

Efflorescence

Efflorescence is in effect a type of staining. Efflorescence staining is a white crystalline deposit that forms on or near the surface of concrete, masonry, and cement based materials. It is the most common post-installation defect in direct adhered exterior ceramic tile, stone, and brick wall systems.

Efflorescence can range from a cosmetic annoyance that is easily removed, to a serious problem that could cause adhesive bond failure or require extensive corrective construction and aggressive removal procedures.

Efflorescence starts as a salt which is dissolved by water; the salt solution is then transported by gravity or by capillary action to a surface exposed to air, where the solution evaporates and leaves behind the crystalline deposit. Efflorescence can also occur beneath the surface or within ceramic tile, stone, or thin brick units.

Occasionally, staining on direct adhered facades is misdiagnosed as efflorescence. Vanadium and molybdenum compounds in ceramic tile, and manganese compounds in thin

brick can be dissolved by acid cleaning, leaving behind a insoluble deposit.

Efflorescence occurs from three simultaneous conditions listed in table 9.4.1. While theoretically efflorescence can not occur if one condition does not exist, it is impracticable to completely eliminate the confluence of these conditions in an exterior wall. However, the conditions that cause efflorescence can be easily controlled and the symptoms minimized, to the point where deposits are not visible, or easily removed and non-recurring.

Causes of efflorescence

- Presence of soluble salts
- Presence of water (for extended period)
- Transporting force (gravity, capillary action, hydrostatic pressure, evaporation)

Presence of soluble salts

There are numerous sources of soluble salts listed in figure 9.6-1. There is always the potential for efflorescence when concrete and cement mortars, adhesives and grouts are exposed to the weather. Other sources of

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 ₃	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

Figure 9.6-1 Sources of soluble salts

soluble salts can be monitored, controlled or completely eliminated.

Efflorescence Sources of soluble salts

- Hydration of cementitious materials (calcium hydroxide)
- Calcium chloride contamination
 - sea salt (airborne, sand)

- mixing water (calcium sulfate or calcium chloride softeners)
 - cement accelerator or anti-freeze admixtures (calcium chloride)
- Acid etching & cleaning residue (chlorides)
 - Lime used in mortars (calcium sulfate)

Cement hydration - The most common source is from cementitious materials, such as concrete, cement plasters / renders, concrete masonry units, concrete backer board units, and cement based mortars, including latex cement adhesive mortars. One of the natural by-products from cement hydration (the chemical process of hardening) is calcium hydroxide, which is soluble in water. If cementitious materials are exposed to water for prolonged periods and evaporate slowly, the calcium hydroxide solution evaporates on the surface of the exterior wall, combines with carbon dioxide in the atmosphere (see also Section 5.4 Carbonation), and forms calcium carbonate, one of many forms of efflorescence. Once the calcium hydroxide is transformed to calcium carbonate efflorescence, it is not soluble in water, making stain removal difficult.

Calcium chloride contamination - A common source of soluble salts is either direct or airborne salt water contamination of mixing sand, back-up wall materials and the surface of the substrate. Mixing water can also be contaminated with high levels of soluble salts. Figure 9.6-1 shows the analysis of samples from 6 different city water supplies as compared to seawater. Typically, water with less than 2000 ppm of total dissolved solids will not have any significant effect on the hydration of Portland cement, although lower concentrations can still cause some efflorescence.

Acid etching- (see Section 5.4 Acid Etching and this section-removal of efflorescence).

Lime in mortars - Unhydrated lime used in leveling mortars / renders contains calcium sulfate, which is a soluble salt. Uncontrolled water penetration through unprotected openings, cracks or incorrectly constructed joints may allow sufficient saturation of lime mortars to dissolve these salts in large quantities. The benefit of the

autogenous or “self-healing” qualities of lime mortars has long been the subject of debate in the masonry industry. The very chemical reaction which can seal hairline cracks in lime mortars can also cause efflorescence.

Presence of water

While you can not control naturally occurring soluble salts in cementitious materials, proper design, construction and maintenance of an exterior wall system can control and minimize wall components from both water penetration. Without sufficient quantities and periods of exposure to water, salts do not have adequate time to dissolve and precipitate to the surface of a facade and efflorescence simply can not occur.

Rain and snow are the principal sources of water. Water which condenses within wall cavities or components is an often overlooked source of water.

Section 2 presented several wall construction types that may be employed (barrier, cavity, and pressure equalized rainscreen walls) to control or prevent water penetration. Each type of wall is designed to minimize efflorescence either by providing barriers to water penetration, minimizing water contact with potential contaminants, or controlling the flow of water that contacts contaminated materials.

Section 3 and 4 presented the proper architectural detailing and materials necessary to prevent water infiltration. Waterproofing and flashing at roof / wall intersections, parapets, window sills and heads, spandrels, movement joints, and perimeter interfaces with other components of the facade wall assembly is the primary solution or remedy to prevent efflorescence.

