

CASE STUDY OF EFFLORESCENCE ON A FAÇADE. HOW CAN IT BE AVOIDED?

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1. INTRODUCTION

The aim of this presentation is the comprehensive analysis of the construction process of a mixed adhered-anchored façade cladding which has developed a pathology involving the appearance of visible white stains on the outside of the building. The case study includes, on the one hand, an examination of the cladding sequence used for the façade and, on the other, an analysis of all the materials involved in the building process. Its final purpose is to determine the causes that led to the pathology and to establish guidelines to avoid the appearance of this defect on façades of similar characteristics in the future.

In recent years there has been a significant increase in the number of façade cladding systems that include ceramic materials. The improvements in the quality of the materials and the technological development of different systems have driven this surge in the ceramic sector.

Owing to this array of building options, it is becoming more and more complicated to establish classifications for different types of ceramic façades; however, broadly speaking, depending on how the installation background and tiles are joined together, we can differentiate three main groups:

1.1. Direct bonding of the ceramic tiles to the background by an adhesive:

The adhesives used in this technique are based on modified cementitious compositions with high proportions of chemically reactive resins. This ensures perfect and long-lasting adhesion, offering the advantages of a cement-like composition (mechanical effect) but without the disadvantages of a pure resin, which is more sensitive to the weather conditions that façades are exposed to, especially variations in temperature and humidity. On very tall façades or for large-sized formats their use is not recommended.

1.2. Mechanical fastening of the ceramic tiles to the background:

Here we can include the group of cladding systems commonly known as ventilated façades. There are numerous systems, with different configurations. Generally speaking, they may be said to consist of two layers between which a cavity is created, through which air freely circulates, providing ventilation, increasing energy efficiency and avoiding condensation. This also eliminates direct thermal bridges with the outer leaf and provides protection against the action of rainwater.

The inner layer provides the installation background for the walling and ensures that it is soundproof and waterproof. The functions of the outer layer include the reception and transmission of the horizontal loads to which the inner structure is exposed, as well as giving the façade its aesthetic component, which is determined by the design and size of the ceramic tiles. The two layers are joined together by means of a metallic substructure, which is often made of aluminium,

the extrusion capability and lightness of which make it the ideal material for this purpose. A continuous layer of thermal insulation is placed between the installation background and the substructure.

A classification of ventilated façades, according to the type of anchoring system which attaches the ceramic tiles to the metal substructure, has often been proposed. Two groups can be distinguished, depending on the aesthetic role of the anchoring system that is used, to be precise its external visibility: Façades with visible and invisible anchoring systems.

Within each of these groups, different configurations can be chosen, depending on the type and size of the ceramic tiles and the aesthetic appearance desired for the building. Given that ventilated façades are not the primary subject of this presentation, the different building options which are currently available are briefly summarized below:

1.2.1. Invisible Anchoring:

- Linear Adhesive

Adhesives are used during the construction process to bond ceramic tiles to the metal substructure. Combinations are usually used to increase installation performance and safety.

- Spot Adhesive

The ceramic tiles are adhered to metal anchors in a factory. This is done by making discrete anchoring points at the corners of the ceramic tiles. Later, during the building process, these anchoring points are mechanically attached to the metal substructure.

- Invisible Sliding Clips

The backs of the ceramic tiles have two rows of grooves along which clips contained in the metallic substructure are inserted.

- Horizontal Joint Clips

The clips arranged on the metal framework are inserted into spaces, which are machined or extruded from the edges of the ceramic tiles.

- Invisible Vertical Joint Clips

In this case the clips are inserted into extruded vertical grooves on the back of the tiles.

- Lateral Groove Profiles

The tiles have (machined or extruded) grooves at the top and bottom and metal T-shaped profiles, which are mechanically attached to the metal substructure, are fitted to them.

- Back Groove Profiles

Longitudinal grooves are made on the back of the tile at an angle of 45°. At the factory an aluminium profile is inserted into this groove. The combined structure is then attached to the metal framework.

- Invisible Glued Profiles

These are quite similar to the above option, as the ceramic tile is fixed to a profile at the factory. In this case attachment is by means of adhesive to avoid the machining of the ceramic tiles. They are attached to the metal substructure in a similar way to back groove profiles.

