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Efflorescence in Portland cement plaster finishes – Tech Bulletin # 101

1) What is efflorescence?

According to Merriam-Webster's Collegiate Dictionary, Tenth Edition, the verb (vi) "to effloresce" means a) "to change to a powder from loss of water of crystallization" and b) "to form or become covered with a powdery crust". Specifically in the plastering industry, the word "efflorescence" accurately describes the manifestation of this process. Efflorescence refers to the crystalline deposit, usually white, that may develop on the surface of integrally colored exterior Portland cement plaster finishes. Efflorescence often occurs during periods of damp, wet and cold weather. Efflorescence may also occur after the fog-coating process due to the additional moisture added to the wall. Efflorescence often occurs right after the completion of the building project, but this is not a definite rule as efflorescence can occur and reoccur at anytime as long as the conditions for its manifestation are not eliminated or reduced from the exterior wall in question.

2) What are the causes of efflorescence?

Efflorescence is the manifestation of a process: water dissolves salts present within a substrate, this salt solution migrates to the substrate's surface, and a salt deposit remains after the water evaporates. Efflorescence is not normally due to application or faulty materials. Rather, it is an unfortunate manifestation of a combination of various factors and events that sometimes take place together at the same time despite human efforts to contain/prevent it.

Two forms of efflorescence have been identified: primary and secondary. They are distinguished by the point in time at which they occur in relation to the curing process. Primary efflorescence occurs during the curing process. Excess water in the wet plaster matrix bleeds to the surface where it eventually evaporates, leaving behind deposits of crystals. Primary efflorescence is often the culprit responsible for the "white bloom" or the "new building bloom" observed in newly constructed buildings with fresh and wet stucco walls. Secondary efflorescence occurs in cured stucco walls that are in cyclical contact with moisture or are subjected to cycles of re-wetting and drying. In this case, the incident moisture penetrates into, and leaches from, the matrix, dissolving soluble salts remained as by-products of the cement hydration process. Upon subsequent drying and wetting cycles, the water can migrate back to the surface and carry with it the dissolved salts.



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Once at the surface, the water will then evaporate and leave behind once again unsightly deposits on the surface of walls. The two forms of efflorescence and how they manifest explain the reason why most efflorescence can occur immediately upon the completion of a building project, while other efflorescence occurs much later on in time.

Efflorescence, in general, can occur on masonry, concrete, brick, and stucco surfaces, among others. Efflorescence, as a problem, has been studied and reported on for more than 100 years. A technical bulletin by T. Rishie, issued by the Division of Building research of the National Research Council, Ottawa, Canada, stated that the following compounds can be found in efflorescence: Sodium Sulfate, Sodium Carbonate, Sodium Silicate, Sodium Bicarbonate, Potassium Sulfate, Calcium Sulfate, Calcium Carbonate, and Magnesium Sulfate. There can also be chlorides, nitrates, and other salts in addition to the listed compounds above.

For the plastering industry in particular, it is a well-accepted fact that the white crystals formed on the surface of the stucco walls, or efflorescence, are often Calcium Carbonates (CaCO_3) crystals. When excess water in the wet plaster matrix bleeds to the surface, it eventually evaporates and leaves behind deposits of calcium hydroxide crystals ($\text{Ca}(\text{OH})_2$) which react with the carbon dioxide (CO_2) in the air to form Calcium Carbonates (CaCO_3). There is a common misconception that efflorescence can only occur at the bottom of the wall, as commonly seen in the case of brick or concrete walls. The truth is this type of efflorescence can occur anywhere on the surface of the stucco walls, and is not limited to certain sections of the walls.

For the process of efflorescence to occur, four things must be present: a) salts, b) physical forces, c) moisture, and d) an opening (no matter how microscopic!).

a) Salts: salts are very common minerals occurring in earthen building materials everywhere. Mixing water in the field can also contain minute quantities of salts. Sand and lime manufactured from various locations can contain different types and quantities of soluble salts despite the manufacturer's effort to eliminate them from their products. Quantities of water-soluble salts as small as a few tenths of one percent are sufficient to cause efflorescence. For the plastering industry, hydrated cement contains a substantial amount of calcium hydroxide as an inevitable by-product of the reaction between cement or lime and water. Another source of soluble salts



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is the soil in contact with basement and retaining walls. Other sources of efflorescence may be seawater exposure or previous attempts at cleaning that did not completely remove contaminants from the surface.

b) Physical Forces: Efflorescence is particularly affected by temperature, humidity, and wind. Physical forces such as wind can force water into a building substrate. The movement of wind over the surface of a building can create pressure differentials that cause the water to move upward. Capillary action can cause water to move upward and laterally within a substrate. Hydrostatic pressure present under below-grade slabs and behind below-grade retaining walls can also cause water and/or water vapor movement. These physical forces, as well as others, can increase the absorption of water that leads to efflorescence.

c) Moisture: Whenever water is present, the potential for efflorescence increases if latent salts exist in the substrate, and/or an external source of salt is present. Repeated cycles of water saturation and evaporation cause salts to migrate from the substrate and efflorescence occurs.

