

Efflorescence in Concrete

Definitions

“Efflorescence” is a crystalline deposit of salts, usually white, that forms on or near the surface of concrete, masonry and cementitious products. It forms when soluble salts are dissolved by water migrating through the cementitious material and then precipitated at its surface by chemical reaction or by evaporation of the salt solution. Efflorescence usually consists of carbonates of calcium, sodium and potassium originating from the cement, but can also consist of salts from the surrounding environment. Iron oxides from the concrete can give the efflorescence a yellow/brown tint.

“Primary efflorescence”, sometimes called “lime bloom”, develops as a whitish bloom or colour fade during setting and curing of the concrete or mortar. It is related to evaporation of the water used to mix the fresh concrete.

“Secondary efflorescence”, sometimes called “lime weeping” or “salt crystallisation” develops later. It is related largely to water from external sources migrating through the concrete, and may appear as a uniform discoloration or as localised encrustations where water exits the concrete.

“Cryptoflorescence” forms below the surface and is not visible unless the crystal growth is sufficient to cause surface scaling.

This Information Bulletin specifically considers efflorescence in cementitious materials, although some of the features discussed may also apply to stone construction or brickwork. It collectively calls all cementitious materials “concrete” unless referring to a specific type. It describes how various mechanisms and factors influence the formation of efflorescence, and gives general guidelines for minimising efflorescence, but the mechanisms and factors are too numerous and complex for solutions to be presented for specific types of concrete or application. It does not

distinguish between the different types of efflorescence unless relevant because they are formed by the same general mechanisms.

Significance

Efflorescence is particularly noticeable on dark or coloured concrete, where its effects are seen as colour differing in intensity and shade from that intended, varying over the surface and changing with time. In addition, dust and dirt from the surrounding environment can be retained in the salt solutions and trapped in efflorescence that subsequently forms from them, creating dirt streaks that highlight drainage patterns and that may be difficult to remove with normal cleaning methods. Efflorescence may also be stained by iron and other metal ions present in the salt solution. Because efflorescence affects the appearance of the concrete, it is frequently considered a problem on prominent, decorative or architectural surfaces.

Very small quantities of the salts need to be dissolved from hydrated cement paste to produce visible efflorescence, and removal of these amounts does not affect its integrity. Consequently efflorescence usually affects only the appearance of the concrete rather than its mechanical performance or durability. However some types of efflorescence can saponify oil-based paints, and large amounts of cryptoflorescence can cause surface scaling.

Occasionally efflorescence may be a symptom of chemical reactions such as sulphate attack that affects concrete performance. Efflorescence may also indicate leaks in a water-retaining structure or undesirable passage of water through other structures that may lead to moisture problems, corrosion of metal components in the structure and decay of timber components.

This Information Bulletin does not consider

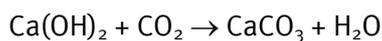
efflorescence caused by chemical attack, or consequences of moisture movement through the structure other than the formation of efflorescence.

Mechanisms Involved in Efflorescence Formation

Chemical Reactions

Efflorescence usually consists of carbonates of calcium, sodium or potassium. These are the product of chemical reactions between atmospheric carbon dioxide and hydroxides of calcium, sodium and potassium from the cement that are dissolved in the pore water.

The reaction that produces calcium carbonate is the same as the reaction known as carbonation, whereby carbon dioxide from the atmosphere with calcium hydroxide:



The reaction may happen in the salt solution in the pores of the concrete, but if evaporation rates are fast enough calcium hydroxide precipitates on the concrete surface and subsequently reacts with carbon dioxide when sufficient moisture becomes available. Calcium carbonate appears as a white haze or bloom diffused over particular areas (usually primary efflorescence) or as a hard white crust (secondary efflorescence). It forms as primary efflorescence when premature drying interrupts cement hydration and the concrete is subsequently wetted. It forms as secondary efflorescence as water from an external source migrates through the concrete and evaporates from its surface. It is almost insoluble in water and can be difficult to remove. It is the cause of most efflorescence problems.

