

CERAMIC TILING PATHOLOGIES

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ABSTRACT

Recent years have witnessed a significant decrease in the number of new buildings with tiled facades, owing to the insufficient assurances provided by tiling performance. On the other hand, interior ceramic flooring is at the present time subject to a significant number of disorders. The most frequent causes of these anomalies are related to the characteristics of the bodies, tile-to-tile joint forming habits, ever-larger tile sizes and the difficulty of optimizing tile installation. Alternative solutions to the foregoing are being increasingly used, which are capable of offering comparable visual appeal and equivalent functional performance.

1. INTRODUCTION

From the marvellous Islamic and Mudejar tiles to the splendid facades of Art Nouveau and Gaudí works, we could draw up an extremely long list of buildings and places of recognized heritage value, scattered all over the world, in which ceramic tilings have been used in some of their multiple varieties. It may be said, without any risk of error, that these applications of great visibility and beauty were for a long time the applications that best embodied the use of adhered ceramic tilings. However, in the course of time, other applications have been identified with this solution, particularly those in which ceramic tilings are able to provide a combined response to certain functional requirements and the demand of visual quality, as well as the possibility of choosing between a variety of types, colours, tones and graphic designs. Particularly noteworthy amongst these applications, because of their quantitative importance, are interior floorings and the wall claddings of wet domains in residential buildings, although these same applications also are frequent in buildings destined for many other uses (hospitals, hotels, etc.)

However, in some of the above applications, especially in facade claddings and flooring layouts, recent years have witnessed an increasing distrust of developers, technicians and builders of obtaining sufficiently satisfactory levels of assurance in the installed end product, which contrasts with the high indices of acceptance that such uses receive from the public in general.

The paragraphs that follow set out the possible causes that can be associated with the problems mentioned, taking as a reference the experience in cases analysed by the UPC Department of Architectural Constructions I and by other areas of the same University.

2. THE PROBLEM OF TILED FACADES

The most frequent cause of concern in facades clad with ceramic tiles is the possibility of tile detachment, with or without attached bonding material, and the subsequent potential risk for passers-by or users of the building. This risk has undoubtedly been heightened since the mid-twentieth century by the routine adoption of external envelope solutions of greater deformability and lower thermal inertia, raising shearing stresses in the materials and interface planes of tiles and bonding materials. This is the origin of the perception that the traditional tile installation systems with lime mortars on coarse walls of greater thermal stability were more durable and safer than the modern adhesive systems, adopted in fact to counteract the greater stresses generated by the new envelope systems.

However, in the study of the casuistry of the detachments observed in these coverings –specifically relating to modern thin-bed applications - the presence has been noted of a multiplicity of possible factors of influence, which require consideration and evaluation in each particular case. These have been briefly detailed in Table 1, for each factor identifying the most frequently associated anomalies.

Note that, in practice, in an endless number of cases, these anomalies do not appear in an isolated form, but occur together and overlap, generating complex pathological situations that require meticulous data recording, extraction of evidence samples, as well as trials and tests to determine the underlying causes, and possibly, eventually, establishing the cause that might have been the determining factor in producing the damage.

