AN EXPLANATION OF THE FORMATION, PREVENTION AND TREATMENT OF EFFLORESCENCE ON CONCRETE MASONRY SEGMENTAL PAVERS

The following explanation and opinions are supplied to give general information on the phenomenon of efflorescence.

Professional advise must be obtained before attempting to identify or treat any concrete units that may exhibit signs of efflorescence.

INTRODUCTION.

The phenomenon of efflorescence on concrete surfaces is familiar to anyone involved in some way or another in the working or use of concrete and concrete products.

The white deposits which, under certain conditions can stubbornly remain where they form for a very long period of time, impair the appearance not only of concrete paving units, but many other exposed concrete surfaces.

It is a particular nuisance where attempts have been made to render the concrete more attractive by colouring it with inorganic pigments.

Although it is now generally acknowledged that the addition of such pigments can neither promote nor hinder the appearance of efflorescence, the whitish deposit is naturally much more striking and upsetting to the eye on coloured surfaces than it is on uncoloured grey concrete.

Although a great deal of work has been done investigating the phenomenon of efflorescence, there is still no effective additive that can be used by concrete manufacturers to prevent the formation of efflorescence on finished concrete products.

Agreement has however been reached to a large extent by researchers world wide, on the mechanism behind the formation of efflorescence, which at least makes it possible to take certain measures to restrict its formation to a large extent.

The following section will therefore deal with the mechanism behind its formation and explain the precautions that can be taken as a result.

THE FORMATION OF EFFLORESCENCE.

Analysis of the white deposits on the surface of concrete indicates that in the majority of cases, it consists predominantly of calcium carbonate ($CaCO_3$), which is insoluble in water.

Only very rarely will the deposits be of other salts, as these are usually soluble in water, and are therefore washed off very rapidly by rain etc.

The presence of this calcium carbonate can be explained as follows:

1. Whilst the concrete is hardening (that is, during the reaction of the cement with the mixing water) not only are familiar calcium hydrosilicates formed but, at the same time, considerable amounts of calcium hydroxide ($Ca(OH)_2$) are emitted.

2. This unavoidable by-product of the hydration process of cement, being a relatively soluble substance, dissolves in the excess water that is always present in wet-cast concrete.

3. During the drying or curing phase of concrete, this excess water mixture, which is actually a calcium hydroxide solution, migrates to the surface of the paving or concrete unit, where it evaporates.

However, since only the water can evaporate, the entrained calcium hydroxide remains behind on the surface of the concrete unit.

4. Here, there is a very rapid carbonation of the hydroxide in which the latter is converted through the absorption of carbon dioxide (CO_2) from the atmosphere into water-insoluble calcium carbonate, which we find again in the chemical analysis of this efflorescence: $Ca(OH)_2 + CO_2 = CaCO_3 + H_20$

5. This kind of efflorescence, which is actually formed during the curing of concrete, is known as, "primary efflorescence" and usually covers the concrete unit in a uniform and closed layer. In extreme cases it may appear to alter the colouring of the affected concrete unit.

6. As we know, the curing of concrete occurs over a long period extending over several weeks and longer.

As a result of this curing process, fresh calcium hydroxide is constantly being released inside the concrete unit during this period.

Hence, even if primary efflorescence can be avoided in the initial concrete mix, renewed penetration of water, (ie a wet / dry cycle) into the concrete unit can and will dissolve this calcium hydroxide, and again transport it to the surface in the same way as described above.

7. This type of efflorescence, which is frequently caused by rain or condensation on the concrete unit, is known as "secondary efflorescence". It usually differs from primary efflorescence in that it occurs very locally, and does not manifest itself evenly over the concrete unit.

THE PREVENTION OF EFFLORESCENCE.

As yet, there is no concrete additive known to prevent the calcium hydroxide from migrating to the surface of concrete units.

Thus, as there is no direct cure, the only action that can be taken, is to consider the direct causes of primary and secondary efflorescence, and act accordingly to limit the effect.

The more excess water there is in the mix that may be allowed to migrate to the surface after the initial concrete set, the greater the risk of primary efflorescence.

This makes it necessary to have the mix as dry as possible at the time of pouring.

Naturally, this may conflict with demands placed on the workability of the concrete but attempts should be made under all circumstances to keep to the lower limits when adding water.

A second method of preventing primary efflorescence is to try and make the chemical reaction of carbonisation, as described earlier, take place below the surface of the concrete unit in question.

In this way, the calcium hydroxide is converted into an insoluble state on the inside of the unit, and thus forms a barrier, preventing or limiting further deposition of the calcium hydroxide on the unit's surface.

In practice, this can only be achieved by slowing down the curing or drying process, such that it is made easier for the carbon dioxide in the air to penetrate into the concrete unit where it can react with the dissolved calcium hydroxide into a insoluble carbonate before it reaches the surface.