Sodium and potassium carbonates and bicarbonates are soft, white and fluffy. They form by reactions similar to the formation of calcium carbonate when the concrete has been exposed to wetting and slow drying. They are soluble in water and are easily removed.

Calcium sulphate efflorescence may result from the reaction between sulphurous gases (e.g. sulphur dioxide, hydrogen sulphide) and calcium hydroxide dissolved in the pore water. It is insoluble in water. In areas with high levels of sulphurous gases this

reaction may be impossible to avoid.

Other salts that may produce efflorescence include sulphates of sodium, potassium, magnesium, calcium and iron; sodium bicarbonate, sodium silicate and indeed almost any other soluble salt such as chloride and nitrate that is found in concrete or masonry or in its surroundings. Sodium and potassium salts and chloride salts are highly soluble and may be washed off by rain. Very small amounts of insoluble iron oxide and hydroxide cause visible yellow/brown discoloration of the concrete surface, which cannot be washed off.

Physical Processes

Efflorescence involves the transfer of water and dissolved salts through the pores of the concrete to its exposed surface and subsequent evaporation of the salt solution through the processes described below.

Water transport: Liquid water movement through concrete can be driven by capillary suction, hydrostatic pressure, concentration gradients, or gravity. Usually more than one driving force influences the migration of water through concrete: drying of a horizontal surface in the absence of an external moisture source is one of the few situations where capillary forces dominate. In partly dry concrete, water (and the salts dissolved therein) is drawn towards the exposed surface through capillary pores less than 10 microns in diameter in the hardened cement paste. The finer these capillaries are, the stronger the surface tension of the water in them, and consequently the rate of moisture transfer by capillary suction will be faster. In contrast, the rate of water transfer through saturated concrete by pressure, concentration gradient, or gravity (i.e. the “permeability” of the concrete) is reduced by finer capillaries. The finer the capillaries the more easily they are blocked by products of cement hydration or efflorescence. However, concretes with very fine pores may be more prone to efflorescence at early ages if allowed to dry before the pores become blocked. Water migrates through concrete by a combination of vapour and liquid diffusion. The relative significance of these two mechanisms varies with pore size and moisture content. Transport through large pores is predominantly by vapour diffusion until the concrete is almost saturated (internal relative humidity greater than 95%). In capillaries, liquid diffusion is significant at internal relative humidities as low as 45%. Salts

are not transported by vapour diffusion, so large pores do not necessarily increase the risk of efflorescence unless the concrete is almost saturated.

Evaporation: The position of the water surface at which water evaporates and efflorescence forms is called the “evaporation front”. Water movement through capillaries can bring the evaporation front close to the concrete surface, where efflorescence will be highly visible. The free water surface in larger pores tends to be below the surface of the concrete, where efflorescence may be less visible but may cause surface scaling if sufficiently extensive. For a given pore size, the position of the evaporation front depends on the relationship between the driving force and the evaporation rate. With fast evaporation rates, the evaporation front may be below the surface of the concrete. When evaporation is slow, the evaporation front is closer to concrete surface, resulting in more visible efflorescence.

Reaction with carbon dioxide: When concrete is saturated or close to saturated, the dissolved salts react with carbon dioxide at the exposed surface, producing visible efflorescence. When the concrete is partly dry the efflorescence may develop slightly below the concrete surface. Formation of insoluble calcium carbonate below the surface in this way may block pores and reduce subsequent efflorescence. When concrete dries rapidly, calcium hydroxide may precipitate within the pores but lack of water prevents the formation of calcium carbonate. When this concrete is subsequently wetted, the risk of efflorescence is considerable as the calcium hydroxide redissolves, reacts with the carbon dioxide and precipitates as calcium carbonate at the surface.

Salt crystallisation: A salt will only precipitate from solution if the pore water is super saturated. The concentration of a particular salt depends on temperature and on evaporation rate as well as the supply of water and the salt. Concrete pore water is usually saturated with calcium hydroxide because there is a plentiful supply of it from the cement and it is not highly soluble. Hygroscopic salts such as sodium and potassium hydroxides absorb moisture from the air so are unlikely to dry out and appear as efflorescence. When sodium hydroxide reacts with carbon dioxide however, sodium carbonate may appear, unless it is mixed with potassium carbonate, which is hygroscopic. Some salts, such as those of sodium and magnesium, are more

prone to forming efflorescence because of their crystal shape.

