



Technical Notes on Brick Construction

Brick Industry Association 11490 Commerce Park Drive, Reston, Virginia 20191

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EFFLORESCENCE PREVENTION AND CONTROL PART II OF II

Abstract: Designers must not only understand the causes and mechanisms of the various types of efflorescence which can occur on brick walls, but should be aware of means to prevent efflorescence and to control it if it does appear. This *Technical Notes* presents a discussion on the importance of design, details, selection of materials, the use of caulking and sealants as well as the importance of good construction practices. An analysis procedure, consisting of a seven-point checklist, is suggested for use in examining problem structures. The concluding discussion addresses methods for the removal of efflorescence.

Key Words: admixtures, analysis procedure, backup, brick, caulking and sealants, coatings, construction practices, design, efflorescence, mortar, prevention, removal.

INTRODUCTION

Efflorescence, the normally harmless deposit of white crystals of salts on the face of brick masonry, can be prevented. An understanding of the nature and mechanisms of efflorescence, as well as the possible sources of soluble salts and moisture, is essential to the prevention of efflorescence.

A detailed discussion of these mechanisms, soluble salts and moisture sources is contained in *Technical Notes 23 Revised*, "Efflorescence-Causes and Mechanisms". This discussion is recommended reading prior to the use of this issue of *Technical Notes*.

This *Technical Notes* addresses recommendations for prevention and control of efflorescence, an analysis checklist for efflorescence problems and procedures for removal of efflorescence.

PREVENTION OF EFFLORESCENCE

It is not practical to attempt to preclude all soluble salts and all moisture from contact with masonry. However, the reduction of each of these contributing factors is highly practicable and will usually reduce or prevent the occurrence and severity of efflorescence.

Selection of Materials

Selecting materials, i.e., facing brick, backup, trim and mortar for minimum content of soluble salts and maximum performance for a watertight structure is the first step in the prevention of efflorescence. The following recommendations are presented to assist the designer in the selection of materials to limit the occurrence of efflorescence.

Brick Units. As stated in *Technical Notes 23 Revised*, brick units which do not contain soluble salts or contribute to efflorescence are available throughout the United States and Canada. It is recommended that all

solid and hollow facing brick be tested for a tendency to effloresce by the efflorescence test contained in ASTM C 67, Standard Methods of Sampling and Testing Brick and Structural Clay Tile.

This test consists of partially immersing representative samples of brick in distilled water for a period of 7 days. At the end of this period, the units are allowed to dry, examined for efflorescence and compared to control samples which were not immersed. Brick should be rated at not more than "slightly effloresced" to be acceptable.

Backup. Many backup materials contain relatively high percentages of alkali which may contribute to efflorescence on the face of a masonry wall. It is suggested, therefore, that backup units be tested for their salt content by the efflorescence test, as described by W. E. Brownell (W.E. Brownell, "The Causes and Control of Efflorescence on Brickwork," Research Report No. 15, Structural Clay Products Institute, 1969.)

When backup materials containing soluble salts are used, it is recommended that the wall details and design be such that the materials containing salts are separated from the facing brick. This design practice avoids through-the-wall migration of water-soluble salts solutions which lead to efflorescence. This can be done by using cavity-type walls, for example.

Mortar. In *Technical Notes 23 Revised*, it is noted that the principal contribution to efflorescence in mortars is the high alkali content of the portland cement. The tendencies of cement toward efflorescence may be predicted with reasonable accuracy from a chemical analysis of the cement. Cements high in alkaline content are more prone to produce efflorescence than cements of lower alkali content.

ASTM Standard Specification for Portland Cement, C 150, contains the following note as part of Section 4,

Chemical Resistance:

"Note 3. Cement containing not more than 0.60 percent alkali calculated as the percentage of Na_2O plus 0.658 times the percentage of K_2O may be specified when the cement is to be used in concrete with aggregates that may be deleteriously reactive. Reference should be made to the Specification for Concrete Aggregates (ASTM Designation: C 33) for suitable criteria of deleterious reactivity."

The alkalis referred to are the total, i.e., acid-soluble, which includes the water-soluble fraction alkalis. In general, the water-soluble alkali content will be of the order of 60 percent of the total. It is stated by Brownell:

"Experience has shown that 0.1 percent free alkali in a portland cement used in common mortars will cause 'new building bloom'; therefore, if such efflorescence is to be avoided, the free alkali of the cement should be less than this and should be specified as low as possible."