TILED FACADES

FACTOR	DEFECT, ANOMALY
BACKGROUND MATERIAL	<ul style="list-style-type: none"> • friability, low cohesion, smaller than the adhesive strength of the bonding material to the tiles and to the background itself.
BACKGROUND PREPARATION	<ul style="list-style-type: none"> • absence of a regulatory homogeneous layer for planarity and absorption. • Presence of demoulding liquids or liquids of another nature. • Insufficient cleaning.
JOINT CHARACTERISTICS AND LAYOUT	<ul style="list-style-type: none"> • Butt joints or narrow tile-to-tile joint widths. • Non-existent or insufficient thermal movement joints in the ceramic tiling.
MOVEMENTS IN THE BUILDING OR IN THE FACADE ITSELF	<ul style="list-style-type: none"> • Fissures coinciding with cracks produced by bending of the decks or differential settling. • Fissures coinciding with hydraulic shrinkage cracks. • Buckling due to shrinkage of the facade envelope owing to thermal causes or load accumulation.
PRODUCT APPLICATION	<ul style="list-style-type: none"> • Exceeding adhesive time of use. • Exceeding the open time for tile installation on the adhesive. • Insufficient tile pressure on the adhesive. • Non-conformity to specifications relating to tile preparation. • Non-conformity to specifications relating to the adhesive mixture or the nominal thickness of the adhesive on the background. • Non-conformity to product installation specifications.
SUITABILITY AND CHARACTERISTICS OF APPLIED PRODUCTS	<ul style="list-style-type: none"> • Mismatch of the adhesive with the characteristics of the background or tiles. • Insufficient or erroneous application specifications. • Product properties that do not coincide with those established in the homologation or specification.
RHEOLOGY AND FATIGUE OF THE MATERIALS	<ul style="list-style-type: none"> • Reduction in the adhesion characteristics of the materials in contact. • Increase in shearing stresses by progressive rigidification of the adhesive material or background.

Table 1. Most frequent anomalies in tiled facades

It may further be noted that although statistics providing detailed information on the causes that originate tile detachments are unavailable, it is well known that the most frequently recurring factors are deficiencies in the application of the products and insufficient preparation of the background, together with a tradition of laying out tiles with very narrow joints, which impedes the adaptation of tiling movement to the movement induced by the envelope and the adhesive.

It shall come as no surprise, in view of the causes that appear most frequently, that the drastic reduction in the application of ceramic tiles on facades began - at least in Spain - a few years after the building boom of the 60s and early 70s of the last century, when skilled labour was scarce and construction conditions were governed by speed rather than quality. Nor shall it come as any surprise, in view of the great number of factors - both intrinsic and extrinsic - which affect the performance and durability of ceramic tilings, that it is difficult to obtain assurable results with conventionally used solutions, which are based on the reliability of the adhesion of the directly fixed materials.

3. THE PROBLEM OF CERAMIC FLOORING

For some years now, ceramic floor tiles measuring 30x30, 40x40 cm or even larger, of thickness of the order of 0.6-0.9 cm, commonly called *stoneware floor tile*, have been a standard solution for interior flooring in residential buildings and also in buildings destined for other uses. However, although their present level of application continues to be high, a growing distrust can be observed in the sector towards this type of solution, owing to the numerous cases of anomalous performance occurring shortly after tile installation.

Analogously to the brief outline above for tiled facades, Table 2 sets out the principal factors that play a role in ceramic flooring performance and the different related anomalies they generate. It can be observed in the table that certain factors and anomalies coincide with those of the tiled facades, whereas others, such as those related to base formation and deck deformation, are specific to floor tiles.

In these cases as well, just as in tiled facades, the original causes of the damage usually involve different, intertwined factors, in which the factor that plays the greatest role in producing the damage can not always be pinpointed, since a great variety of issues may be involved, such as:

- a) Intrinsic brittleness of the ceramic flooring itself, made up of tiles with very high size/thickness ratios, which can reach high tensional levels when absorbing compression or flexo-compression stresses.
- b) Narrow tile-to-tile joint width, which aggravates the foregoing problem by reducing the tile deformation capacity in the direction of the flooring itself.
- c) The difficulty, which increases with rising tile size, of achieving direct bonding of the whole tile surface with the adhesive material.
- d) The difficulty of forming appropriately thick, deformable and adhesive bases to act as levelling and mechanical transition layers between the deck or slab and the flooring (on this point there is a great divergence among the various recommended practices for the formation of bases and their mechanical relation to the elements in bending).

