Efflorescence: Cause and Control[1]

ef-flo-res-cence (ef∍ le res∍ens), 1. a change on the surface to a powdery substance upon exposure to air, as a crystalline substance through loss of water. 2. to become incrusted or covered with crystals of salt or the like through evaporation or chemical change.

Efflorescence is the stubborn problem that has caused confusion and trouble for masonry since the first time it appeared thousands of years ago on ancient masonry walls. Efflorescence is normally the white, powdery scum that can appear on masonry walls after construction but can also be brown green or yellow, depending on the type of salts. Nobody likes it, nobody wants it on their walls, but occasionally this persistent problem appears.

Great deals of time, money and effort have been spent trying to solve the difficulties efflorescence generates. Many test programs have been developed and numerous attempts have been made to eliminate the efflorescence problem. Unfortunately, nothing has proven 100% effective against this very stubborn problem. However, even though no surefire cure has been discovered, a great deal has been learned about how efflorescence works and how to prevent it, and if preventive measures are inadequate, how to remove the efflorescence if it does appear.

This article explains the mechanics of white efflorescence, how to help prevent efflorescence and some traditional methods used to remove efflorescence from new walls.

What is Efflorescence?

We know that efflorescence is a fine, white, powdery deposit of water-soluble salts left on the surface of masonry as the water evaporates. These efflorescent salt deposits tend to appear at the worst times, usually about a month after the building is constructed, and sometimes as long as a year after completion.

Required Conditions:

Efflorescence is not a simple subject. Three conditions must exist before efflorescence will occur.

- First: There must be water-soluble salts present somewhere in the wall.
- Second: There must be sufficient moisture in the wall to render the salts into a soluble solution.
- Third: There must be a path for the soluble salts to migrate through to the surface where the moisture can evaporate, thus depositing the salts which then crystallize and cause efflorescence.

All three conditions must exist. If any one of these conditions is not present, then efflorescence cannot occur.

Even though the efflorescence problem is complex, it is not difficult to prevent.

Although no economically feasible way exists to totally eliminate any one of these three conditions, it is quite simple to reduce all three and make it nearly impossible for efflorescence to occur.

Source of Efflorescent Salts

A chemical analysis of efflorescent salts in the Southern California area (1) reveals that they are principally alkalies of Sodium Sulfates (Na_3S0_4) and Potassium Sulfates (K_2S0_4). These are the main soluble salts to be concerned with in Southern California since these are 90% of the efflorescence found in this area. These alkali sulfates appear because they exist somewhere within the masonry wall, either in the brick, the mortar, or the grout, or possibly a combination of these three. These alkalies combine with sulfates from the masonry to form sulfate salts. The alkali sulfates in the wall are dissolved by water into a solution which then moves through the natural pores in the masonry. The solution migrates to the surface of the wall where the water evaporates, depositing the salts on the wall and generating the white powdery scum we know as efflorescence.

Figure 1. Typical white efflorescent salts on brick and block masonry

[1] Based on a technical paper written by Michael Merrigan, P.E., originally published in The Masonry Society Journal, January-June, 1986

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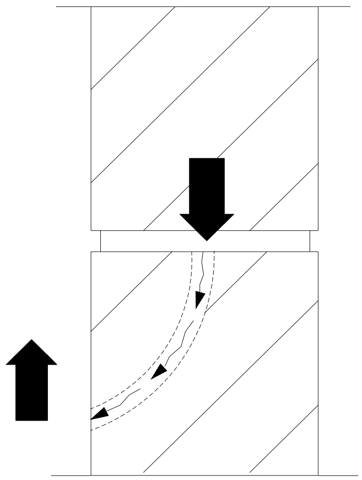

Figure 2. Possible path of water soluble salts that form efflorescence

Research into each of the materials used in masonry walls reveals that the main source of alkalies for the salts is the Portland cements used in the mortar and grout. Using a low alkali Portland cement will often eliminate the efflorescent problem. It is recommended that low alkali Portland cement be used to reduce the chances of efflorescence occurring. Low alkali Portland cement has 0.6% alkali or less, by weight in the cement (2, 3).

Another culprit is, of course, the clay brick itself. The natural clays used in the manufacture of brick often contain soluble alkali sulfates. Most modern fired clay brick have balanced chemical additives, such as Barium Carbonate ($BaCO_3$), to immobilize the sulfates and render them insoluble (4). This prevents the salts from being dissolved into a solution that could migrate through the wall to the surface. Most fired clay brick do not greatly contribute towards the efflorescence problem.

The next source for soluble salts would be the sand used in the mortar and grout. Contaminated sands with soluble alkali sulfates will cause efflorescence unless the sulfates are removed. Using clean, washed sand will eliminate any efflorescing contribution.

