrate the wall.

Moisture penetration of the wall, and with it, efflorescence, may be almost completely prevented by proper design, construction, and maintenance of the building.

DIVISION OF BUILDING RESEARCH • NATIONAL RESEARCH COUNCIL • OTTAWA, CANADA

July, 1950.

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PART I - CAUSE OF EFFLORESCENCE

1. What Efflorescence Is

When moisture gains access to masonry walls, the water-soluble salts present in the masonry materials are taken into solution, and as soon as the weather becomes favourable for evaporation of this accumulated moisture, the salts are carried in solution toward the outer face of the wall. The concentration of the salts in solution increase with continued evaporation, until the salts finally crystallize out, forming a whitish deposit which is termed efflorescence.

The point at which crystallization occurs will depend largely on the capillary properties of the materials. It may be in a layer just behind the surface, or directly on the surface. In the former case, the crystallization may lead to disruption and spalling of the surface layer; in the latter case, it provides disfigurement.

While efflorescence is most common in the early spring when walls saturated by melting snow or late winter rains are drying out, it may occur at any time of the year. It may appear quite generally over a wall or be confined to certain small areas.

The two general conditions necessary to produce efflorescence, in all instances, are:

a. Soluble salts present in the wall materials.

b. Moisture to carry these salts towards or onto the wall surface.

2. Nature of the Soluble Salts

Some of the salts frequently found in efflorescence are calcium sulphate (gypsum), magnesium sulphate (epsom salts), sodium chloride (table salt), sodium sulphate and potassium sulphate. These are all soluble in water, though calcium sulphate is considerably less soluble than the others and is less

likely on this account to form a major constituent of efflorescence. In cases where serious failure of brickwork by salt action have been reported at the British Building Research Station, it has nearly always been found that magnesium sulphate was the destructive agent.

The presence of nitrates and chlorides is usually an indication of contamination from some external source, such as ground-water or material stored in contact with the affected masonry.

3. Origin of the Salts

Hardly any masonry material is exempt from the possibility of containing sufficient soluble salts to contribute to the development of noticeable efflorescence if moisture penetrates the wall. The usual sources of soluble salts are:

(a) Facing or back-up material, such as building limestones, bricks, hollow tile, concrete units, or monolithic concrete.

(b) Mortars and plasters. In this case, the salts may be due to one or more of the ingredients. Portland cements, certain sands, and certain limes contain soluble salts; and in some instances the mixing water for the mortar or plaster may contain soluble salts.

(c) Ground-water or some other external source.

Salts are introduced into the cement from both the raw materials and the coal ash. Some of this salt content may be volatilized in the kiln and carried away in the dust, the amount so removed increasing with harder burning.

Salts present in the bricks may originally have been present in the clay or tempering water. They may have been produced during the manufacturing process by the decomposition of compounds present in the clay or by the action of sulphur gases in the kiln. The content of soluble salts in bricks varies greatly, although the actual quantity of soluble salts is very small, even in bricks which may produce efflorescence. Moreover, the effect of soluble salt content in building materials is so intimately bound up with the capillary properties and pore structures that a material should not be condemned on its salt content alone, with the possible exception of the content of magnesium salts.

Even if the facing brick is carefully chosen, salts contained in the back-up units or in the mortar used for jointing and pointing may be transferred to facings by the movement of water in the walls. This might lead a casual observer to the erroneous conclusion that the facing bricks were directly responsible, whereas they may actually have been almost free from soluble salts originally.

In this connection, it is interesting to note that tests at the U.S. Bureau of Standards on 55 types of face brick from as many different manufacturers in various parts of the United States were examined for soluble salts, and the majority were found to contain less than 0.05 per cent of soluble sulphuric anhydride, an amount insufficient to cause efflorescence under conditions favourable for such. It would seem therefore, that the face-brick manufacturers have reduced the tendency of their product to effloresce to a considerable extent.

It is claimed by the Structural Clay Products Institute that probably more than 90 per cent of the output of structural clay products in this country will not tend to effloresce. They point out, however, that second-hand brick, because of its uncertain origin and previous contact with mortar and plaster, may frequently be a source of efflorescence.

4. Methods of Moisture Penetration

Moisture may come in contact with walls from driving rains, melting snow, or ground-water, and may penetrate the walls as a result of the following:

(a) Insufficient attention of the architect to precautionary detail in designing.

(b) Poor workmanship and materials used during the construction period.

(c) Improper maintenance or operation of the completed building.

The U. S. Bureau of Standards has made a detailed study of 250 cases of efflorescence and wall disintegration, and concluded that all but one or two of the cases could have been prevented by either proper design, construction, or maintenance.

