Ponencia 153 - B
AVOIDING EFFLORESCENCE ON EXTERNAL TILING THROUGH DESIGN AND CONSTRUCTION PRINCIPLES.

Colin Cass. B. Ed., Dip. T. (Technical)

Sydney Institute of TAFE, Sydney, Australia. colin@cass.org

"In time, and with water, everything changes."
- Leonardo da Vinci

ABSTRACT
It is an unfortunate outcome for finished tile work when an external façade or tiled pavement on a project becomes disfigured by a build up of efflorescence stains.

These ugly disfigurements are usually a calcium based deposit arising from soluble salts within the bedding mortar and elsewhere in the tiling system that become insoluble when they react with the atmosphere.

This paper concentrates on the most common type of soluble salt (calcium hydroxide); where it comes from, and how to avoid it presenting as a calcium build up on the surface of external tiling. In simple terms the paper sets out the two main principles for avoiding efflorescence staining: “Limiting water ingress” and “Controlling water egress”.

A series of photographs show how the flow of subterranean water can be directed to pre designed outlets so no efflorescence appears on the face of the tiling. It also outlines how water ingress can be minimised through the prudent use of sealers and waterproofing membranes. Photos from projects where efflorescence staining has successfully been avoided are also included.

This paper aims to have architects, designers, builders, and tile installers, understand their options in cooperating to ensure efflorescence does not form on external tiling.

INTRODUCTION
The manufacturing, transport and installation of a ceramic tiling system requires significant capital investment, technical expertise, design and installation skill. The whole process from raw materials to finished installed product also has a significant environmental output. It is therefore incumbent on those involved in the delivery of finished tile systems to ensure their work results in a long lasting, low maintenance and serviceable finish. After all, these are key advantages ceramic tiles have over competing surfaces. It is a loss to the tile industry generally and to the building owners in particular when what could be a fine example of finished tile work is disfigured by ugly white stains when soluble materials from within the system harden on the surface. Yet this calcification, generally, if not accurately referred to as efflorescence, can usually be avoided if minor alterations are made in design, workmanship and materials use.

This paper is not meant to be a scientific exploration of the chemistry behind the formation of various types of efflorescence; rather it aims to be an easy to understand but technically valid guide for tiling system designers, builders and tile installers so they can avoid efflorescence forming on the surface of finished external tile claddings and floors. It also details procedures that can see existing efflorescence removed with the least chance of it returning. First it is helpful to understand a little about how and why efflorescence forms.

WHAT IS EFFLORESCENCE AND HOW DOES IT FORM?
Definition from chemistry- Efflorescence: the process of losing water of hydration from a hydrate;
or,
Definition from construction- Efflorescence: an accumulation of calcium crystals and/or salts that disfigures the top, edges or underside of masonry structures.

Without water efflorescence cannot form, this is why the problem is almost only found on external tiles and bricks exposed to rain. However, salts that cause efflorescence can also come from moisture leaching into the tiling system from elsewhere, such as ground water, or planter boxes, from the mixing water or the aggregate. Occasionally a small amount can emanate from the tiles themselves. Efflorescence is regarded having two main types, primary and secondary. Primary efflorescence occurs as part of the hydration process of cement setting and usually appears as a bloom on the surface of newly finished construction work. It is usually easily removed by brushing, or with a weak 5 part water to 1 part phosphoric acid wash. It tends not to return.

Secondary efflorescence only occurs when continuous or cyclical saturation of a cementitious material allows free lime or other salts within the masonry to be dissolved and to migrate to the surface. This is sometimes referred to as leaching too. Secondary efflorescence can be very difficult to stop, and may continue to leach out of the masonry for many years. This paper addresses this secondary efflorescence. (**Photo 1**)

1. An example secondary efflorescence with calcium carbonate forming on the surface of external stair tiling.

2. Efflorescence forming where moisture below the impervious tiles rises through cracks in the grout

Efflorescence relating to tile work:
Most tiles installed around the world are now laid using adhesive. Very often the adhesive is applied to a cementitious layer of mortar (render or screed) used to make the background flat enough for accurate tile installation. The substrates behind this intervening layer are again usually masonry or concrete. This means the usual systems for laying tiles provide a generous amount of porous cementitious material. These cementitious materials contain large volumes of a soluble salt, calcium hydroxide (up to 20% of the weight of the cement content)[1] The calcium hydroxide is formed during the manufacture and hydration of the cement used in the substrate or screed. It is this calcium hydroxide that delivers the basic ingredient for the formation of calcium carbonate material on the surface of the tile work when the exposure conditions are conducive.