Factors Influencing the Formation of Efflorescence

Efflorescence usually results from a combination of factors rather than having a single cause. The following section describes how features of concrete materials, construction practice and service environment influence the chemical reactions and physical processes that cause efflorescence.

Features of the Concrete

Cement is the principle source of soluble salts, containing up to 2%. High alkali cement may increase the risk of efflorescence because the concrete pore solution contains more sodium and potassium hydroxide, which not only increases the amount of salt available but also increases the solubility of carbon dioxide in the pore solution. Rapid hardening cement may also be more prone to efflorescence. White cement is more prone to calcium carbonate efflorescence but its lower alkali content makes it less susceptible to soluble efflorescence, and it contains little iron to cause iron discoloration. High alumina cement does not produce calcium hydroxide when it hydrates so does not cause efflorescence. Cement composition may contribute to iron discoloration of efflorescence. Despite these effects, overall the brand or type of Portland cement has less effect on efflorescence than the cement content of the concrete.

Lime used in masonry mortar is an extra source of calcium hydroxide and may contain up to 0.7% soluble salt. Unhydrated and partly hydrated lime are more soluble and therefore present a greater risk of efflorescence.

Pozzolans used in sufficient quantity consume calcium hydroxide and so reduce efflorescence, providing they do not contain significant amounts of water soluble alkali or sulphate. They also produce a finer pore structure, which will reduce water permeability but may increase capillary suction especially at early ages. Pozzolans are used to replace a proportion of the aggregate fines in products to be autoclaved. Slower reacting pozzolans such as fly ash mitigate against

secondary efflorescence. Ground blast furnace slag, while strictly speaking is not a pozzolan, has the same effect since its hydration doesn't produce calcium hydroxide. High reactivity pozzolans such as metakaolin or microsilica when used at about 15% cement replacement will normally not only provide more strength but also prevent primary efflorescence.

Admixtures may or may not influence efflorescence, depending on their composition, how they are used, and the dominant water transport mechanism. For example, integral water repellents such as stearates and silicones reduce capillary suction but have little effect on water permeability, so they may reduce primary efflorescence caused by premature drying, but will not reduce efflorescence caused by transfer of water under gravity or pressure. On the other hand, water reducing admixtures and integral waterproofers (based on cement and other particulates) used to create a finer pore structure may reduce water permeability, but not capillary suction. Admixtures containing sodium and potassium may increase the risk of soluble efflorescence. Admixtures affect the pore structure of the hardened cement paste, and can make it more or less resistant to movement of water depending on the concrete mix design. Overall, if used to reduce water to cement ratio the improved workability they bring may outweigh any of their disadvantages.

Pigments may introduce extra salts, increasing the risk of efflorescence. Particulate pigments act as fine fillers, reducing water permeability but possibly increasing capillary suction. Pigments generally create a colour contrast which increases the visual effect of efflorescence.

Aggregates that may increase the risk of efflorescence include those contaminated with sea salts and those containing soluble sulphates, such as expanded clay/shale or sulphides which subsequently oxidise such as slag.

Water complying with NZS 3121:1986 should not contain significant amounts of soluble salts or other materials that would promote efflorescence. The soluble salt content of recycled wash water is higher than that of potable water, and is not easy to manage. Recycled wash water is therefore not recommended for use in applications where appearance is critical.

Water content of the fresh concrete will influence

the formation of primary efflorescence because the lower the water content for a given water to cement ratio, the less water there is to migrate to the concrete surface

Water to cement ratio (w/c) determines the shape, size distribution, volume and continuity of pores in the hardened cement paste, which in turn influence the volume and rate of water and salt transfer. The lower the w/c, the finer and less continuous the pores. If they are continuous their reduced diameter will increase capillary suction. Low water to cement ratio may therefore increase primary efflorescence if the concrete is not cured properly. Low water to cement ratios reduce secondary efflorescence because the pores are finer and can be blocked by products of hydration or primary efflorescence, but the efflorescence that does form will tend to be close to the exposed surface. In masonry, efflorescence may develop either on the mortar or on the block, whichever is the more permeable.