Sealers & coatings

Water repellent coatings are commonly specified as a temporary and somewhat ineffective solution to fundamentally poor wall design and/or construction. In some cases, water repellents may actually contribute to, rather than prevent the formation of efflorescence. Water repellents can not stop water from penetrating the hairline cracks in the surface of cladding, or from penetrating through improperly designed or constructed joints and openings.

Water repellents also do not prevent water infiltration caused by poor wall design or construction. As the infiltrated water travels to the surface by capillary action to evaporate, it is stopped by the repellent, where it then evaporates through the coating (silicone or acrylic coatings are vapor permeable) and leaves behind the soluble salts to crystallize just below the surface of the cladding. The collection of efflorescence under the water repellent coating may cause spalling of the cladding material, or may result in gross accumulation of efflorescence (see sealers & coatings, this section).

Effects of efflorescence

The initial occurrence of efflorescence is primarily considered an aesthetic defect. However, if the fundamental cause (typically water infiltration) is left uncorrected, continued efflorescence can become a functional defect and effect the integrity and safety of a direct adhered facade.

The primary danger is potential bond failure resulting from continued depletion of calcium and subsequent loss of strength of

cementitious adhesives and underlying cementitious components. The crystallization of soluble salts, especially those that form in the adhesive -cladding interface, or within the cladding material (see sealers & coatings, this section) can exert more pressure than the volume expansion forces caused by ice formation. This mechanism may also result in spalling or bond failure.

Fluid migration

Fluid migration from sealant joint materials is a common source of staining in direct adhered facades. This defect most often occurs with certain types of silicone sealants, but can also be caused by some types of soluble polymers found in polymer mortar additives.

Typical Analysis of City Water Supplies and Seawater							
Parts per million							
Analysis No.	1	2	3	4	5	6	Seawater*
Silica (SiO ₂)	2.4	0.0	6.5	9.4	22.0	3.0	-----
Iron (Fe)	0.1	0.0	0.0	0.2	0.1	0.0	-----
Calcium (Ca)	5.8	15.3	29.5	96.0	3.0	1.3	50-480
Magnesium (Mg)	1.4	5.5	7.6	27.0	2.4	0.3	260-1410
Sodium (Na)	1.7	16.1	2.3	183.0	215.0	1.4	2190-12,200
Potassium (K)	0.7	0.0	1.6	18.0	9.8	0.2	70-550
Bicarbonate (HCO ₃)	14.0	35.8	122.0	334.0	549.0	4.1	-----
Sulfate (SO ₄)	9.7	59.9	5.3	121.0	11.0	2.6	580-2810
Chloride (Cl)	2.0	3.0	1.4	280.0	22.0	1.0	3960-20,000
Nitrate (NO ₃)	0.5	0.0	1.6	0.2	0.5	0.0	-----
Total dissolved solids	31.0	250.0	125.0	983.0	564.0	19.0	35,000

*Different seas contain different amounts of dissolved salts.

Figure 6.4-1 Analysis of city water and seawater samples for soluble salt levels

This problem is more a function of a manufacturer's formulation than polymer type (see Section 4 movement joints-compatibility). There is no correlation with a particular polymer type (i.e.,silicone vs. polyurethane), because the problem is typically caused by plastiizer additives and not the polymers. Fluid streaking though, depends on both formulation and sealant polymer type. There are several new generation silicones on the market, (such as Dow Corning® #756 Silicone Sealant HP) which have specifically addressed and overcome the above aesthetic problems associated with sealants used as both movement joints and fillers between pieces of cladding. Fluid migration is also known as "latex migration" when referring to staining caused by water soluble latex additives. It is recommended to verify that a manufacturer's polymer formulation for a liquid latex additive or a dry dispersive polymer powder is not water soluble. Similarly, all installations of external cladding which use latex cement adhesive mortars must be protected from significant rain exposure during the initial setting period (typically 12-24 hours) during which any polymer may be subject to fluid migration or leaching (see Section 7 Weather Protection- wet conditions). Fluid migration staining can manifest as follows:

- **Darkening of the cladding material** - the plasticizers of certain sealants or polymers can be absorbed by porous cladding materials like natural stone or bricks. Permanent darkening of the edges of the cladding in contact with the sealant can occur.
- **Waterproofing of the cladding (hydrophobic action)** adjacent to sealant joints may be caused by sealant fluid migration. The cladding area near the joints will remain dry, and the internal areas will absorb moisture, leading to a darkening of the cladding surface in areas away from the sealant joints. This phenomenon is dependent on the absorption of the cladding material, and is typical of more porous natural stones and applications which use improperly specified fluid flexible sealants to fill all the joints between the cladding pieces or

tiles. Typically this condition is not permanent.

- **Dirt pick-up on the cladding** adjacent to sealant joints where fluid has been absorbed by porous cladding material. Dirt pick-up is another common problem and is a function of type of exposure, surface hardness, type of and length of cure, and the formulation, but not the sealant polymer type.
- **Rundown of the fluid** component can accumulate on horizontal edges and replicate normal dirt runoff patterns or be improperly diagnosed as efflorescence.