That is, the soluble salt calcium hydroxide (Ca(OH)2) can be carried to the surface of the tile work by regular but usually intermittent water where it reacts with carbon dioxide (CO2) from the atmosphere to form calcium carbonate (CaCO3) when the water evaporates. Calcium hydroxide is not the only soluble salt that causes efflorescence staining, but it is the most abundant soluble salt found in the efflorescence that forms on tiling.

Movement of water through masonry materials:
Any ingress of rain water to a building system will obviously follow the path of gravity, finding its way to the lowest point or exit. In walls it may simply exit at the face, or travel down to the floor. If a flooring substrate has a gradient down to an area where there is no outlet, then this area of the tiling screed will become saturated and be the reservoir for this, now salt laden water. This salt solution will then rise to the surface of the tiling because it is attracted to the warmer or dryer atmospheric conditions through a process of equilibration. As the water evaporates a calcium build up will remain. If the tiled area is exposed to sunlight or warm conditions it will act like a layer of plastic sheeting over an area of damp, but seemingly dry concrete. Condensation will form on the undersides of the tiles and the natural movement of the moisture upwards through the tile joints will see efflorescence crystal growth along the tile joints and onto the surface of the tiles. (**Photo 2**.)

[1] http://www.first-materials.com/prodsvcs/trublnin.html

3. Concrete treated with a nanotechnology based sealer repels water. Efficacy with friable mortars is not yet known.[2]

4. The application of a penetrating sealer prevents or minimises water penetration through the tiles and grout

HOW TO PREVENT EFFLORESCENCE

It is unlikely that all primary efflorescence can be completely eliminated; this is why it is often regarded as an aesthetic problem and treated as a building maintenance issue. However, secondary efflorescence can be virtually eliminated through good design and good construction practice.

The two key principals for minimising efflorescence are to:

1 Minimise the entry of water into the tiling system;

2 Direct water that penetrates the tiling system to a designed outlet.

PAVING: If efflorescence is to be minimised, it is necessary to have a positive gradient to designated outlets in the substrate before any membrane and overlaying screed is applied. This is because water that finds its way into the mortar will pond on the membrane surface if there is incorrect gradient and encourage the formation of efflorescence above the area of ponding.

1) **How to minimise the entry of water into the tile screed**. This can be achieved by three means;

a) Treating the cured tile screed with a liquid waterproofing penetrant that is compatible with both the membrane and the tile adhesive being used. Such penetrants are usually a type of methyl silicate or nano sized mortar additive. (**Photo 3**)

or

b) Applying a waterproofing membrane both under and over the screed;

and/or

c) Sealing the surface of the tiles and grout joints with a penetrating water repellent. (**Photo 4**)

1a) **The advantages** of a) treating the cured tile screed with a penetrant are that;

- Water is prevented from entering the tile bed (unless it cracks).
- The penetrant is at the underside of the tiles where it is protected from the environment.
- The application of a liquid penetrant is quicker and less costly than a secondary membrane system (detailed below).

The disadvantages of a) treating the cured tile screed with a penetrant are that;

- The system is rigid. If the screed cracks water will enter the screed and will be re-drawn to the surface by capillary and thermal action. This will result in the formation of efflorescence near the cracks.
- The porous nature of most tiling screeds limits the effectiveness of penetrating methyl silicate type products.

[2] Nanovations 3001 additive http://www.nanovations.com.au/Concrete.htm

- The process will slow up the tiling process due to the curing time required for the screed and the penetrant.
- Wet bed fixing of tiles cannot be undertaken with this method.

1b) **The advantages** of b) applying a waterproofing membrane both under & over the screed; See **figure 1**.

- Excludes moisture from the tile screed.
- Better ability to withstand movement and any cracking of the screed.