A **mix design** that optimises the aggregate grading to allow the minimum binder content for the required workability and hardened concrete performance, and that minimises the water content and water to cement ratio will minimise efflorescence by reducing the capillary suction and the permeability of the concrete.

Variable **concrete quality** resulting from incomplete mixing or inconsistent compaction or curing may cause localised areas of efflorescence.

Mixing

Admixtures, pozzolans and pigments need to be added in the correct sequence to ensure they are fully dispersed in the cement paste. The sequence will depend on type and form of the admixture, pozzolan or pigment, the type of concrete and the mixing process. If the concrete is not properly mixed the pore structure will not be uniform. Colour and efflorescence may then vary over the finished surface.

Compaction and Finishing

Concrete must be adequately compacted to dissipate large voids that reduce its strength. Too much compactive effort can increase the water content and water to cement ratio at formed and unformed surfaces, making them more susceptible to primary and secondary efflorescence.

Overworking an unformed surface during finishing, or floating it while the concrete is bleeding will have the same effect. Permeable formwork liners may help to reduce this effect on formed surfaces by absorbing excess water. It is important therefore that concrete workability, compaction and finishing methods be optimised. For precast products, different materials, mix designs and casting equipment will require different operating procedures.

Curing

Curing aims to retain the mix water in the concrete to ensure that the cement hydrates to provide adequate strength and resistance to moisture transfer. New concrete is relatively porous and permeable, and when water evaporates from its surface it is quickly replaced by mix water from within the concrete, producing a layer of calcium carbonate efflorescence at the surface that can give the concrete a very light colour. This efflorescence blocks surface pores, preventing subsequent ingress of curing water that is needed to replace the evaporated mix water needed to hydrate the cement. Concrete exposed to such premature drying will not gain strength fully and will remain relatively permeable beneath the layer of efflorescence. In new concrete that has been properly cured, water lost by evaporation cannot be replaced by water from deeper within the concrete because the pores are less continuous. Evaporation and formation of efflorescence then takes place below the concrete surface, and the concrete retains a grey colour.

Conditions prior to curing, particularly of dry cast concrete units, are critical. At this stage the concrete is porous and permeable and so both dries and absorbs water quickly, making it highly prone to efflorescence if allowed to dry. Drying is exacerbated by exposure to sun and wind.

Curing temperature is less important than humidity, although cool temperatures will prolong setting, bleeding and hardening and may therefore increase primary efflorescence, particularly at high humidities where water may condense on the concrete surface. Curing at humidity less than 65% RH increases the risk of efflorescence. Exposure to condensation and runoff during curing increases the risk of localised efflorescence spots, patches and runs. Curing at 80-95% humidity is believed to be the optimum to protect against efflorescence, although it may not be as effective for development

of strength and water resistance as curing at higher humidity or in water.

Curing in a carbon dioxide-rich atmosphere (more than 5%) reduces efflorescence by converting calcium hydroxide to calcium carbonate. This blocks the concrete pores at or near the surface, thereby reducing the evaporation of pore water and the ingress of carbon dioxide and producing a uniform surface appearance.

Steam curing can reduce efflorescence, particularly if the concrete contains pozzolan, because the amount of free calcium hydroxide in the hardened cement paste is reduced. Higher temperatures are more effective. The air in steam curing chambers should be kept saturated while concrete units are loaded.

High pressure steam curing (autoclaving) reduces efflorescence because the calcium hydroxide is consumed in reactions with silica minerals or pozzolan during the curing process. Aggregates that contain soluble sulphates, such as some expanded clays and shales, must be avoided because the sulphates can cause severe efflorescence in autoclaved concrete.