1.2.2. **Visible Anchoring:**

- Visible Clips

The clips are fixed to the four corners of the tile, each clip being shared by four pieces. The clips hold the lower ceramic tiles in place and support and keep the upper pieces in place.

- Visible Profile

In this case the metal profile itself is an important aesthetic component in the composition. The pieces are confined between the metal profiles by the wings they have for this purpose.

- Visible Drill Holes

Holes are drilled into the ceramic tiles and their four corners are screwed directly onto the metal profiles from the outside.

1.3. **Mixed adhesive-mechanical attachment:**

The two previous systems are combined, given that cement adhesives are used but they are reinforced by mechanical joints between the tiles and the installation background.

The process of constructing a tiled façade entails various steps. The range of possibilities, in terms of installation techniques, the number and type of layers in the façade and materials (ceramic and adhesive materials, etc.) is enormous and is conveniently described in various literature sources; this is why, in this presentation, we will primarily describe those aspects which are in some way related to the pathology detected in this case study.

Before cladding a façade, various key elements need to be considered:

1.4. **The installation background**

Also known as the building envelope or enclosure, it is the surface on which the tiles are installed. On façades it is normally composed of various layers which are arranged consecutively in order to increase insulation. Sometimes the final

outer layer is arranged in such a way that it optimizes the surface for the subsequent adhesion of the ceramic tiles.

Installation backgrounds usually consist of a masonry structure, of brick or ceramic or concrete blocks, and concrete walls made *in situ* or built with prefabricated elements.

When choosing the most suitable procedure for installing a cladding system, the characteristics of the installation background need to be taken into account. The most important of these are:

Dimensional stability: The installation background should not suffer significant dimensional variations over time in order to avoid creating stresses. For example, the shrinkage that occurs when concrete structures are setting takes about 6 months and is irreversible so it is necessary to wait this long before tiling a façade.

Flexibility: Very large buildings may be subjected to structural movements, for example as a result of the action of wind, which can cause stresses between the different layers of a façade. To minimize this problem a mixed adhesive/anchored cladding system, an increased number of installation joints and smaller formats are used.

Other characteristics which should be taken into account include: the sensitivity of the installation background to water, which can give rise to problems of expansion, decomposition, collapse or the appearance of fungi, lichens and so on, recurring in these cases to the use of a waterproofing primer where necessary. The preparation of the installation background must be optimal to ensure the subsequent adhesion of the ceramic tiles, so it should not contain elements that might crumble (a layer of primer should be applied where necessary) and its level of absorption and roughness should be optimal. Finally, we must ensure that the installation background is level and remove any potential irregularities. The application of a levelling layer is usually required in order to provide an optimal surface for tiling.

When necessary, in order to avoid these problems, especially dimensional stability and flexibility, the ceramic layer can be made independent of the building envelope by applying decoupling, separating or regularizing layers.

As we mentioned above, the thin-bed technique is the one with the most advantages. To use this technique, it is necessary to apply a regularizing layer, which has been perfectly screeded using bricklaying mortar. Bricklaying or plastering mortars must be selected in accordance with the UNE-EN 998-2 and UNE-EN 998-1 quality standards respectively, the most suitable being GP-CSIII-W1 or W2 mortar.

1.5. Movement Joints

To avoid stresses between the different layers of the façade, movement joints of different types and serving different purposes are designed:

- Structural Movement Joints: which reach the building envelope and are filled with elastic materials.
- Perimeter Movement Joints: these are used to avoid the accumulation of stresses and are primarily used in joins between tiling and other materials. They must be continuous and are filled with compressible material.
- Partition Movement Joints: which subdivide large surfaces into smaller surfaces (50-70 m²) and even smaller ones in places where weather conditions are extreme.

1.6. Installation Technique

Traditionally, the cladding of façades with ceramic tiles has been done using thick-bed mortar; however, in recent years the development of a wide range of special adhesives that offer considerable advantages, both in terms of the adhesion they provide between different substrates and their durability over time, has led to an inversion of this tendency and the thin-bed fixing method is gaining ground.

A thin layer of mortar is applied on top of a regularization layer, which avoids the manipulation of the cement by installers and there is plenty of time for rectification.