This severe limitation on water-soluble alkali content can be met only by a few cements, other than portland blast-furnace slag cement and masonry cements made with slag cement.

It should be stated, however, that all investigators do not agree. Many believe that Brownell is extremely conservative.

Other ingredients for mortar, i.e., lime, sand and water, should also be selected with care, although their contribution to efflorescence may be less frequent (see *Technical Notes 23 Revised*).

Mortar types and proportions should be selected on the bases of structural and exposure requirements for the particular project. Recommendations for mortar are contained in *Technical Notes 8 Revised* and *Technical Notes 8B*.

Admixtures. Admixtures for mortar are generally not recommended because of their unknown ingredients and the lack of data on their effect on bond strength and, consequently, watertightness of masonry walls.

Design

The most meticulous design and detailing may be thwarted by the selection of inappropriate materials or by poor workmanship. The converse is also true; the use of the best possible materials and craftsmanship will not in themselves ensure a successful and permanent structure, if the design is improper.

Wall Sections. The design of a masonry wall and the selection of materials for construction should, from the standpoint of resistance to rain penetration, be based upon the exposures to which the wall will be subjected.

There are two principal methods employed for preventing penetration of wind-driven rain into the body of the masonry. One is to provide a cavity or airspace behind the exterior masonry wythe to channel water through weepholes back to the outside of the wall. A second method is to provide an internal barrier to water penetra-

tion in back of the exterior wythe. These two wall types are generally referred to as "drainage" and "barrier" wall types, respectively, and are discussed in detail in *Technical Notes 7 Series*. In general, the "drainage" type walls are recommended for maximum resistance to rain penetration and minimum efflorescence.

Details. As previously stated, one of the necessary conditions for the occurrence of efflorescence is the presence of moisture in the wall assembly. The preclusion of this moisture will thwart the mechanisms for efflorescence. Therefore, much depends on the design and attention to certain critical details. Of primary importance are those details associated with the prevention of the entry of moisture into the masonry assembly. Also of importance are details that will direct water away from wall tops and horizontal surfaces.

Design recommendations, wall types, workmanship characteristics, detailing, flashing, drips and weepholes are some of the points to which careful attention must be paid in order to prevent the occurrence of efflorescence. These subjects are discussed with recommendations in *Technical Notes 7 Series*.

Caulking and Sealants. Too frequently, caulking is used as a means of correcting or hiding poor workmanship rather than as an integral part of construction which should be designed and installed in the same manner as other elements of the structure.

Joints between masonry and door and window frames, expansion joints and other locations where caulking is required, are the most frequent sources of rain penetration into masonry. These vulnerable locations should be given careful attention during design and construction. Also, maintenance programs should be established to inspect and replace sealants or caulking which have dried, or become ineffective. It is noted that the expected life of the best available sealant material is only 4 to 10 years, depending on the exposure.

Construction Practices

As previously discussed, it is apparent that construction practices and workmanship employed in building masonry walls can seriously affect the walls' tendency to effloresce. Some discussion and recommendations for proper construction practices follow.

Workmanship. Workmanship characterized by the complete filling of all mortar joints intended to receive mortar is desirable, as is the need to keep all cavities clean and free of mortar droppings. Attention to both of these items is of primary importance in preventing moisture penetration to the interior of masonry. It is also of paramount importance in preventing the occurrence of efflorescence. *Technical Notes 7B Revised* discusses the workmanship practices which should be employed in the construction of masonry walls.

Protection. Partially completed masonry walls exposed to rain and other elements during construction may become saturated with water and can require weeks, or even months (depending on climatic conditions), after

the completion of the building for the masonry to dry. This prolonged saturation may cause many "slightly" soluble salts, as well as the highly soluble salts, to go into solution. Such conditions may also contribute to the contamination of the masonry with soluble salts from elsewhere in the construction (concrete, plaster, trim, etc.).

During construction, all walls should be kept dry by covering with a strong, waterproof membrane at the end of each workday or shutdown period. Mortar boards, scaffold planks and light plastic sheets weighted with brick should not be accepted as suitable cover. Metal clamps, similar to bicycle clips, are commercially available in a variety of sizes to meet various wall thicknesses. These are used in conjunction with plastic sheets or water-repellent tarpaulin material and offer excellent protection for extended periods of time. For masonry construction during cold weather, see *Technical Notes 1 Series* for winter protection recommendations and construction procedures.