The disadvantages of b) applying a secondary membrane over the cured screed;

- Double membrane means about double the cost of waterproofing.
- The process will slow up the tiling process because the screed has to be sufficiently dry to avoid failure of the second membrane.
- Essential bond breaker / fillet joints in the secondary membrane at the wall/floor junction may interfere with the tiling process. Tiling may have to finish 5mm or more from walls.
- Some of the chemicals used may not be compatible with the tile adhesive and the membrane. Note: because of tile adhesive bonding issues, solvent based polyurethane membranes are NOT to be used as a secondary membrane system.
- Wet bed fixing of tiles cannot be used with this method.

NOTE: Having only a membrane on top of the screed is acceptable, and it reduces the cost and some of the time delay, however, detailing the bond breaker or fillet joints is critical and difficult because it must occur at the junction of walls and floors and be contained within the thickness of the tile.

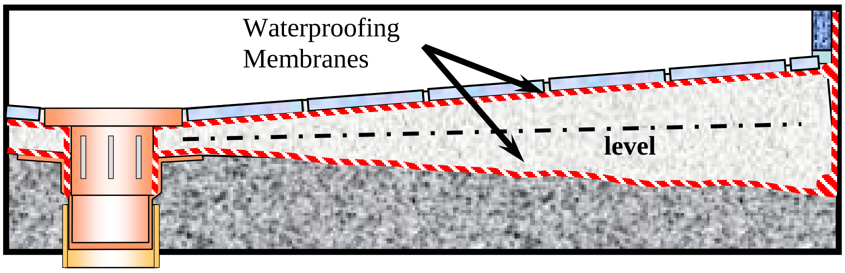

Figure 1. Waterproofing membrane on top of screed as well as on the substrate.

1c) **The advantages** of c) sealing the surface of the tiles and grout joints with a water repellent;

- Does not delay the tiling process.
- It is possible to wet bed tiles.
- Makes the tile and grout more stain resistant.

The disadvantages of c) sealing the surface of the tiles and grout joints with a water repellent;

- Minor cracks in the grouting will lead to water penetration.
- Water will bead on the surface which may lessen the slip resistance of the finished surface.
- The surface sealer will require periodic re-application.

This system should not be relied upon as the sole method of minimizing efflorescence as it is likely the water will eventually enter through small cracks in the system.

2 Allow water that penetrates the screed to drain;

- This method of efflorescence prevention relies on any water that penetrates the tile screed draining to a designated outlet. Therefore it is imperative that there be positive falls in the substrate before any waterproofing membrane or overlaying screed is applied. See **figures 2 and 3**.

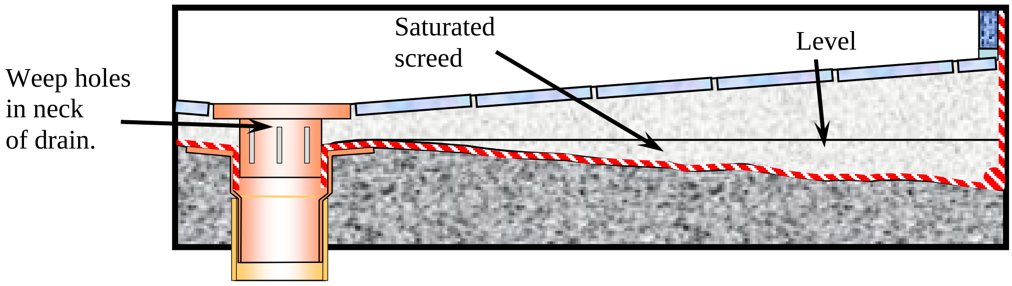

Figure 2. Membrane over negative gradient in substrate. To be avoided as efflorescence will almost certainly occur.

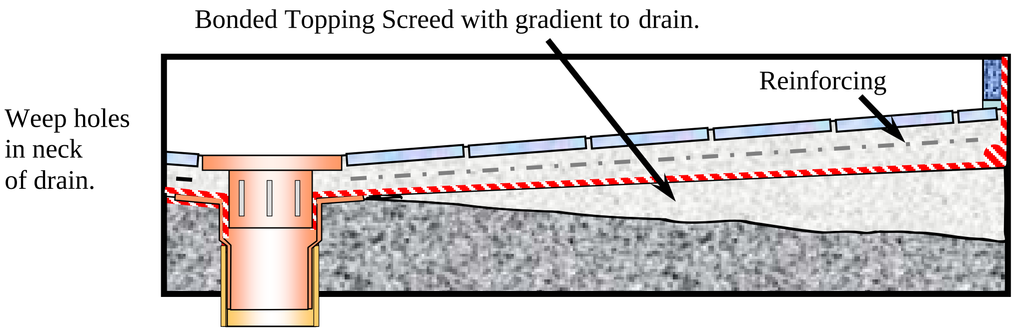

Figure 3. Membrane acts as a slip sheet therefore a reinforced screed is required. Efflorescence can still rise from the bedding mortar.