Precipitation, both during and after the construction process, encourages efflorescence. Efflorescence most often appears on buildings after long periods of precipitation during cool weather. During such periods, walls become increasingly saturated from the outside to inside. A building's warm interior can encourage such saturation. Voids in the substrate can also become extremely saturated with water vapor. As the weather clears, the walls begin to dry. Drying, caused by evaporation, occurs from the outside in and from the top down. As this evaporation occurs, water travels down from the top of a wall unit until an obstruction is encountered or when least resistance is found, which explains why efflorescence occurs randomly on the surface.

During freeze-thaw cycles, ice may thaw from the side closest to the interior due to warming and water will be absorbed deep into the substrate, trapped by the outer skin of ice. Upon melting, water migrating back to the surface may be extremely saturated with salts, which are heavily deposited on the surface due to a very slow rate of evaporation.

Condensation is another major source of moisture in the field. Increased thermal resistance of a wall will make the outside components colder. Moisture laden air, moving through the building envelope, is cooled and



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becomes more saturated. When it reaches total saturation at its dew point, water condenses out of the air. This condensation may occur inside the wall cavity or on the exterior wall surface. Therefore, the apparent absence of moisture does not necessarily eliminate the chance of efflorescence.

For all the reasons above, efflorescence sometimes is classified as a seasonal problem. In the summer, even after long rainy periods, moisture evaporates so quickly that comparatively small amounts of salts are brought to the surface. Usually, efflorescence is observed to be more common in the winter when a slower rate of evaporation, combined with cold and damp nights, allows successful migration of salts to the surface to cause efflorescence.

d) Openings: The upward movement of water created by wind-driven rain and pressure differential intrude through various openings in the walls. Cement based products, such as stucco, are naturally porous and thus have numerous capillaries or pathways for water and/or water vapor to move through them. Other obvious pathways include hairline cracks, voids caused by shrinkage, bug holes, and improper building designs.

3) Suggested prevention and remedies

Since many factors influence the formation of efflorescence, it is difficult to predict if and when any will appear. We can only try to control to some degree factors i.e. moisture and salts that contribute to the efflorescence, others i.e. mother nature, for example, are out of our control.

In general, low water absorption is the best insurance against efflorescence. Properly graded aggregates, low water-cement ratios, and proper curing techniques will assure Portland cement products of their maximum density and lowest water absorption contents.

Given the characteristics of construction raw materials, it is virtually impossible and non-practical to eliminate all the soluble salts, construct walls containing no free moisture, or completely eliminate paths of moisture migration. However, steps can be taken to minimize the extent of these important contributing factors to efflorescence. Good workmanship is, for example, one of the most effective means of limiting the potential for efflorescence. Efforts should be taken whenever possible to ensure proper curing (protect the walls from cold temperatures, premature drying, or wrong



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use of admixtures), provide for good drainage (properly designed and installed waterstops, flashing, rain gutters, weepholes, etc.), and to limit water entry as much as possible from all sides and sources of the structure in question.

Once the salt deposits have manifested as efflorescence on the surface, a variety of methods have been suggested for effective removal. In general, most efflorescence can be removed by dry brushing followed by flushing with clean water. The plastering industry oftentimes deals with efflorescence caused by Calcium Carbonate deposits. Calcium Carbonate efflorescence is a more serious problem compared to other types of efflorescence, since it is extremely difficult to remove. It usually appears as a white "bloom" and in worst cases forms a hard white crust.

The removal practice developed in this case has been to saturate the wall as thoroughly as possible with water, wash with a diluted acid, follow immediately with an alkaline wash, then rinse with clean water. The acid recommended is two to five (2-5) parts hydrochloric to one hundred (100) parts water, or twenty parts vinegar to one hundred (100) parts water. The alkaline wash recommended is diluted household ammonia.

Care should be taken to assure that the cleaning solution and technique do not physically damage the surface of the walls. Improper cleaning procedures can significantly change the appearance of the wall and/or contribute to additional efflorescence in the future.

Omega Products International, Inc.
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