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Ritchie, T.

Publisher's version / Version de l'éditeur:

Proceedings, Rilem/CIB Symposium on Moisture Problems in Buildings: 1965, Helsinki, Finland, p. 8, 1966-07-01

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EFFLORESCENCE ON MASONRY

by

T. Ritchie

RILEM/CIB Symposium, Helsinki, 1965
"Moisture Problems in Buildings"
PREPRINT 2 - 3

Technical Paper No. 223
of the
Division of Building Research

OTTAWA
July 1966

Price 25 cents

NRC 9127

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EFFLORESCENCE ON MASONRY

T. RITCHIE*)

National Research Council,
Division of Building Research, Ottawa
Canada

SUMMARY

Efflorescence is a problem of interest in building science for two reasons; it frequently causes severe disfiguration of buildings, and it may be the cause of decay of masonry materials. Efflorescence results from the movement of a solution of salts to the masonry surface where evaporation of the water takes place and the salts are deposited. The occurrence of efflorescence is influenced by the degree of dampness of masonry and the conditions of drying, both of which are controlled in large measure by weather factors. Decay is caused by crystallization of salts within the masonry material.

The design and construction of a building to avoid excessive wetting of the masonry and the selection of materials free of soluble salts provide a solution to the efflorescence problem.

MOISTURE AND EFFLORESCENCE

Wherever efflorescence forms on buildings it indicates a moisture problem, because moisture is an essential factor in its occurrence. Efflorescence is the formation of salt deposits on the surface of masonry, and frequently results in severe disfiguration of buildings. For this reason alone it is a serious problem to many Canadian architects and builders. The presence of salts in masonry, however, may be of greater importance for another reason, in that they may be capable of

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*) Research Officer, Inorganic Materials Section, Division of Building Research, National Research Council, Ottawa.

causing decay of masonry materials. The problem of efflorescence is therefore of interest not only in regard to the aesthetics of masonry, but also to its durability.

Although efflorescence is in theory the result of the salts in masonry being taken into solution by water, followed by movement of the solution to the surface where evaporation of the water takes place and the salts are deposited, the actual occurrence of efflorescence on buildings is influenced by several other important factors.

In studies made in the Division of Building Research of the National Research Council, Canada, many buildings seriously marred in appearance by efflorescence have been examined. Several cases of decay of masonry materials caused from efflorescence have also been investigated. These experiences and the results of studies reported by others in the literature form the basis of the general view of the efflorescence problem presented in this paper.

FACTORS AFFECTING THE OCCURRENCE OF EFFLORESCENCE

Soluble salts must be present in masonry for efflorescence to develop, but their presence does not necessarily mean that efflorescence will occur. Wetting of the masonry must take place and subsequent movement of the moisture occur for efflorescence to develop. Several factors influence both the wetting of masonry and the movement of moisture within it, and thus influence the occurrence of efflorescence.

a) Moisture in newly-constructed masonry

Because of the nature of masonry construction, which involves bringing together a wet mortar and a unit that may be either dry or wet, the moisture content of the masonry is very high immediately after construction. The water in mortar may amount to 18 per cent or more of the weight of the mortar, and if bricks are soaked before laying the water in them may amount to 10 per cent or more of their weight. It has been found at the Division, and it is generally considered to be the case, that the higher the moisture content of newly-constructed masonry, the greater the amount of efflorescence that will subsequently form on it.

b) Seasonal effects

The occurrence of efflorescence on buildings in Canada follows a general pattern in that newly-constructed buildings are particularly affected; efflorescence does not develop, however, until the beginning of the cool season following construction. In most areas of Canada this may be said to begin late in November. The recurrence of efflorescence on previously-affected buildings also takes place in the cool season. If no measures have been taken to remove masonry of efflorescence, it

remains until the following summer, gradually diminishing as the weather becomes warmer. It does not usually recur in the second cool season, but if it does, the deposits of salts are less heavy and less extensive.