The key ways to dispose of (salt laden) water that has found its way into the mortar is to allow it to escape at the neck of any drainage grate or sump. In other words, do not allow the grate to be sealed to the membrane unless there are weep holes in the side of the grate. See **photo 5**. Also, ensure the capacity of the drain is sufficient to allow easy evacuation of surface water, or else back up water will re-enter the bedding system through the weep holes. Be aware that the diameter of the drain may decrease as salts build up in the pipe.

Do not allow substrate falls to go to a free edge unless the salt laden water is collected by a gutter, or unless the area is not going to be adversely affected by the appearance of efflorescence. (eg. a garden bed) **Photo 6**.

A “sealed in” “water stop” angle should be fitted at free edges and behind the nosing at the top of stairs, ensuring a positive fall in the substrate from the water stop to the drainage outlet. The vertical leg of the water-stop angle should finish flush with the surface of the tiling. (Waterstop angles are usually 90 degree extrusions of metal or plastic sealed to the surface or incorporated into the waterproofing system.) See **figure 4**. This will prevent water that enters the bedding on the deck from escaping over the free edge. Often on stairs, it is advisable to have a surface gutter run down the side of the stairs with a drainage cell beneath it, this way the only efflorescence that can form on the risers and treads is from the limited amount of calcium hydroxide available in the stair tiling. **Photo 7**.

Waterstop angle detail.

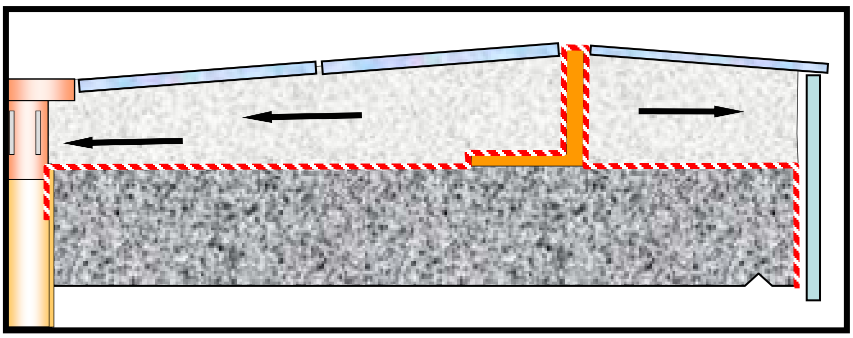

Figure 4. Angles can stop the bulk of water in the screed of a deck from exiting over a free edge or down a flight of stairs.

As subterranean water will take the easiest path, in large areas, or where large volumes of subterranean water are expected, strips of drainage cell material can be placed on the waterproofing, beneath the screed to provide for easy movement of the water to the designated outlet. **Photo 8**.

If efflorescence is thought likely to be a problem, it is good practice to combine the relevant aspects of principles 1 and 2 above.

	
5. When the drain is open at the neck, and there is a gradient in the substrate to the drain, the efflorescence forms down the drain pipe and not on the tiles.	6. Where the gradient in the substrate leads to a free edge, efflorescence will form on the riser. To avoid this problem have a "waterstop" angle sealed to the floor at the edge or 1 tile in from the edge, and have the substrate behind the angle graded to a drain.

	
7. A gutter down the left edge of the stairs which contains drainage cell material under the tile, will see water from the landing take that pathway and stop it from emerging through the stair risers.	**8**. Drainage cell fabric under the tiling screed makes it easy to direct subterranean water to designated outlets.

CLADDING: Most of the above procedures set out for paving can apply equally to cladding, however, the bond strength of multi-layer systems must be satisfactory for the mass of the tiles being used, and it is recommended that tiling above about 3 metres should be on an engineered system. The most important single factor for preventing efflorescence in wall tiling is the prevention of water ingress usually through a capping system at the top and exposed edges.