The water used in the mortar and grout during construction can also be a source of contaminants. Clean, potable, salt free water must be used at all times. Tests of Colorado River tap water show only insignificant amounts of salts in the water. Water from other sources should be checked for their alkali sulfate contents to be sure no efflorescing salts will be introduced into the masonry wall.

In the past, hydrated lime used in the mortar was thought to have been responsible for efflorescence. This did make sense to the layperson. After all, anyone can make a logical connection between the *white* lime and the *white* efflorescent salts. However, chemical analysis and experimental tests proved otherwise. Hydrated lime ($Ca(OH)_2$) does not contribute sufficiently towards the soluble alkali sulfates necessary for efflorescence to occur (generally only $^1/_4$ to $^1/_{10}$ the efflorescing potential of the cements). In addition, the hydrated limes also reduce the voids in the mortar, thus reducing the area for capillary flow of any solutions in the wall.

Potential efflorescent problems can be greatly reduced by using low alkali cements, clean washed sands and clean, potable salt free water.

Controlling Efflorescence

Even if soluble alkali sulfates exist in a masonry wall, before the sulfates can cause efflorescence the salts must be dissolved into solution by water. If no moisture reaches the sulfates then they cannot be rendered into solution and migrate to the surface where the water will evaporate, leaving the sulfate salts on the surface to crystallize and become efflorescence. Attention must be given to preventing any soluble alkaline sulfates from being rendered into solution by water.

This is difficult since during construction water is naturally used in the mortar and grout, therefore the amount of water in the wall should be controlled to only that amount necessary for actual construction. The majority of the water is absorbed into the masonry and used to chemically react with the Portland cement and hydrated lime and is thus not free water.

The next critical concern is to prevent any water from penetrating into the masonry wall where it could cause efflorescence to occur. This can be done with good architectural details and quality masonry construction. Designing with overhanging eaves, copings and flashings, and careful attention to landscaping and sprinklers will reduce the chances of water entering the wall. In addition, specifying tooled, compacted mortar joints (concave or "V" type) will also reduce the potential for water infiltration. See Figures 3 and 4 for good efflorescence controlling design.

As mentioned earlier, for efflorescence to appear, the alkali sulfates must be able to travel through the pores in the masonry to the surface. If the natural pores in the wall can be reduced, it becomes harder for the salts to migrate through to the surface. Consolidating the grout with mechanical vibration will greatly reduce any voids in the grout, as well as improving the bond of the steel and the masonry wall. Dense tooled mortar joints will also reduce the porous nature of the wall and make it difficult for the salts to migrate.

Grout admixtures that claim to inhibit efflorescence can also be used. These chemical additives claim to improve the flow of the grout mix while decreasing the water content. They also claim to reduce voids in the grout due to shrinkage.

Special care must be taken when using these grout admixtures. Individual manufacturers have developed them and their actual contents are protected trade secrets. The manufacturer's recommendations must be closely followed.

Figure 3. Overhanging eaves will help greatly to prevent moisture from entering this stack bond CMU wall.

Figure 4. A full metal coping helps in waterproofing a wall and eliminates moisture penetration through the tops of parapets

To summarize, three conditions must exist before efflorescence can occur. If these three conditions can be controlled, there should be no effloresing of masonry walls.

1. Reduce all soluble alkali sulfates.
2. Use good details to prevent water from entering the masonry.
3. Use good construction practices to eliminate migratory paths for moisture.

Remember, it is very difficult to totally control any one of these three conditions, but it is relatively simple to reduce the effect each one has towards efflorescence.

Removing Efflorescence

Despite all efforts, efflorescence may sometimes occur. A detail may have been omitted. Materials may have been incorrectly specified or may not have been used as specified. Sometimes conditions just naturally conspire to generate efflorescence on a wall. The materials may not have been covered or stored on pallets off the ground. Unknown salts could infiltrate masonry materials during a wind storm or simply through ignorance and misuse of the materials. Salt laden soils could be backfilled against a wall where the salts could be absorbed and cause efflorescence. Whatever the reason, when efflorescence does appear, it has to be removed.

The first step in removing efflorescence should be an attempt to identify the salts. If the salts are water soluble, the best removal method is with a dry brush. Rinsing with water or natural weathering process may also be effective. Alternately, if the efflorescence is in small patches or limited areas, hand washing with a mild detergent and a stiff bristle brush will often prove sufficient.

