Controlling Efflorescence

By Jonathan E. Dongell and Jerry B. Werner

Efflorescence typically manifests itself as a white salt deposit on the surface of a material. Its occurrence may be of little consequence or may be a sign of significant internal distress. It may appear as a white powdery dusting across the surface or as a thick hardened white crust exuding from cracks. It may intensify in wet periods and diminish in dry periods. It may encompass a large majority of the surface or may be confined to small areas of the surface.

This article is an introduction to the topic of efflorescence. Various mechanisms and factors that facilitate the formation of efflorescence and methods for reducing or eliminating its occurrence are introduced. Consideration for the aesthetic ramifications, and structural implications, of the presence of efflorescence is offered. Of course, every structure is unique. Therefore, having a thorough understanding of the facts and conditions for a specific project (mixture design, application, and placement environment) is necessary to determine a preferred course of action.

Mechanism

Assuming there is an evaporation front on at least one surface of the structure, three other factors must be present for efflorescence to form:

1. An available supply of soluble salt-forming components;
2. A sufficient supply of moisture to transport the salt-forming components in solution; and
3. Sufficient permeability, or spacial interconnectivity, within the structure to allow the transport of the salt-forming solution to the surface.

The mechanisms that create efflorescence are evaporation and precipitation. However, other transport mechanism(s) are typically present, allowing the overall process to proceed. These are the driving forces that move moisture into, through, and/or upward to the surface of the structure (a more detailed discussion on these transport mechanisms can be found in "Durability and Exposure Conditions of Cementitious Materials," *Shotcrete* magazine, Spring 2015).

Knowing that the aforementioned factors and mechanisms are necessary for efflorescence to form allows insight into measures that might be taken to reduce or stop its occurrence.

Salt-Forming Components

A primary source of efflorescence-forming material derives from the abundance of calcium hydroxide (CH) that is liberated during the hydration of cement. A majority of this CH is liberated early on, when a structure is young. CH formation

Fig. 1: Infinity edge (water-retaining wall) of swimming pool—2-year-old pool with no specific integral waterproofing or densifier controls

Fig. 2(a and b): Newly placed precast stone pavers

Fig. 3: Aged concrete slab deterioration

is a normal occurrence within hydraulic cement. Over time, ongoing hydration tends to densify the matrix of the structure, which seals shut much of the spacial interconnectivity and confines the CH. Carbonation of the upper surface also tends to densify and seal the surface of the structure over time. Prior to this, however, if sufficient moisture is introduced to the structure, CH can be taken into solution and transported from within the structure to the upper surface, forming efflorescence.

Alkalis (Na, K) may also be present in various components of the mixture design in minor amounts, but significantly more concentrated amounts of alkali (Na, K) are often found to originate from the soil, water, or other materials in contact with the structure.

Supply of Moisture

Efflorescence cannot form without sufficient moisture. It is important, during construction, to incorporate a means of removing or diverting moisture away from the structure whenever possible, allowing water to drain away from the structure quickly and unimpeded. Structures in constant water or saturated soil contact on one side, and an evaporation front on the other, are of primary concern. Such conditions often exist with retaining walls, negative edge or aboveground walls of swimming pools, basements, and tunnels. In this case, measures should be taken that essentially render the structure watertight (water resistant). Constant single-direct transport of water through cementitious materials increases the leaching of the calcium components, or the influx of deleterious ions into the structure from the saturated side, or a combination both, resulting in severe deterioration of the structure over time. Such structures, designed to be viewed on the "evaporation front" or "nega-

Fig. 4: Efflorescence buildup that caused delamination of tiles; more than just an aesthetic problem

Fig. 5: Efflorescence caused by water in transit

tive pressure" side and aesthetic appearance is of primary importance, should incorporate a method of densification or waterproofing of the structure that inhibits any moisture migration (moisture resistant).

Permeability

There are several effective ways to inhibit the mobility of water or moisture through a cementitious structure:

1. Solid waterproof membranes can be placed that inhibit water from entering into the cementitious structure;
2. Pozzolan can be incorporated into the mixture design, which combines with CH to form insoluble compounds and further densify the matrix;
3. Polymers can be incorporated into the mixture design to densify the matrix, or to form a co-matrix with cement;
4. Reducing the water-cement ratio (*w/c*), or the use of a water reducer, can reduce permeability;
5. Integral waterproofing or water-resistive additives can be incorporated into the mixture design;
6. Efflorescence-reducing additive (ERA) can be incorporated into the mixture design;
7. Integral waterproofing or other densifiers can be sprayed on, or applied as a slurry coat, to the surface of the cementitious structure; and
8. Incorporating methods of application, finishing, and curing that optimize consolidation of the matrix and produce a dense upper surface.

Each of these, whether individually or in combination, are effective at reducing or stopping the movement of water or moisture through the structure.

Fig. 6: Example of spray-applied densifier

Efflorescence and Durability

Typically, efflorescence is more of a cosmetic eyesore, and less of a durability concern. The intended finish is merely altered by the unsightly deposition of salts. In such cases, new efflorescence (also known as "bloom") can generally be removed from the structure with little to no damage to the surface. This efflorescence typically consists of many small individual grains or crystals. A bristle brush and water will often remove such efflorescence that is days old. However, these crystalline deposits can build up and carbonate from either CO_2 in air or CO_3 in water. If allowed to form into a hardened dense deposit, removal can be very difficult.

A similar buildup, known as sub-efflorescence, can develop at the interface of the structure surface and surface coatings, tile, or other coverings; or just below the upper finished surface of the structure. If this buildup continues unimpeded, a form of salt attack can cause the deterioration and weakening of the binder system. Ultimately, this may lead to a complete failure of the binder system, causing the debonding of the coating or covering from the substrate, or the delamination or peeling away of the upper surface of the cementitious structure. Structures such as swimming pool vanishing edges, retaining walls, basements, and tanks can be especially vulnerable. Methods of preventing the migration of moisture, as mentioned previously, should be considered in the initial design and construction.

Penetrations (for example, pipes, lights, or joints) or abnormalities (such as holes and cracks) within the structure can create open pathways, allowing the facilitated transport of salt-laden solutions to the surface. Small overlooked holes or gaps during application, or certain cracks (shrinkage, autogenous, or plastic), may often simply be plugged or patched. Structural movement cracks, or cracking due to some internal stress mechanism within the structure, require a more in-depth investigation be undertaken and evaluation as to cause and remedy be determined.

Applying non-breathable paints, sealers, and other coatings onto the surface of a surface experiencing efflorescence is to be avoided. Such coatings, which are less permeable than the cementitious structure, do not allow moisture to escape at the same rate. This impedance of moisture can create a buildup of moisture, pressure, and salts below at the structure/coating interface which, in turn, causes spalling or delamination of the coating and often spalling of the upper layer of the structure as well.

Conclusions

Early on, the appearance of efflorescence may be nothing more than an unsightly appearance on the surface of a structure. However, continued efflorescence growth or new efflorescence that develops on an aged structure may be a sign of a more serious issue. Avoiding the occurrence of efflorescence completely in all environments may not be possible. But with the implementation of certain construction practices, enhanced mixture designs, and/or the inclusion of a waterproofer/ERA/densifier, efflorescence can generally be controlled.

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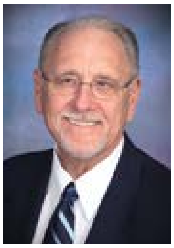

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