MOVEMENT JOINTS: Limiting water ingress into both wall and floor tiling systems through properly designed and installed movement control joints is essential. This will usually involve surface preparation, priming, the use of joint backing materials, the provision of recommended width to depth ratios for the sealant, and the use of suitable exterior grade sealants. A maintenance schedule for the sealant joints should also be provided.

HOW TO REMOVE EFFLORESCENCE

If efflorescence has formed, and it has to be removed, the following procedures are recommended.

- Physically scrape off any build up by mechanical means. If wire brushes are used be sure they have stainless steel bristles.
- Sweep up, bag and dispose of residues.
- Check that acids will not negatively affect the tiles. If they will, use a chelating cleaner (below).
- Wash the surface with phosphoric acid mixed with 5 parts water, repeat washing until the stains have dissolved. More aggressive acids such as hydrochloric/muriatic can be used with great care.
- Flush the surface liberally with water, and neutralise with a mild ammonia and water solution or other neutraliser.
- Allow to dry and check results, repeat acid washing if necessary.
- After cleaning try to establish where water may be entering the mortar behind the tiling, and implement water ingress reduction methods set out in 1. above. Generally the minimum treatment required after cleaning is sealing with a penetrating hydrophobic sealer.

Chelating cleaners, such as those containing ethylenediamine tetra acetic acid (EDTA), apart from not being very aggressive when treating efflorescence on calcareous stone, such as limestone and marble, can have the added benefit of rendering soluble salts insoluble, thereby limiting the calcium hydroxide available for future release. However, in cases of severe efflorescence, chelating cleaners will not render sufficient soluble salts insoluble to make a great difference.

The golden rule for all sealers and cleaning agents is to try them on a small and inconspicuous area first.

It has been reported that the incorporation of Class-F fly ash or metakaolin in concrete mixes can lock up significant amounts of calcium hydroxide, however, the author could find no test results stating this method was able to reduce efflorescence in friable cement mortars such as those used for floor tiling.

SUMMARY

The main form of efflorescence that disfigures tile work, that from calcium hydroxide, can be stopped from causing significant and recurring disfigurement if some easily achievable design rules are followed. They are "limit water ingress" and "control water egress". There are a range of options by which water ingress to the tiling system can be minimised, including binding, waterproofing and sealing. Without water the efflorescence cannot form. Then, in the likely event of some water managing to eventually penetrate the tiling system, it is crucial that such water be directed to an outlet so any efflorescence that does form, will be in a predetermined inconspicuous location. This directing of the subterranean water is achieved through gradients in the substrate, subterranean flow paths through drainage cells in the bedding, and by the incorporation of waterstop angles at or near free edges. If these rules are followed, efflorescence can be all but eliminated from the face of finished exterior tiling.

Colin Cass
Tiling Consultant and Head Teacher of Tiling
Sydney Institute of TAFE, Sydney, Australia
e-mail: colin@cass.org

References and bibliography:

- "Efflorescence in concrete" 2006 Cement & Concrete Association of New Zealand, Level 6, 142 Featherston Street, PO Box 448, Wellington, http://www.cca.org.nz/shop/downloads/IB44.pdf
- Eric Doehne, Conservation Scientist, Getty Conservation Institute. Talk presented to Australian Institute of Architects. Sydney. 2006 http://www.getty.edu/conservation/science/salt/index.html
- http://www.globalsafe.com.au/What%20is%20Efflorescence.pdf
- NSW Master Builders Guide to External Waterproofing: Balcony Decks 2007 enquiries@mbansw.asn.au
- Advanced Cement Technologies, LLC. PO B0X 4966 Blaine, Washington USA
- http://www.metakaolin.com/
- "Out Damn Spot" Peter Hartog, Discovering Stone Magazine. Australian Tile Publications Issue 4. 2004
- Nanovations Pty Ltd, 7 Miami Place Frenchs Forest NSW 2086 Australia
- http://www.nanovations.com.au/Concrete.htm
- Lea's Chemistry of Cement 7 Concrete: Elsevier Butterworth-Heinemann 4th Edition various authors. 2004