The traditional method of cleaning has been sandblasting, which, of course, works. Unfortunately it removes just about everything else, too. The abrasive action of the sand erodes the surface of the brick and the tooled mortar joints along with any deposited salts. This increases the porous qualities of the masonry and the water absorptive nature of the wall. Sandblasting will also damage the integrity of the dense tooled mortar joints. A well-tooled and compacted mortar joint readily sheds moisture and provides minimum voids for penetration. After sandblasting, the mortar is more porous, has voids for infiltration, and may even reveal cracks in the mortar. Additionally, the appearance of the masonry wall will be changed since the texture of the brick has been made slightly coarser.

Sandblasting should be used with caution and afterwards the masonry should be sealed with a waterproofing material.

An alternative to sandblasting, which has shown good success when done properly is the use of special chemical cleaners. Most chemical cleaning agents are proprietary and must be used according to the manufacturer's directions. Generally, thorough presoaking and post washing with clean potable water is required. Presoaking is done to saturate the wall, reducing its natural porous tendencies and limiting the depth of penetration of the cleaning solution. After the cleaning solution has been used, the wall must be thoroughly washed with clean water to remove any of the cleaning chemicals. This is very important since most cleaning agents are acidic in nature and cannot be permitted to remain in the wall where they will continue to react with and erode the masonry itself.

A conventional chemical cleaner that has been used for removing efflorescence is muriatic acid in a mild solution, usually one part muriatic acid (hydrochloric acid, HC1) to 12 parts water. Several mild individual applications are better than one overpowering dose. Again, care must be taken to thoroughly presoak the wall with clean water and to thoroughly flush the wall of all remaining acids with clean water.

Cleaning efflorescence from masonry walls does not cure the problem; it only removes the symptoms. After cleaning, the efflorescence will reappear unless the natural efflorescent chain is broken. Due to the added water used when pre-soaking and post-flushing the walls when using chemical or acid cleaners, the efflorescence will sometimes reappear, often stronger than before.

After final sandblasting or acid cleaning of the efflorescence from the masonry, the wall should be sealed. The efflorescence already indicates that soluble alkali sulfates may exist in the wall and that the sulfates have migratory paths to the surface. All we can prevent now is the moisture from entering the masonry and rendering the sulfates into solution.

Care must be taken not to trap the salts below the surface of the masonry. This condition is known as crytoflorescence. If the salts are stopped just below the surface, for instance by a silicon water repellent, the water will still evaporate, depositing the salts behind the surface, which then crystallize. The expanding salt crystals can exceed the tensile strength of the brick causing spalling or disintegration of the brick.

South and West facing walls are normally less prone to efflorescence since the sun exposure moves the point of evaporation further into the wall. The point of evaporation is where efflorescence occurs. On the other hand, North and East facing walls are normally cooler and the point of evaporation remains on the surface of the wall where the efflorescence occurs.

It is not a cure-all to simply seal a wall when efflorescence already exists. The presence of efflorescence shows that the salts are already in the wall, have sufficient water to be made soluble, and that migratory paths exist for the salt solution to travel through to the surface. It would be better, if possible, to wait until the efflorescence problem has been reduced to a minimum before sealing the wall.

Efflorescence is a controllable condition that should not be a problem in modern masonry. Breaking the chain of conditions necessary for efflorescence can be done with good details, the correct materials and quality construction.

Related Material

BIA Technical Notes on Brick Construction, Brick Institute of America, Reston, Virginia
Note 20 Revised, *Cleaning Brick Masonry*
Note 23 Revised, *Efflorescence Causes and Mechanisms*
Note 23A Revised, *Efflorescence Prevention and Control*

NCMA Technical Notes for Concrete Masonry Design and Construction, National Concrete masonry Association, Herndon, Virginia
Note 8-3A, *Control and Removal of Efflorescence*

ASTM C 1400-98, *Standard Guide for Reduction of Efflorescence Potential in New Masonry Walls*

Reinforced Grouted Brick Masonry Construction, Masonry Institute of America, Los Angeles, California.

APPENDIX

REFERENCES

1. *Investigation of the Source of Efflorescence of Brick Masonry*, Donald W. Bolme and Lester P. Berriman, Stanford Research Institute, Clay Products Promotional Fund, 1960.

2. *The Causes and Control of Efflorescence on Brickwork*, Wayne E. Brownell, Structural Clay Products Institute, 1969.

3. *Investigation of Methods for Reducing Efflorescence of Masonry*, James M. Ross and Lester P. Berriman, Stanford Research Institute, Clay Products Promotional Fund, 1961.

4. *Fundamental Factors Influencing Efflorescence of Clay Products*, W. E. Brownell, The Journal of The American Ceramic Society, Dec. 1949.

5. *Can Efflorescence be Controlled?*, Jeffrey Elder, Brick Architecture and Landscape, Summer, 1995