In Part II of this paper, some of the generally recognized methods of preventing moisture penetration into the walls will be discussed.

It should be noted at this point, however, that in the case of a new building, a uniform coating of deposited salts may appear, even when all reasonable precautions have been taken. This condition is the result of the very large quantities of water used in the construction process. After the walls have had an opportunity to dry thoroughly, a final cleaning or sometimes a few rains will wash away the efflorescence and it seldom appears again.

The view is held by some that new brickwork is particularly liable to damp penetration troubles, and that the normal progress of weathering diminishes the permeability of the wall by a process of silting up pores by dirt and vegetation.

5. Why Efflorescence Should be Prevented

Efflorescence should be prevented because of its unsightliness and because crystallization in a layer just behind the wall surface may cause the surface layer of the masonry to spall.

Another, and even more serious aspect of the situation, is that efflorescence, except in the case of a new building as noted above, is a symptom of moisture penetration into the walls. Wet walls result in decreased insulation value of the wall and in damp interiors, and may eventually lead to partial or complete disintegration of the wall. It is essential that excessive moisture penetration be prevented, and if this is achieved, then at the same time the possibility of efflorescence occurring will have been almost completely eliminated.

PART II - PREVENTION OF EFFLORESCENCE

1. Control by Manufacturers of Masonry Materials

The manufacturers of masonry materials have not yet succeeded in devising any simple method, capable of general application, to limit the soluble salts in their products. Numerous attempts have been made to develop admixtures which would combine with the soluble salts present to form insoluble compounds. Barium carbonate is one such admixture which has been used and is still used; however, investigations to date indicate that admixtures are not completely effective in reducing efflorescence.

By exercising close control of the drying and burning operations, the manufacturers of face-brick have done much to reduce the possibility of efflorescence in their products. For example, certain salts tend to be decomposed and expelled from bricks by hard firing, and in a kiln where close temperature control is not maintained, there may often be considerable variations in temperature, resulting in a higher concentration of salts in those bricks coming from the cooler part of the kiln.

The relatively close controls maintained by the face-brick industry in part justify the cost difference between face-brick and the cheaper clay products, such as hollow tile and common brick, which are generally used as backing materials. From an economic standpoint, it is not always practicable for the manufacturers of these cheaper products to adopt the procedures used by the face-brick industry.

At present, the surest preventative of efflorescence is to keep water out of the masonry. This factor must be controlled by the architect in designing the building, by the contractor in erecting the building, and by the owner in maintaining and operating the building.

2. Keeping Walls Dry by Proper Design and Construction.

Present knowledge of building construction has not reached the stage where the problem of keeping the walls dry can be said to be on a satisfactory design basis. The problem is complicated by the fact that the approach must be different for different forms of construction. For example, solid walls of dense, non-absorptive material, such as concrete walling, require a different technique than walls of porous, absorptive materials, such as brick.

Some of the details which are important in the design and construction of masonry walls in general if walls are to be kept dry are listed below.

Foundations

(a) Install adequate drains along footings.

(b) Provide membrane waterproofing on the outside of foundation walls.

(c) Install damp-proofing in a masonry course immediately above grade.

Walls Above Foundations

(a) Start the first course of masonry units well away from contact with the earth and extend rain water leaders to the ground to avoid splashing the brickwork.

(b) Protect walls under construction to prevent rain or melting snow from entering. When masons are not working, cover the top of the walls with weighted tarpaulins, overhanging one or two feet on each side. Bricks stored on the job should also be kept dry.

(c) A mortar possessing a high degree of workability and water retentiveness should be used. Slaked quicklime putty and a number of hydrated limes have such characteristics and will assure a satisfactory mortar if used in quantities up to 2 parts lime solids to 1 of cement. Workability will be improved by the use of well-graded, clean sand with a fineness modulus of about 2.2. The mortar should be accurately proportioned and be mixed for at least 2 minutes in a mechanical batch mixer. Mortar that is between ½ and 2 hours old will have the most plastic characteristics.

All joints in masonry walls should be filled. Joints should be concave tooled, first while quite soft and a second time when the mortar starts to stiffen.

(d) If possible, a brick with a 24-hour cold absorption of between 4 and 10 per cent should be selected. Although moisture-proof walls can be built with bricks having an absorption lower than 4 per cent or higher than 10 per cent, the hazards are increased, and extra precautions must be taken.