Service Environment

Moisture: Rain and run-off is the primary source of moisture in concrete above ground. Groundwater is a common source in basements, retaining walls and foundations. Condensation can also provide enough moisture for efflorescence. Early exposure to an external water source increases efflorescence, whereas curing at constant high humidity without condensation maintains internal moisture at a constant level and minimises the permeability of the hydrated cement paste, thereby reducing efflorescence. Defects that direct water and runoff onto the concrete surface and provide a means of ingress into the concrete will increase efflorescence during service. These include inadequate detailing for moisture control; leaky gutters and downpipes; poorly filled mortar joints; cracks and permeable concrete. Efflorescence caused by such defects will tend to be localised where the water contacts the concrete surface or evaporates from it.

Weather conditions: At lower temperatures evaporation rates are slow, allowing pore solutions to reach the surface of the concrete before evaporating, and calcium hydroxide is more soluble

so the pore solution contains more calcium hydroxide. These features increase visible efflorescence during or immediately after cooler weather. In warmer weather, evaporation rates are faster, and depending on the rate of water migration pore solutions may evaporate beneath the concrete surface where the efflorescence formed will be less visible. Higher wind speeds will increase evaporation rates for given temperatures and humidities, possibly to the extent where evaporation occurs below the concrete surface. Still, cold days therefore present the highest risk for visible efflorescence to be produced, particularly if moisture condenses on the concrete surface. As a result, efflorescence may appear as a seasonal or cyclical effect.

External salt: The development of efflorescence will eventually stop unless there is an external source of soluble salts. This may be from a natural source, e.g. salts in seawater, sea spray or groundwater, or from an industrial source, e.g. chemicals in contact with the concrete, sulphates from industrial fumes or carbon dioxide from fuel burning. Salts may also be sourced from leaks in piped services, or from infill grout or insulation panels in contact with the concrete and a moisture source such as a leak.

Cleaning materials: Caustic soda, washing soda, soda ash, scouring powders, and some detergents used in routine cleaning and maintenance may contribute to efflorescence.

Minimising the Risk of Efflorescence

Efflorescence requires the presence of soluble salts, water, and passage of water through the concrete. It will not occur if just one of these components is eliminated. This is rarely possible, so the best approach is to minimise all three.

The combination of mechanisms and factors influencing efflorescence differs for every combination of concrete age, materials, mix design, application and exposure condition so it is not possible to provide simple rules that will prevent efflorescence in all circumstances. The following guidelines, however, will help to reduce the risk of efflorescence. The general principle is to minimise the pore volume and pore size in the hardened cement paste and to minimise the concrete's exposure to wetting and drying in service.

Concrete Manufacture

Raw materials should contain as little soluble salt as possible. Marine-sourced aggregates should be avoided or washed. Low alkali cement is preferred. Lime should be free from calcium sulphate. Mixing water should be free from significant quantities of salts that may cause efflorescence (see NZS 3121:1986). Seawater should not be used. Keep tools and equipment clean and free from rust and salt.

Concrete permeability should be as low as possible. This means aggregates graded to minimise their voids content, sufficient cementitious binder (possibly containing a pozzolan), low water content and water to cement ratio, effective but not excessive compaction, a dense impermeable surface finish, and curing at appropriate temperature and humidity to ensure adequate cement hydration but without exposing the concrete surface to uneven moisture conditions, drips or condensation. High binder contents may, however, result in higher water contents, which may increase the risk of shrinkage and affect masonry surface finish. In dry-cast products, very low water to cement ratios may reduce primary efflorescence but increase secondary efflorescence unless water content and compaction are optimised to minimise voids. Admixtures may be used to reduce water content and water to cement ratio but should not contain large amounts of highly soluble ions such as sodium, potassium, chloride or sulphate. Integral water repellents may be effective against efflorescence where transport of water is driven by capillary suction, provided their soluble salt content is low and they do not entrain excess air when the concrete is mixed. Masonry mortars should be no stronger or denser than necessary to achieve a satisfactory workability and bond, otherwise drying and efflorescence will develop on the masonry rather than at the joint.

Curing

Concrete should not be allowed to dry between casting and curing, e.g. by exposure to wind or high temperature.