Stain removal methods and materials

Traditional stain cleaning methods for direct adhered facades include washing with water and detergents, and use of hydrochloric (muriatic) acid and fluoridic acid solutions. Acid cleaning is less desirable today, not only due to environmental and safety concerns, but also due to the lack of skilled labor (acid cleaning is covered in detail under the subject of efflorescence). As a result, there are several new, less invasive methods available on the market today for removal of efflorescence and staining.

Less aggressive chemical cleaning compounds, such as mild ammonium bifluoride cleaning agents, with pH values of 4.5-4.7, are well suited to ceramic tile, stone and brick cladding and have been proven over the past 15 years. These cleaning agents are use in conjunction with high pressure (120 kg/cm²) hot water (80 C) to achieve maximum cleaning effect. The advantages of high pressure hot water are the mechanical effect of the water pressure, minimal use of water, quick drying, and the high dissolving power of hot water (80 C water has 16 times dissolving power compared to 20 C water).

Another less aggressive cleaning method, known as "soft" cleaning, was invented over 30 years ago, but only recently has this method been more widely available and cost-effective. These types of systems

use proprietary equipment¹ that deliver fine, safe powders (limestone and aluminum silicate crystals) at low pressures (60 psi [.4 Mpa]). The equipment also reduces temperature of the compressed air @ 200 F [930 C] to condense and separate out any water in the air; no water, chemicals or detergents are used. Proprietary equipment may also include enclosures which contain dust and flush residue. Soft cleaning systems are effective on a variety of soiling, stains, and efflorescence

¹ "Erasoft", Minerva Corp., Torrance, CA, USA or "Facade Gommage" Thomann-Henry, Paris, France

Efflorescence removal methods & materials

Prior to removal of efflorescence, it is highly recommended to analyze the cause of efflorescence and take corrective action to prevent recurrence. Analysis of the cause will also provide clues as to the type of efflorescence and recommended cleaning method without resorting to expensive chemical analysis.

Determine the age of the installation at the time efflorescence appeared. In buildings less

than one year old, the source of salts are usually from cementitious mortars and grouts, and the source of water is commonly residual construction moisture. The appearance of efflorescence in an older building indicates a new water leak or new source of salts, such as from acid cleaning residue. Do not overlook condensation within the wall or leaking pipes as a sudden source of water

Location of the efflorescence will offer clues as to the entry source of water.

Chemical analysis of efflorescence can be conducted by a commercial testing laboratory using x-ray diffraction and petrographic analysis to accurately identify the types of minerals present. This procedure is recommended for buildings with an extensive problem, or where previous attempts to clean with minimally intrusive methods have failed.

Removal methods vary according to the type of efflorescence. Therefore it is of critical importance to evaluate the cause and chemical composition of efflorescence prior to selecting a removal method.

Many efflorescence salts are water soluble and will disappear with normal weathering or from dry brushing. Washing is only recommended in warm weather so that the wash water can evaporate quickly and not have the opportunity to dissolve more salts. Similarly, select a cleaning method which itself can not contribute additional soluble salts. For example, acid cleaning can deposit potassium chloride residue (a soluble salt) if not applied, neutralized and rinsed properly.

Calcium carbonate efflorescence is a type of efflorescence where the calcium salts combine with carbon dioxide in the air and form a hard, crusty deposit which is insoluble in water. However, long term exposure to air and rain water will gradually transform this residue to calcium hydrogencarbonate, which is soluble in water. So long term weathering may eliminate this type of efflorescence. Unfortunately, if the condition is not acceptable in the long term, and water cleaning proves ineffective, it may be necessary to wash the surface with a dilute solution (5-10%) of hydrochloric (muriatic) acid. Aqueous solutions of acids are commercially available for ease of handling and prevention of dilution errors. For integrally pigmented grouts, a 2% maximum solution is recommended, otherwise, surface etching will reveal aggregate and wash away color at the surface.

Acids should not be used on glazed tiles, for the acid solution will etch and dull the glaze surface, or react with compounds in the glaze and redeposit brown stains on the cladding which are insoluble and impossible to remove without ruining the tile.

Before applying any acid solution, always test a small, inconspicuous area to determine any adverse effect. Just prior to application, saturate the surfaces with water to prevent acid residue from absorbing below the surface. While most acids quickly lose strength upon contact with a cementitious material and do not dissolve cement below the surface, saturating the surface is more important to prevent absorption of soluble salt residue (potassium chloride) which then can not be surface neutralized and rinsed with water. This condition in itself can be a source of soluble salts and allow recurrence of the efflorescence problem intended to be corrected by the acid cleaning.

Application of acid solutions should be made to small areas less than 10 ft² (1 m²) and left to dwell for no more than 5 minutes before brushing with a stiff acid resistant brush and immediately rinsing with water. Acid solutions can also be neutralized with a 10% solution of ammonia or potassium hydroxide.