This seasonal influence on the occurrence of efflorescence is believed to be due mainly to differences in the rate of evaporation of water from the masonry in the cool and warm seasons. Under cool weather conditions the plane of evaporation is at the surface of the masonry; in the warm season it is beneath the masonry surface.

Several reasons may be advanced for the decreased intensity, or non-recurrence, of efflorescence in the second cool season. The amount of salts in the masonry decreases as a part of the efflorescence of the first occurrence is washed or blown off; the moisture in the masonry also is less than that of the first cool season because of the loss of the construction moisture; and the properties of the masonry probably change, in that the surface pores become partly filled, thus affecting not only the wetting by rain but also the subsequent evaporation.

c) Weather effects

A further seasonal influence on efflorescence is provided by the wetting of masonry by rain. The intensity of rainfall varies seasonally at many locations in Canada, and the moisture level of masonry may rise to a relatively high value at a certain period during the year, for example, just prior to the start of the cool season.

Direction influences efflorescence that results from local weather conditions. In a few of the buildings examined all the walls were affected to the same degree by efflorescence. Usually, however, efflorescence develops on certain walls and not on others, or no particular areas only. In Ottawa the affected wall usually faces east, the direction from which rain often comes prior to the start of, and during, the cool season. The higher moisture level in the masonry of the east wall promotes the eventual occurrence of efflorescence. An example of this directional influence on efflorescence is shown in Figure 1, which shows the east wall of a building (located in Ottawa) heavily marked by efflorescence although the north wall is little affected.

It frequently happens that efflorescence occurs only at the top of a wall (Figure 2). This difference in the behaviour of the upper and lower parts of a wall may be accounted for by differences in the degree of wetting they have received. One study of a particular unshielded wall was made at DBR by attaching cups at various locations on the wall to catch the rain. On this particular wall much greater wetting occurs near the top than elsewhere.

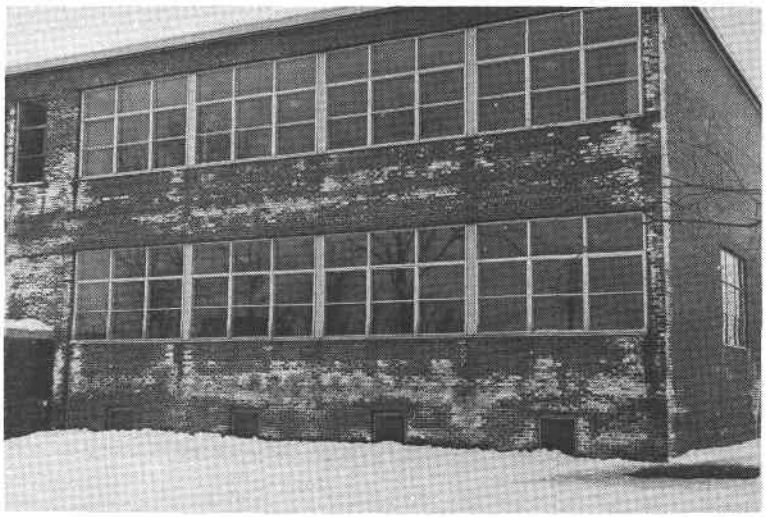

Figure 1. Directional influence on efflorescence; east wall affected, north wall much less affected.

Figure 2. Efflorescence at the top of a wall.

d) Building design and occupancy

Wall areas subjected to heavy wetting because of certain design features or faults of construction are usually affected by efflorescence. A high level of humidity in a building and condensation within the wall or on its surface may also bring it about. In the building shown in Figure 3, for example, a meat processing plant having a high level of humidity, condensation occurs on the windows in the cold season so that moisture is supplied to the adjacent brick-work; the particular drying conditions produce the unusual pattern of efflorescence shown. In this wall, the efflorescence recurs each cold season and is not apparent in the summer.

Efflorescence only at the top of a wall, already described as due to unequal wetting by rain, may sometimes be accounted for by the condensation process. Passage of warm moist air through openings near the top of a wall (resulting from "chimney action" of buildings) and subsequent condensation of the water vapour on the masonry supplies moisture to the masonry and thus promotes the occurrence of efflorescence.