Storage of Materials. The method of storing materials at a construction project site may influence future occurrence of efflorescence. Materials should be stored in such a manner as to avoid their saturation by rain, snow and ground moisture, as well as contamination from salts or other matter which may contribute to efflorescence.

Masonry Units - Masonry units should be stored off the ground to avoid contamination by dirt and ground water which may contain soluble salts. They should also be covered by a waterproof membrane to keep them dry.

Cementitious Materials - Cementitious materials for mortar should be stored off the ground and either inside or under cover.

Sand - Sand for mortar should also be stored off the ground to prevent contamination from dirt, plant life, organic materials and ground water, any of which may be a contributor to efflorescence. In addition, it is advisable to store sand and other aggregates under a protective membrane cover, if possible.

Analysis Procedure

An examination of a problem structure using the following checklist may be sufficient to determine the cause and extent of the efflorescence problem, and to suggest methods for repair and alleviation.

1. *Determine the age of the structure* at the time when the efflorescence first appeared. If "new building bloom" is involved (structures less than one year old), the source of the salts is often the cement in the mortar, and the source of the moisture is usually the construction water. If, however, the building is over a year old, other sources must be considered.

If the structure is over two years old, construction details should be examined for possible leaks in the wall or in the surrounding construction. The appearance of efflorescence on an established building, which has been free of efflorescence, is usually attributable to a new source of water in the masonry.

2. *The location of the efflorescence*, both on the struc-

ture and on the individual units or mortar joints, should also be carefully noted. The location on the building may offer some information as to where the water is entering. The location of salt crystals on the joints or the units may be of help in determining the source of the salts. The recent use or occupancy of the building should also be noted. For example, has it been vacant for some time or has there been new construction? In short, what has occurred that might cause, or trigger, the appearance of the efflorescence?

3. *The condition of the masonry* should be carefully examined. The profile of the mortar joints, the condition of the mortar, the quality of workmanship employed, the condition of caulking and sealant joints, the condition of flashing and drips, any deterioration or eroding of mortar joints in copings or in sills should all be carefully noted. This information should offer clues as to the entry paths of moisture into the construction.

4. *The wall sections and details* of construction should be examined for an indication of possible paths of moisture travel, and for possible sources of contamination by soluble salts. A careful examination of roof and wall juncture and flashing details should be made. A comparison of "contract drawings" with "as built drawings" may be helpful. This examination will also be useful for the later determination of steps for repair or alleviation of the efflorescence.

5. *Laboratory test reports* on the materials of construction should be examined, if they are available. This will help determine the source of the soluble salts, and may be of use in analyzing and making repair judgments.

6. *The identification of efflorescence* is sometimes of use. This can be done by commercial testing laboratories. X-ray defraction analysis is sometimes used. Petrographic analysis or chemical analysis is also possible. In some instances, it is useful to know both the type of salts present and their relative quantity.

Table 1 is taken from Brownell's report and is described as a table of most probable sources of salts.

7. *Miscellaneous sources of water* should also be considered if all other sources seem to be eliminated. Some of these sources are: condensation within the wall, leaky pipes, faulty drains and condensation on heating or plumbing pipes. Although somewhat rare, if a condensation analysis is necessary, the methods are described in *Technical Notes 7C* and *7D*.

Corrections and Solutions

When the mechanisms causing the efflorescent salts to appear have been established and the sources of salts or moisture are identified (usually the latter), the problem of making suitable corrections must be addressed. Such solutions to efflorescence problems usually involve preventing the entry of water into the masonry and removing the efflorescence from the wall.