Within the wide range that exists, the materials that are suitable for installing porcelain tile sheets are cementitious adhesives, which consist of hydraulic conglomerates, mineral fillers and organic additives to which the appropriate amount of water is added before use. We recommend type C2 (enhanced cement adhesive) with an extended open time (E) and reduced slip (T). The definitions and specifications for these adhesives are included in the UNE EN 12004:2001 Standard.

Adhesion occurs as a result of a double mechanism; on the one hand, a mechanical mechanism in which the pores of the material which is to be bonded are filled with the adhesive and, on the other hand, a chemical mechanism, as a result of direct contact between the ceramic tile and the substrate.

1.7. Mechanical Anchoring

Despite the excellent performance of these adhesives, in many cases it is necessary to complement the adhesive with a mechanical anchoring system so the façade cladding system becomes mixed. Although compulsory use of a mixed anchoring system may vary, depending on local Regulations, its use is recommended in the following cases:

- tile size larger than 35x35 cm
- façade height exceeding six metres

As with ventilated façades, there are several possibilities with respect to the type of anchoring system, which can be visible or invisible, machining of the pieces being necessary in some cases. In the case described in this presentation, a metal substructure was not used and the anchoring elements were inserted inside the separation joints during the tiling process.

1.8. Grouting

An installation joint is the separation that is left between all contiguous ceramic tiles. The width of the joint depends on functional (absorption of internal stresses) and aesthetic requirements. This process is performed after tiling and the definitive securing of the anchoring system.

The materials that are used are included in the UNE EN 13888 Standard. As occurs with materials with bonding properties, the materials used for grouting are classified according to their nature; in the case which concerns us, latex-enhanced CG2 cementitious grouting material is recommended.

1.9. Monitoring of the Building Project

- Project information
- Control of materials
- Testing
- Progress checks (inspections, etc.)

1.10. Cleaning Procedure after Installation

Cement deposits left after installation and grouting are removed, first by washing the tiles with water, and then using diluted acid and finally by rinsing them.

After this final step the process of constructing the façade is completed.

1.11. Description of the Façade and Its Pathology

Given that the mistakes committed during the construction phase are cited in the bibliography as decisive factors in the appearance of defects of this type, the tiling process was analysed in detail and in close collaboration with the company that developed the project. The aim was to find anything in the execution of the project that might be related to the appearance of the stains.

This section includes a description of the façade construction process, covering every kind of detail: the order in which the tiles were installed, in accordance with the orientation of the building, the use of different materials for adhesion and grouting, tests conducted on materials during the construction process, isolation

of the most common routes for the entry of water, the weather conditions during the installation period and compliance with the recommended setting times for materials.

The building consists of two modules, which were completed one after the other, in accordance with the following sequence in both cases: cladding was initiated on the southern side of the buildings and subsequently, and in this order, the East, North and West sides were completed. The steps in the execution of the building project and its progress were as follows:

1.11.1. Screeding

The installation background was checked to ensure that it was level. Then any dust and dirt were removed from the façade, screeds were used approximately every metre and a 5 to 10 mm thick regularization layer was applied. A conventional mortar was used.

The mixture was prepared using washed sand with a particle size of 0 to 3 mm. The approximate dose of the cement mortar mix was 1/5 and, to ensure better conditioning and applicability of the lime extract sample was added at the dose indicated by the manufacturer. Fibreglass filaments were also added to the mixture to reinforce it.

During the screeding process, the layer that was applied was compressed before it was completely dry using a float or trowel. In this way, it was provided with cohesion and compactness. Finally, after verifying that the installation background was flat, it was left to set and dry for 28 days until the level of residual moisture was confirmed to be 3% using a hygrometer.

1.11.2. Layout

The site management team prepared the layout and the measurements were subsequently checked by the installation team. During this process, the joint movements were designed, as well as the position of the adjustment pieces. The joint movements were made to coincide vertically with the windows and horizontally with the structural elements of the building.

1.11.3. Facing Tiling

Prior to tiling the façade, the cohesion of the screed layer was tested by scraping it with a hard brush and checking for any possible fragmentation. Nothing untoward was observed.

Other operations performed during the process on a daily basis and on-site were as follows: observation to detect the possible presence of moisture on the back of the ceramic tiles, which could create an anti-bonding film between the adhesive and the tiles; analysis of overexposure to sunlight and wind at any point on the façade, which could produce a rapid loss of water in the adhesive and a consequent decrease in its open time, and confirmation that there was no risk of frost

during the execution period, as it is extremely detrimental to the performance of adhesives.