Concrete should be cured for as long as possible in accordance with NZS 3109 using methods appropriate for the application and desired quality of surface finish. Curing by covering with polythene is not recommended where aesthetics are

important because it can produce uneven surface moisture conditions or condensation that result in uneven colouring or efflorescence. Curing at 20°C and a minimum of 80% relative humidity (RH) reduces efflorescence.

Chambers used for curing factory-cast units, including steam curing chambers, should be designed and operated to avoid condensation and run-off. They should have a means of keeping units damp before curing begins, e.g. by fog spray.

Carbon dioxide curing reduces efflorescence but is relatively expensive.

Autoclaving will prevent efflorescence if the concrete contains a reactive silica pozzolan, but aggregates that contain soluble sulphates must be avoided.

Storage after Curing

To minimise efflorescence after the curing stage, uniform temperature and humidity need to be maintained inside the concrete.

Masonry units should be stacked on pallets on a well-drained surface after curing, in transit and while stored on site. The stacked units should be protected with waterproof covers to protect them from rain and rapid drying. Under the covers, air should be able to circulate uniformly between the units as much as possible to prevent localised drying or condensation and runoff.

After curing, precast units should be allowed to dry under cover with all surfaces exposed to good ventilation.

Surface Treatments

Treatment of the surface with a water repellent before it is exposed to moisture will reduce efflorescence and is recommended for coloured concrete and other architectural finishes where colour change or efflorescence would be unacceptable. The surface should be cleaned if necessary at the completion of curing then the surface treatment applied according to the manufacturer's directions.

Effectiveness of the surface treatment will depend on concrete permeability and quality of curing.

Surface treatments for surfaces exposed to

moisture should be permeable to water vapour to allow water in the concrete to evaporate.

Silanes, siloxanes and silicones are suitable water repellents for surfaces exposed to moisture. Siloxanes and silicones are bigger molecules and are more suited to porous materials such as masonry. Alkali siliconates are also available but these may produce potassium carbonate efflorescence and are generally less effective than the silicones.

Film forming treatments must be impermeable to carbon dioxide. Acrylic emulsions and solvent-based solutions are suitable.

On substrates that contain large amounts of soluble salts or are subject to significant ingress of moisture from the opposite surface (e.g. basement walls or floor slabs without a dampproof membrane) vapour permeable surface treatments may cause localised salt concentration and crystallisation beneath the treated surface leading to surface flaking or spalling, particularly in porous or soft masonry. Water resistant and vapour proof polyurethane or epoxy should be used on such surfaces.

Moisture Control in Service

The key to reducing efflorescence is to reduce moisture transfer in and out of the concrete.

Concrete should be protected from wetting and drying during construction. The top of each course of masonry should be covered at the end of each day to protect from rain or dew.

Mortar joints should be finished with a v-shaped or concave tool to compact the exposed mortar surface, ensure a tight bond between the mortar and the masonry unit, and provide some shelter to the mortar. Deteriorated or defective joints should be re-pointed.

Design should include adequate detailing for joint sealants, flashings, waterstops, dampproofing, weepholes, dripformers, copings and sills, and these should be properly installed and maintained. Eaves will protect walls and openings from moisture. Horizontal surfaces such as floors, roofs and parapets must allow water to drain from them. Pavement sub-bases and bedding layers should be well drained, without drainage being blocked by perimeter strips or mortared-in features.

Exterior walls should be designed to equalise internal and external vapour pressures, or be lined with vapour barriers, or the interior surfaces coated with paint that is impermeable to water vapour. Cavity walls should be designed to minimise condensation.

Landscaping features that would expose the concrete to wetting and drying in service, such as water features or gardens that need watering, should be avoided.

Cracked or permeable concrete and damaged moisture control details and appurtenances should be repaired.

Removal

To identify an appropriate means of removing efflorescence and preventing its recurrence its cause must be established. For example, concrete may need to be isolated from soil or groundwater to prevent the crystallisation of sulphate salts, or a leak may need to be repaired. The composition of the efflorescence should be identified if the concrete is in contact with an external source of salts, because it may indicate chemical reactions that affect the concrete's durability. The primary example of this is sodium sulphate, which can attack hydrated cement paste, and can cause surface scaling as its crystal form changes with

changes in temperature and humidity.