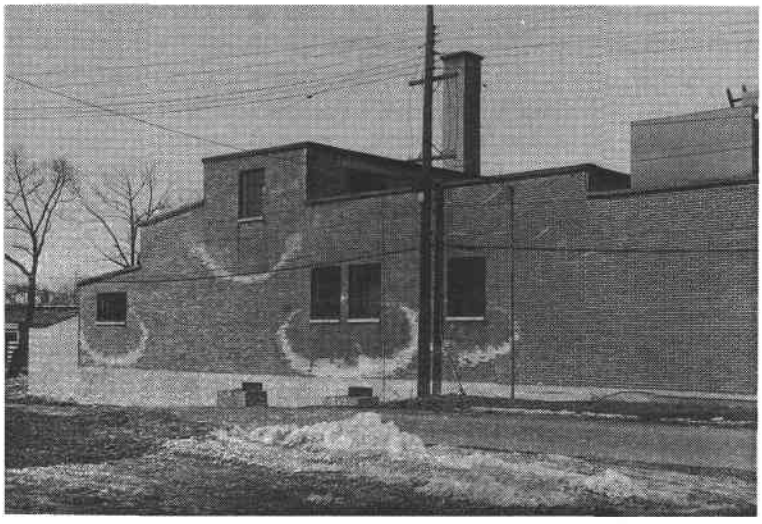

Figure 3. Efflorescence related to condensation of water vapour.

COMPOSITION OF EFFLORESCENCE

Samples of efflosrescence were obtained from many buildings constructed of bricks from various sources and of different mortar materials. Chemical analysis of these samples showed that in all of them a major constituent was a salt of sodium or potassium, usually sulphate. The only sample that contained no sulphate was taken from a building free of efflorescence on the bricks but heavy with deposits on the mortar joints; this efflorescence was mainly sodium carbonate. Samples taken from walls of concrete bricks and sand-lime bricks were similar in composition to the samples taken from clay brick masonry. Only one sample, that taken from the building shown in Figure 3, contained a considerable amount of a magnesium compound.

Because of the nature of efflorescence on masonry (as fine and fibrous salt deposits) a small amount of efflorescence by weight is usually sufficient to produce a great change in the appearance of the masonry. In one instance, for example, the red clay bricks of a wall were completely covered with white efflorescence; when it was carefully removed from the face of one of the bricks and weighed, the amount was less than a third of a gram (less than 0.012 ounce).

SOURCE OF EFFLORESCENCE

Soluble salts may be present in either bricks or mortar in amounts sufficient to form efflorescence on the masonry. It is even possible for a brick that is initially free of soluble salts to be contaminated as a result of the migration of salts from the mortar into the brick so that efflorescence forms on the brick surface.

The predominance of sodium and potassium compounds in efflorescence indicates mortar as a probable source; it has been demonstrated in several studies that Portland cement in mortar contributes such materials to efflosrescence on brick masonry. Sulphate and carbonate materials are usually also present in mortar. There is evidence, however, that efflorescence of sodium and potassium sulphate on clay bricks results from the migration of a solution of sodium and potassium hydroxide from the mortar into the brick, where a reaction takes place with sulphate compounds or with sulphur dioxide gas adsorbed on the surfaces of the internal pores during the firing of the brick.

EFFLORESCENCE AND DURABILITY

It has long been known that certain salts promote the decay of masonry materials, and examination frequently reveals salt deposits where decay has taken place. In this connection mention may be made of the well-known soundness test for concrete aggregates in which the stone is alternately soaked in a solution of sodium sulphate or magnesium sulphate and dried. The crystallization of these salts in the stone may set up internal stresses sufficiently powerful to disrupt it.