A C2 TE S1 adhesive was used, in accordance with the UNE EN 12004 Standard; in other words a deformable, cementitious, reduced slip adhesive with a long open time, which is recommended for exterior façades. The indications of the manufacturer of the adhesive were followed, with regard to both the mixing and maturing time.

The adhesive was applied twice, using a notched trowel suited in size and design to the format of the tiles. A thin layer was applied to the sides of the tiles using the smooth side of the trowel. The open time of the adhesive was regularly checked. To do this, pieces were lifted after they had been stuck in place and the adhesive layer was checked to see if it had broken cohesively and was evenly distributed between the building envelope and the tiles. Once the ceramic tiles had been laid, both the joints and the outer surface of the tiles were cleaned thoroughly in order to facilitate the processes which were to follow.

1.11.4. Metal Anchoring

In this type of façade, in addition to the chemical adhesion produced by the adhesive between the ceramic tiles and the installation background, a physical bond is created by clips which are attached on one side to the ceramic tiles. They are inserted into previously machined grooves in the tiles and into the installation background by means of rawlplugs and screws. This anchoring system is hidden from view. The clips are inserted into the grooves on the tiles as the façade is cladded.

Three days after the adhesive had set, the tiles were definitively fixed in place using rawlplugs and screws.

1.11.5. Grouting

The joint width chosen for this façade was 8 mm.

A cement classified as CG2 (enhanced cement for joints) was used, in accordance with EN 13888. The manufacturer's instructions were followed at all times. The process was conducted by two workmen, one of whom filled the joints with the grouting material using a rubber trowel; once the material began to set (when it is no longer shiny or fails to stick when touched), the other workman removed any excess cement using a trowel fitted with a scourer to clean the joints and a damp sponge to finish off the cleaning procedure using clean water.

While this was being done on the north side of the building, a random change in the tone of the joints, which significantly affected the appearance of the building as a whole, was observed. After unsuccessful attempts to clean the surface using acid products, it was concluded that this was not a merely superficial change so the cement was replaced with another material with the same CG2 characteristics, but which set more quickly and was the right tone. The rest of the façade was

grouted with this second material without further incidents. At this time the white stains had not yet appeared on the surface of the façade.

Given the satisfactory, homogenous and uniform aspect of the joints and the absence of cracks, the use of water repellents was considered unnecessary.

1.11.6. Movement Joints: structural and partition joints

During this phase the expansion and partition joints designed during the layout phase were filled. They were filled with special elastic materials designed for this type of application.

Uneven surfaces and points of contact with other materials, such as steel, stone or metal, were also sealed with elastic material.

1.11.7. Final Cleaning Procedure

After the sealing process, the façade was washed using clean water, rubbing the cement stains with an abrasive scourer. Where necessary, a cement-removing acid recommended by the manufacturer was used, following his instructions for use. In this case, the cement remover was rinsed off using plenty of water to avoid the product damaging the joints.

1.11.8. Appearance of stains following the first rains.

During the construction of the façade, the only problem which occurred was the loss of colour of the joints. The white stains on the façade had not appeared when the façade was completed. They appeared later with the arrival of heavy rain and probably the movement of water between the different layers of the cladding system.

2. ANALYSIS OF THE POSSIBLE CAUSES

There is a pathology that can be seen on many of the ceramic façades of the buildings in our cities, although generally it is only an aesthetic defect and has no major consequences: **efflorescence**.

Efflorescence consists of deposits of crystallized salts (normally calcium-based salts). They are precipitated onto the surface of ceramic tiles in the form of stains, which are generally white in colour.

Depending on the type of efflorescence, we may see different manifestations:

- **Type I Efflorescence** consists of superficial deposits of white-coloured salts which are highly soluble in water. They emerge as a very thin layer and are located at the centre or on the edges of bricks, although they also cover mortar joints. They are very common.
- **Type II Efflorescence (cryptoefflorescence or subefflorescence)**, in which the pieces are badly chipped or layers of brick a few millimetres thick

readily peel off. This usually occurs in humid or maritime locations, and is not very common.