A second preventive measure is to ensure that the concrete units in question dry out as slowly as possible.

This is best achieved by making sure that the humidity of the surrounding air is as high as possible.

Closed curing chambers are particularly suitable for this.

However, it is often sufficient enough simply to cover the concrete elements with plastic sheeting allowing the humidity that is generated during the hydration / curing process to be captured and increased rapidly during the first few days of curing.

It is however, important when adopting this process, to avoid moisture condensation on the paving units.

Contamination of the concrete in question by this condensate can lead to severe secondary efflorescence.

Efflorescence of this kind also frequently occurs when freshly made concrete units are stacked too close together and evaporating excess water condenses on the face of the units.

For this reason, wherever possible, concrete paving units should be stacked with a space between them so that evaporating water can escape freely between the slabs.

Should it not be possible to slow down the drying in this way, the products should be kept inside the building or under protection until completely dry.

In other words, place them outdoors as late as possible after the initial curing process has occurred.

Freshly manufactured concrete units can dry out very quickly in the open air due to direct sunshine and/or wind passing over their surfaces, and this may also lead to severe efflorescence on the unit surfaces.

Even when stored in a building, draughts should therefore be prevented in an effort to minimise the likelihood of this occurring.

There is very little that can be done to prevent secondary efflorescence which occurs long after the material has been made.

It is important therefore to choose a method of manufacture, such as wet-cast pouring to achieve good compaction of the material utilising selected and suitably graded aggregates with good consistency. In this way a denser concrete unit is guaranteed which will prove more difficult to penetrate by moisture and thus limit the potential to develop efflorescence long term.

ELIMINATING EFFLORESCENCE.

By closely observing the precautions mentioned above, it is generally possible to prevent, to a large extent, the occurrence of efflorescence.

In some cases, where this has not been succeeded despite taking the necessary care, or where severe secondary efflorescence has appeared over the course of time, it may be possible to remove lime deposits.

In situations where paving units have already been laid, this can be done by lightly shotblasting or sandblasting the units insitu.

In this way a thin layer of concrete from the surface can be removed to expose the clean uncontaminated concrete below the surface.

This process is however very difficult to control and not generally recommended as it does in fact erode the surface of the concrete, which in the case of a non-exposed aggregate type product, would be unacceptable.

An alternate technique, but again very difficult to control, is to wash the surface of the pavement in question with a dilute mixture of hydrochloric acid.

The process here is firstly to thoroughly wet the paving area in question with clear fresh water and ensure that it is totally saturated.

In this way the pores of the concrete fill up with water which prevents the mild acid solution from penetrating too deeply into the stone and causing additional efflorescence in the form of water-soluble salts.

Then apply a dilute solution of water to hydrochloric acid (15 parts water to 1 part acid) to the paving surface preferably brushing at the same time.

After being allowed to take effect for approximately 10 seconds, rinse off the acid wash with plenty of clear fresh water.

With this acid treatment, just as with sandblasting or shotblasting, a thin layer of the concrete paving surface is removed, thus appearance of the paving in question can be changed if not carefully controlled.

It must be pointed out that the inorganic pigments suitable for the colouring of concrete will survive the effects of a light controlled acid wash without damage, although a slightly darkened appearance of the colour may eventuate.

This change in colour is more likely to be as a result of the removal of the light (white) efflorescence on the surface, rather than a change of the inorganic pigment.

However, in most cases, even if no attempt is made to remove the efflorescence, it is more than likely that it will disperse after a period of time in line with the chemical reaction:

$CaCO_3 + CO_2 + H_20 = Ca(HCO_3)_2$

In other words, soluble calcium hydrogen carbonate is gradually formed from the insoluble calcium carbonate under the continued influence of carbon dioxide and water, and this calcium hydrogen carbonate is easily washed away with rainwater.

Depending on weather conditions, this process may however take up to two years to complete.

It must be noted that efflorescence may also be attributed to the material on which the concrete units are in contact with, particularly in the case of the concrete segmental paving.

Concrete paving is usually laid on a bedding of sand, and naturally occurring salts within the bedding sand can and will, through the action of capillarity migrate to the surface of the paving and be deposited on the face of the unit.

Additionally, when paving units are laid on a bed of concrete mortar, calcium hydroxide emitted from the curing mortar bed can migrate through the paving surface.

The process and types of efflorescence are exactly as detailed previously and if required, will need treating as described.

SUMMARY.

Efflorescence can be described as a “passing nuisance”. Invariably , these unsightly deposits will be blamed on the concrete manufacturer, unjustifiably in most cases because this so-called efflorescence is a natural phenomenon.

Efflorescence should be seen for what it is, a sign of life from a product made of natural, raw materials.