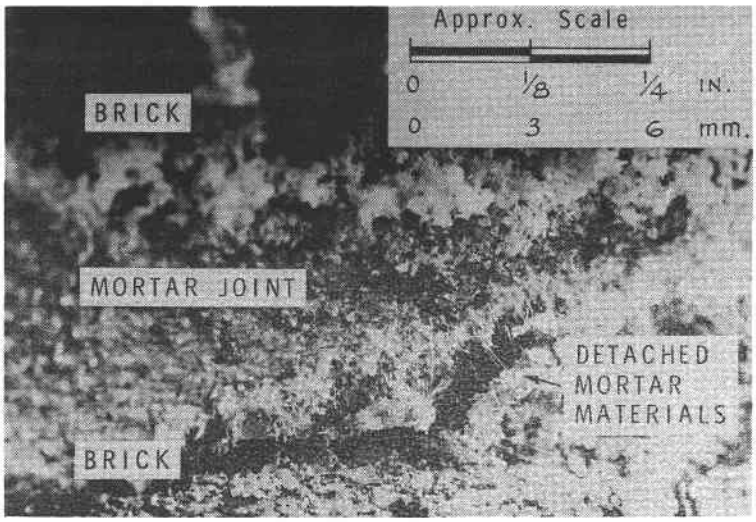

Figure 4. Decay of mortar caused by salt crystallization.

As sodium sulphate and other sulphates are usually major constituents of efflorescence, it is not surprising that there is frequently a link between efflorescence and decay. In studies of a few cases of decayed masonry, chemical analysis showed a much higher content of sulphate salts than was present in apparently sound material in the same area of the wall, a confirmation of the results of early similar studies which indicated that decay frequently results from the presence of sulphate compounds in masonry.

As mentioned previously, evaporation of the water in masonry may occur at the surface or within the material, depending on the conditions of evaporation. In the latter case there is a plane of evaporation in which salt crystallization takes place. As the salts form, directional growth may occur. The material is therefore stressed in tension in a plane. Materials frequently decay in a manner indicating that such a process has taken place, in that flakes or even a large thin slab of the material becomes detached from the original mass. The mortar joint shown in Figure 4, for example, was affected by efflorescence. Flakes and other pieces of mortar were removed from the joint, some of the detached material still held by the fine fibrous crystals projecting from the body of the mortar.

SOLUTION OF THE EFFLORESCENCE PROBLEM

The most obvious solution to the problem is to use masonry materials free of highly-soluble salts, particularly those of sodium and potassium. A high degree

of control of such soluble salts in mortar materials and clay bricks is now possible in their manufacture, and the selection of materials low in soluble salts is favourable to efflorescence-free masonry.

The nature of the surface of a masonry material may be changed by the application of a water-repellent material such as silicone in such a way that the formation of efflorescence on the surface is prevented. Such surface treatment has been used with problems of efflorescence, but few reports of carefully controlled and detailed investigations of such treatments on buildings have been presented in the literature. There are indications that treatment of masonry materials with water-repellents, which interfere with the migration of salt solutions, invites a situation that may promote spalling and flaking of the material.

An important factor in the control of efflorescence is the design of the building. The lack of means to shed water from walls, permitting moisture to accumulate in masonry, is dangerous with regard not only to the occurrence of efflorescence but also to damage from freezing. Careful construction of masonry is also necessary to make it as rain-resistant as possible. The more easily wetted a wall is (by rain or condensation), the more favourable conditions become for the occurrence of efflorescence.

CONCLUSIONS

Efflorescence is in large part a moisture problem of buildings. Its occurrence depends initially on the presence of soluble salts in the masonry. They may be present in solution when the masonry is constructed because of moisture already present in the materials used, or they may be taken into solution subsequently when the masonry is wetted by rain or by other means. A certain level of moisture in masonry and certain conditions of drying are necessary for salts to migrate to the surface and be deposited there. Drying conditions are important, therefore, and efflorescence is usually a seasonal problem.

Salts normally found in efflorescence on masonry are capable of causing decay of masonry materials as a result of simple crystallization of the salts within the material that causes internal pressure.

The most promising solution to the problem of efflorescence appears to be the selection of masonry materials free of highly-soluble salts, and buildings designed in such a way that excessive wetting of the masonry by rain or by condensation is prevented.

This paper is a contribution from the Division of Building Research, National Research Council, Canada, and is published with the approval of the Director of the Division.