- **Type III Efflorescence (exudations)** consists of white superficial deposits that take the form of trails. They are not very water-soluble and in the presence of hydrochloric acid they are effervescent. They are difficult to eradicate.
- **Type IV Efflorescence** adopts the form of brown trails over brickwork and mortar joints. They are uncommon and usually appear on highly fired bricks.
- **Type V Efflorescence** consists of greenish yellow stains. They are very rare.
- **Type VI Efflorescence** in which dark brown or black stains appear on bricks (normally bricks containing brown pigment) and joints. They differ from type IV efflorescence due to the colour of the bricks, as they are pigmented with manganese dioxide.

For efflorescence to be produced 3 factors must coincide:

- There must be free soluble salts inside the affected wall
- There must be water to transport these salts to the surface
- There must be pores in the grouting mortar

Origin of the Salts:

- Mortars and the products they are mixed with are the main source of salts and the cause of the appearance of most types of efflorescence.
- The terrain on which a building stands may contain salts and direct contact between the terrain and the affected wall or floor plus its inherent humidity is another common cause of efflorescence.
- Tiles may even contain certain salts. Owing to the chemical composition of the raw materials used during the tile manufacturing process and the high temperatures used, it is rare for tiles to be sources of efflorescence. However, as stains tend to appear on the surfaces of tiles, these materials are often mistakenly blamed as the cause of efflorescence.
- The water used in the construction of the façade, as the water in the province of Castellon has one of the highest calcium concentrations in mg/l in the whole of Spain.

Origin of the Water:

- Rain and wind, which cause water to infiltrate the ceramic material and mortar and dissolve the salts.

- Condensation water. Although they may be insulated, sometimes water is produced by interstitial condensation inside walls.
- Water used during construction. In some places water drawn from a well or from the local water supply may contain high concentrations of salts.
- The terrain on which the building stands may be predominantly humid.

The masonry or under-floor must not permit contact between salts and water. Design plays an important role here. Such contact must be prevented by using impermeable barriers, avoiding cracks, filtrations, etc.

2.1. Prevention of Efflorescence:

We will focus our analysis on efflorescence in which salts are dissolved within the masonry of a building and migrate to the outer surface of ceramic tiles. Such efflorescence can be very difficult to detain and may continue to migrate from the masonry for many years.

In ceramic wall cladding systems applied using adhesives, we associate many of the problems that develop with the apparent infiltration of rainwater. This internal moisture not only causes water leakage and staining. It is often the factor which is responsible for the appearance of efflorescence.

Most of the tiles installed in the world are applied using adhesive. Often the adhesive is applied on top of a layer of cement or mortar, which is used to make the surface level enough to ensure proper installation. The substrates found behind this intermediate layer are once again generally masonry or concrete. This implies that the usual systems for laying tiles supply plenty of porous cement material. These cement materials contain large amounts of soluble salts, leading to the formation of calcium hydroxide. Calcium hydroxide is formed during the manufacture and hydration of the cement used in substrates. It is this calcium hydroxide which provides the basic ingredient for the formation of calcium carbonate on the tile surface when the conditions of exposure are favourable.

The most important factor for avoiding efflorescence on wall cladding is the prevention of water infiltration, which is usually mediated by the system used to crown the tops of exposed tiles.



Fig. 1-Absence of Coping on a Terrace Wall

As can be seen in the photograph, the absence of coping as a finish to the wall serves as a route for water infiltration.

It is essential to limit the infiltration of water into wall cladding systems by using elastic expansion joints. Normally this will entail preparing the surface, using primers and materials that support joints, and employing a width-depth value recommended for the sealer and sealing agents that are suitable for outdoor use. A maintenance programme should also be supplied for the sealing joints.

The only time when water infiltration need not be taken into consideration would be in cases in which a grouting mortar that does not include cement in its composition is used. There are now solutions that have been investigated in detail in order to meet these requirements, in which cement conglomerates are replaced by state-of-the-art organic resins. As a result, the product which is applied has greater elasticity than cement mortar, shows virtually no absorption and offers us the certainty that there is no possibility of carbonation occurring.