Recommendations for the correction of water penetration

TABLE 1
Common Sources of Efflorescence

Principal Efflorescing Salt		Most Probable Source
Calcium sulfate	CaSO ₄ •2H ₂ O	Brick
Sodium sulfate	Na ₂ SO ₄ •10H ₂ O	Cement-brick reactions
Potassium sulfate	K ₂ SO ₄	Cement-brick reactions
Calcium carbonate	CaCO ₃	Mortar or concrete backing
Sodium carbonate	Na ₂ CO ₃	Mortar
Potassium carbonate	K ₂ CO ₃	Mortar
Potassium chloride	KCl	Acid cleaning
Sodium chloride	NaCl	Sea water
Vanadyl sulfate	VO ₂ SO ₄	Brick
Vanadyl chloride	VOCl ₂	Acid cleaning
Manganese oxide	Mn ₂ O ₄	Brick
Iron oxide	Fe ₂ O ₃ or Fe(OH) ₃	Iron in contact or brick with black core
Calcium hydroxide	Ca(OH) ₂	Cement

in masonry walls are contained in *Technical Notes 7 Series*.

Coatings

Silicone or acrylic applications are among the solutions open suggested for prevention of efflorescence. The application of a coating to a masonry wall may prevent recurrence of efflorescence. However, the application of a coating to masonry which has a tendency to effloresce, without stopping the mechanisms causing the occurrence of that efflorescence, may lead to disintegration of the masonry.

As stated in *Technical Notes 7E*, water gaining entrance into the masonry will still take soluble salts into solution. Then, as the water travels toward the treated surface, most of it will be stopped at the inner depth of the coating penetration (usually 1/8 to 1/4 in. [3 to 6 mm]) from the face. At this point, the water will evaporate, passing through the treated area as vapor and will present no problem. However, the soluble salts contained will be deposited within the masonry at the point where the water evaporates. The crystalline growth, at that point, can develop tremendous pressures which may result in brick spalling. It is for this reason that coatings are not recommended as a treatment for efflorescence problems.

REMOVAL OF EFFLORESCENCE

As a general rule, the removal of efflorescent salts from the face of masonry is a relatively easy operation. As stated, most efflorescent salts are water-soluble and many will disappear of their own accord with normal weathering. This is especially true of "new building bloom".

It is usually not advisable to *wash* efflorescence off of the brickwork except in warm, dry weather, since this results in the availability of considerably more moisture which may bring more salts to the surface. Many efflorescent salts can be removed by dry brushing.

For recommendations concerning the removal of the efflorescent salts and other stains on masonry walls, see *Technical Notes 20 Revised*. Special care should be exercised in the cleaning operation of new masonry, since improper procedures and errors can contribute to or cause efflorescence and/or other staining.

SUMMARY

As stated, the mechanisms for efflorescence require the presence of soluble salts and moisture. To prevent or stop the occurrence of efflorescence, the elimination of either will suffice.

Recommendations have been offered in this *Technical Notes* for the proper selection of materials, wall sections and design details to reduce to a minimum the available salts and the opportunity for water penetration. A discussion of the sources of moisture and salts and the mechanisms of efflorescence is contained in *Technical Notes 23 Revised*.

The information contained in this *Technical Notes* is based on the available data and the experience of the technical staff of the Brick Institute of America. This information should be recognized as recommendations which, if followed with good judgment, should result in brick masonry that performs successfully.

Final decisions on the use of details and materials as discussed in this *Technical Notes* are not within the purview of the Brick Institute of America and must rest with the project designer, owner or both.

REFERENCES

Information beyond that discussed in this *Technical Notes* is contained in the following publications:

1. *Selected ASTM Standards for Brick*, compiled by ASTM for Brick Institute of America, August 1985.
2. *Technical Notes on Brick Construction 1 Revised*, "Cold Weather Masonry Construction-Introduction", Reissued July 1981.
3. *Technical Notes on Brick Construction 1A*, "Cold Weather Masonry Construction--Construction and Protection Recommendations," Reissued December 1982
4. *Technical Notes on Brick Construction 1B*, "Cold Weather Masonry Construction--Winter Building Techniques in Europe," Reissued December 1984.
5. *Technical Notes on Brick Construction 1C*, "Cold Weather Masonry Construction--Contemporary Bearing Wall Buildings," Reissued July 1981.

6. *Technical Notes on Brick Construction* 7 Series on the subject of Water Resistance of Brick Masonry.
7. *Technical Notes on Brick Construction* 8 Revised, "Portland Cement-Lime Mortars for Brick Masonry", September 1972.
8. *Technical Notes on Brick Construction* 20 Revised, "Cleaning Brick Masonry", Sept.-Oct. 1977.
9. *Technical Notes* 23 Revised, "Efflorescence, Causes and Mechanisms, Part I of II", May 1985.