(e) It is preferable that bricks be kept and laid dry, but if bricks are used with an absorption higher than 10 per cent, they should be wetted. This moisture may carry soluble salts to the surface of the masonry and thereby contribute to efflorescence; but wetting the bricks will prevent them

from absorbing excessive moisture from the mortar, which would have the more serious consequence of reducing the ultimate water-tightness of the wall.

If it is necessary to wet the bricks, they should be wetted as uniformly as possible 24 to 48 hours in advance of the time needed for use, and the pile should be kept covered with a tarpaulin to prevent loss of moisture.

Bricks should never be wetted in freezing weather.

(f) On some building projects it may be considered desirable to make a chemical analysis of the brick. L. A. Palmer states in Technological Paper No. 370 of the U. S. Bureau of Standards that a brick containing 0.05 per cent or less of water-soluble sulphuric anhydride in its outer 1/8 inch of exposed surface, is not apt to contribute to efflorescence.

A test which is more readily performed than chemical analysis is the wick test, originally described in Research Paper No. 1015 of the U. S. National Bureau of Standards by Messrs. McBurney and Parsons. A summary of this test is included in Appendix 11 of the Tentative Method of Test for Suction and Efflorescence of Brick, A.S.T.M. Designation C67-42T.

(g) Avoid forming a water table of projecting bricks. To corbel out with one or more courses of brick or any other masonry material is always a dangerous procedure unless the projecting courses are so situated as to be protected from exposure to moisture penetration.

(h) Provide adequate drips on cornices, chimney caps, sills, and other masonry projections. Grooves should be at least 5/8 inches wide and 3/8 inches deep, and projections should be at least 2 inches to keep the drip away from the wall.

(i) Non-corrosive metal or bituminous flashing should be placed under cornices, chimney caps, sills and projecting courses of masonry.

(j) Caulk around windows and door frames.

(k) Use lug sills at windows and wherever practical avoid joints in sills.

(l) Flash the washes of pediments and dormers.

(m) When high humidities may be present within masonry buildings careful consideration should be given to the control of water vapour flow in order that condensation may be prevented in cold weather. Condensation may be prevented by the careful selection and application of vapour barriers, and where possible by the provision of ventilation to remove vapour-laden air.

Parapets

(a) The use of parapet walls should be avoided whenever possible. If they must be used, they should be constructed with great care, using good quality materials. Flashing should cover the back side of parapet walls but it should be free-standing, in order that there may be circulation of air in the space between flashing and wall.

(b) A coping of low permeability and good frost resistance should be used, and this coping should have a through flashing under it extending at least $\frac{1}{4}$ inch past the face of the wall on either side.

3. Keeping Walls Dry by Careful Maintenance

Walls may be properly built, but they must also be properly maintained to stay dry. It is especially important that flashings, gutters, downspouts and copings be kept in good state of repair and that cracked or poorly filled joints be promptly raked out and repointed.

When efflorescence appears on the walls of a building that has been in service for several years, it is evidence that moisture is penetrating the walls. The source of penetration should be located and remedial action taken.

"The location of efflorescence does not necessarily mean that water is entering the wall at that point, but frequently provides a clue to the source of the trouble. For example, streaking from the top of a wall down or, at times, patches some distance from the top, would point to defective copings or gutters. Efflorescence under windows would put the sills and caulking around the frame under suspicion. Efflorescence on the courses of a foundation, close to the ground, especially with a rather porous brick, would indicate ground water drawn up by capillary suction. A single patch of efflorescence on a wall, with no observable relation to masonry openings, may sometimes be explained on the grounds of a badly defective mortar joint or by a projecting brick forming a water table".*

If a serious defect has been built into the wall, it will often be difficult to remedy the condition permanently by a surface repair. An error of omission can be equally serious and difficult to remedy. A damp-proof membrane, for example, is practically impossible to insert after the wall has been built.

PART III- REMOVAL OF EFFLORESCENCE

When efflorescence has resulted from excessive soaking during construction, and the wall has finally dried out and repels moisture successfully, then the efflorescence will gradually be washed away by the rains and disappear with time. This process may be hastened by washing away with water applied with stiff scrubbing brushes; or, if this is not effective, wet the wall with water, then scrub with water containing not more than 10 per cent of muriatic (hydrochloric) acid and, immediately thereafter, rinse thoroughly with plain water. If muriatic acid is used, it is particularly important that the wall be wetted with water first, and it is important also that the solution should not contain more than 10 per cent muriatic acid.

Obviously, if moisture is penetrating a wall due to faulty design, construction, or maintenance, then the measures described above will be useless, inasmuch as the efflorescence will reappear. The underlying defect must first be remedied in order to finally be rid of the efflorescence.

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- fails to consider effect of cavity walls
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