3. DIAGNOSIS OF THE PATHOLOGY

The chemical analyses performed on the grouting mortar samples extracted from the façade revealed that the pathology under investigation was essentially derived from a carbonation process affecting the mortar. However, there is a pathology which causes an equivalent aesthetic effect and which occurs in the same way in this type of façade. It is caused by the migration of soluble salts that are present in the background on which tiles are installed and the phenomenon is commonly known as "efflorescence". Since both pathologies are closely linked to the systems used to construct the façade in this case study, in this analysis they will both be taken into consideration.

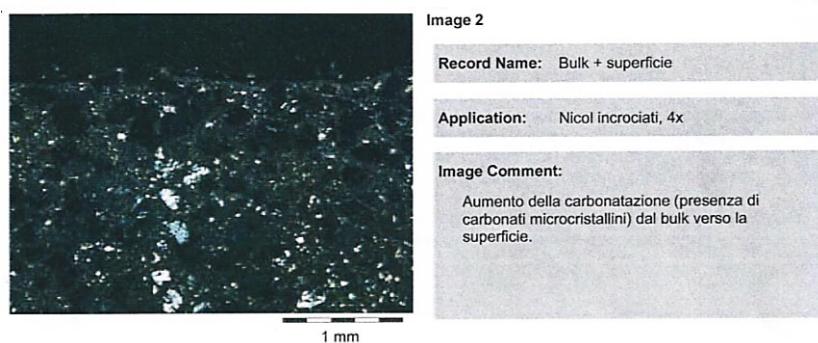


Fig. 2-Photo Depicting Carbonation of Grouting Mortar

When we look more closely at the stains that appeared on the COII (Building works) of Castellon, the different types of carbonated efflorescence are:

- Calcium carbonations or efflorescence: These are due to the action of atmospheric CO₂ on the calcium deposits produced during the hydration of cement clinker, which gives rise to the formation of insoluble carbonate deposits on the surface. They appear more often on rendered surfaces and surfaces to which mortar has been applied.
- Limestone efflorescence: The likelihood of this type of efflorescence appearing is very low. In combination with CO₂ and in the presence of moisture a soluble acid salt is formed which is later converted into an insoluble carbonate.

Carbonation occurs as a result of a chemical reaction between Calcium Hydroxide in the cement in the grouting mortar and Carbon Dioxide in the atmosphere. This reaction that converts Carbon Dioxide into carbonic acid, which is then able to react with Calcium Hydroxide, only occurs in the presence of water. The end product of this reaction is Calcium Carbonate, which is predominantly white in colour and determined the grouting malfunction which is the subject of this study. The magnitude of this phenomenon will depend on the factors indicated above: The Calcium Hydroxide content of the cement present in the grouting mortar, the CO₂ concentration in the air and the moisture present in the reaction medium.

In the chemical analyses performed on samples of the efflorescence that appeared on the façade of the COII of Castellon, the presence of calcium carbonate was observed. It is worthy of mention that no sulphates were detected.

The calcium carbonation patterns found on the façade of the COII of Castellon are shown below.

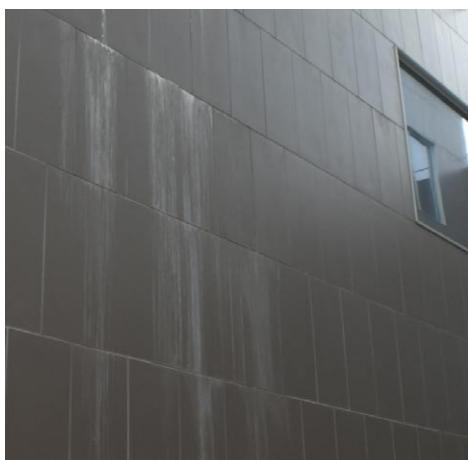


Fig. 3. Efflorescence on an Indoor Passage

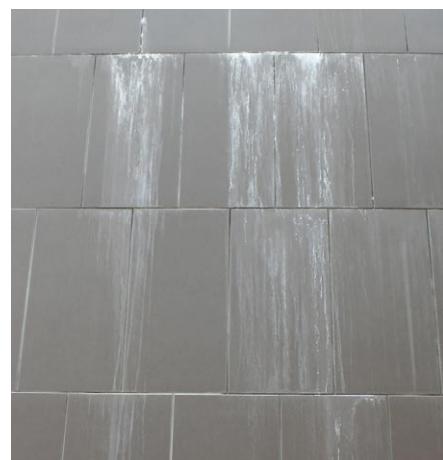


Fig. 4. Efflorescence in an Office Building



Fig. 5. Open Joint on a Terrace Roof

Nowadays cement grouting mortars have cement contents above 40% of their total weight. This is why the origin of this pathology is intrinsically linked to the type of material involved in the raw materials used. There are technologies that enable us to minimize their effects, but if the building conditions that encourage their appearance are in place it is practically impossible entirely to avoid efflorescence. Apart from selecting the type of grouting material we employ, given that controlling the amount of CO₂ present in the air is not feasible, the variable which we can have most influence on during application tasks is moisture.