Primary Efflorescence

Primary efflorescence may eventually be dissolved from exposed surfaces by rainwater, which is slightly acidic. If it is extensive or needs to be removed before applying a sealer it may be able to be removed with water shortly after it forms, or by treating with dilute acid as described below.

Secondary Efflorescence

Fresh deposits of water-soluble efflorescence such as alkali sulphate and calcium sulphate can be removed with a stiff bristle brush. Remove the loosened material from the concrete and surrounding surfaces with a vacuum cleaner. Repeat dry brushing as deposits appear is likely to be the most effective treatment. Wet brushing may work if dry brushing is ineffective, but washing with water may result in salt redepositing when the water evaporates.

Efflorescence that is not soluble in water, such as calcium carbonate, may be removed by high pressure water jetting, possibly adding fine sand to the stream. Light sand blasting may also be effective but may alter the surface texture so the whole surface needs to be treated. Dilute acid is effective, especially on calcium carbonate, but will alter the surface colour and texture.



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Hydrochloric (muriatic) acid diluted 1 part acid to at least 10 parts water is suitable for general concrete cleaning, provided it does not contact any metal components. For coloured concrete a 1:50 solution should be used to avoid excess etching that may expose the aggregate and change the concrete's surface colour and texture. The concrete is wetted with water, the acid is then brushed in and allowed to react for up to five minutes, and rinsed off with plenty of clean

water (check the wash water with pH indicator paper to make sure all acid is removed). Surfaces to be painted should be neutralised by washing with 10% ammonia or potassium hydroxide solutions, or allowed to weather for at least a month before painting. Treatment of a trial area is recommended before treating the entire surface. Only small areas should be treated at a time. Multiple washings with a higher dilution of acid are less likely to etch the surface than one washing with a higher acid concentration. Acetic acid, citric acid, phosphoric acid and acid based proprietary cleaners are also suitable.

If the composition of the efflorescence is unknown, washing with acid as for insoluble efflorescence is usually effective, although it may be preferable to first try dry- or wet-brushing.

Testing

The following tests provide a means of comparing the efflorescence potential of different concretes. They cannot be specified or used as acceptance tests, because the formation of efflorescence on concrete in service will be determined by the conditions it is exposed to rather than the results of a laboratory test, and because the history of samples prior to test cannot be controlled and will influence the test results. Nevertheless, the relative performance of similar materials in laboratory testing may be maintained in service, so the tests may be useful for manufacturers wishing to improve their products.

- AS/NZS 4456.6 (based on ASTM C67);
- Measurement of salt content of run-off from laboratory samples that have been exposed to dripping water under controlled conditions;
- Measurement of concrete sorptivity;

- Measurement of concrete permeability;
- Measurement of concrete absorption;
- Measurement of concrete density.

These tests are sensitive to the age of the concrete and to the evaporation rate (temperature, humidity and air flow) so are best suited for comparing materials of the same age at the same time or under tightly controlled laboratory conditions. Measurement of density and absorption are the least favoured methods because they do not account for resistance to water migration, which is a major factor in efflorescence formation.

Summary

Efflorescence results from the interactions of water migrating through the concrete and subsequently evaporating from its surface, salts within the water, and carbon dioxide and other atmospheric gases. It may create an undesirable appearance but rarely affects the mechanical properties or durability of the concrete.

The formation of efflorescence is influenced by many interacting factors, some of which may conflict. It can be reduced or even prevented by controlling water ingress, water migration through the concrete and evaporation during manufacture, construction and in the completed concrete structure or product, and by minimising its exposure to sources of soluble salts. The optimum solution will vary between different concrete materials, products and manufacturing processes, but overall the key is to ensure that the concrete and concrete surface are as impermeable as possible by appropriate mix design, finishing and curing, and by design detailing and maintenance that minimises the exposure of the finished structure to water ingress.

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