Therefore, it is a question of ensuring that, during the grouting mortar setting process, the moisture and temperature variables that will allow the mortar we apply to dry out and harden as quickly as possible are achieved. This will limit the risk of the pathology developing. The foregoing variable has undoubtedly encouraged the development of grouting mortar carbonation in the specific case of the façade we have analysed, given that water was shown to be a determining factor.

4. CONCLUSIONS

Moisture levels must be monitored at all times during construction. Otherwise, it will mean that, before they are clad, walls will be saturated with water. This moisture would take a long time to be eliminated and could appear in the form of efflorescence in the future.

Some basic recommendations which should be taken into account when installing ceramic tiles on vertical façades in order to prevent the appearance of efflorescence would include:

- Monitoring the hardness of the water used during the entire ceramic tile installing process: checking for the absence of calcium hydroxide.
- Controlling the aggregates used during the screeding of the façade: testing for the absence of calcium hydroxide.
- Drying of the screed façade: checks to ensure that the residual moisture of the screed façade, once dry, is no higher than 3%.

- Monitoring of soluble salts in the ceramic tiles to be used on the façade.
- Selection of a suitable adhesive containing no harmful substances that would promote the development of efflorescence.
- Use of mortars that set normally and harden rapidly in the joints between ceramic tiles, thus avoiding the appearance of cracks after the grouting mortar hardens.
- Once the grouting mortar has hardened, a colourless sealing product should be applied to the joints to avoid the infiltration of water.
- Use a good design for the façade, making use of elastic joints, both vertically and horizontally, to avoid thermal expansion of the façade breaking the grouting.
- All the façade elements other than the ceramic tiling must be well sealed and waterproofed to avoid the infiltration of water.
- Ensure regular maintenance of the façade in order to repair possible defects that might appear in all the elements that could cause water to infiltrate into the wall.
- Install the tiling on the façade during periods when there is low rainfall, covering the façade if possible to avoid the infiltration of rainwater and try to tile the façade when the temperature is no higher than 24°C.
- Perform a chemical analysis of all the products used during the installation of the ceramic tiles.

If the problem of efflorescence arises, a possible solution could be preventive maintenance of the façade.

This maintenance would include the following steps:

1. Cleaning the entire façade to remove carbonate stains that have appeared on the surface of the ceramic tiles using a 10% solution of hydrochloric or acetic acid or any of the commercial products sold for this purpose, depending on how resistant the stains are.
2. Sealing all the joints which are in a bad state of repair, either using grouting material (in the case of joints between two ceramic tiles) or a sealing resin.
3. Waterproofing of all the joints with some kind of colourless sealant using a spray gun, paint roller, cloth or paintbrush.
4. Repairing all the elements of the façade that could cause the filtration of water into the façade wall, such as cracks, gaps, poor grouting, elements of the metalwork in a bad state of repair, etc.

5. Sealing of all the joints of the façade corresponding to window frames with elastic joints using epoxy base.
6. Regular monitoring of the façade to remove possible efflorescence that might appear, reparation of the joints that have deteriorated and maintenance in general.

A possible future solution to the problem of efflorescence would be the application of nanotechnology directly to the façade, more specifically the direct application of active nanolayers to achieve heterogeneous photocatalysis. As a result of these layers, materials can acquire new SELF-CLEANING, ANTI-POLLUTION, HYDROPHOBIC or HYDROPHILIC, OLEOPHOBIC, ANTI-BACTERIAL, LUMINESCENT, UV RESISTANT, ANTI-AGEING or ANTI-CORROSION properties.

These new products can confer new capabilities and applications to conventional materials, delivering highly innovative and efficient solutions that could substantially improve the Environment and our quality of life, as well as endowing materials with new properties.

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