STONEWARE FLOOR TILE

FACTOR	DEFECTO, ANOMALÍA
FORMATION OF THE BASE	<ul style="list-style-type: none"> • Fractures in the floor tile coinciding with shrinkage fissures in the base made with too stiff mortar. • Presence of loose tiles owing to insufficient adhesion in the mortar base-adhesive or adhesive-tile interface.
JOINT CHARACTERISTICS AND LAYOUT	<ul style="list-style-type: none"> • Butt joints or narrow tile-to-tile joint widths • Absence of a perimeter joint along enclosing vertical abutments.
THERMAL MOVEMENTS	<ul style="list-style-type: none"> • Flexo-compression stresses and zone buckling in the flooring caused by differential thermal expansion of the ceramic tiles relative to the base.
BENDING MOVEMENTS IN THE BACKGROUNDS	<ul style="list-style-type: none"> • Flexo-compression stresses and zone buckling in the flooring caused by elastic and delayed flexion deformation of the deck
PRODUCT APPLICATION	<ul style="list-style-type: none"> • Exceeding adhesive time of use. • Exceeding the open time for tile installation on the adhesive • Insufficient tile pressure on the adhesive or breaks in the spread of the adhesive on the base • Non-conformity to specifications relating to tile preparation • Non-conformity to specifications relating to the adhesive mixture or the nominal thickness of the adhesive on the background. • Non-conformity to product installation specifications.
SUITABILITY AND CHARACTERISTICS OF THE APPLIED PRODUCTS	<ul style="list-style-type: none"> • Mismatch of the adhesive with the characteristics of the background or tiles. • Insufficient or erroneous application specifications. • Product properties that do not coincide with those established in the homologation or specification.
RHEOLOGY AND FATIGUE OF THE MATERIALS	<ul style="list-style-type: none"> • Slow reduction in the adhesion characteristics of the materials in contact. • Increase in shearing stresses by progressive rigidification of the adhesive material or background.

Table 2. Most frequent anomalies in ceramic floorings

- e) Effect of the deformations in bending undergone by decks in the period subsequent to tile installation (active deflection), when their tensional state increases, which is more significant as tile size grows, tile-to-tile joints become narrower, the materials in the deck-flooring interface (base layer and adhesive) become more rigid and the perimeter joints become less effective. Note the importance of this type of delayed deformation in flat decks of site-poured concrete, because of their high plastic flow.
- f) Effect of temperature variations on the tensional state of the flooring, when the thermal expansions act in the same sense as the deck deformations treated in the previous point. The thermal jump between zones of the same flooring caused by the proximity of heating or regimes of intense different sunlight can also be a critical factor in flooring performance. In this case the tensional increase and feasibility of buckling due to thermal effects will be the more likely, the larger and thinner are the tiles, the narrower are the tile-to-tile joints, the less effective are the perimeter joints and the weaker the adhesion in the tile-adhesive and adhesive-mortar base interface or, should this be the case, directly in the tile-mortar base.

This complex set of factors and situations needs to be taken into account to avoid damage occurring in ceramic flooring.

4. INTERIOR WALL CLADDINGS

These applications, which entail much less risk than external claddings, do however need the same rigor in their installation with regard to the adoption and installation of appropriate products in terms of the background material to which they must adhere, arrangement of spacers for appropriate tile-to-tile joint forming, and foresight of the effects on the ceramic cladding of the transmission of flexo-compression stresses stemming from bending of the decks, when the rigidity of the tiling exceeds that of the background, which is almost always the case. In brief, these are the situations that most frequently generate damage in interior ceramic tilings in buildings.

5. ALTERNATIVE SOLUTIONS

The relative reduction of the level of application of adhered facade claddings in urban buildings has passed practically unnoticed owing to the existence of a wide range of products and solutions of very different nature, which have met the needs and requirements of demand during these last lustrums. In addition to the use of fair face brick masonry, which has increased its presence in buildings of dwellings, the use of prefabricated panels of architectural concrete or metal components and ventilated curtain walls with mechanically fastened, highly varying cladding materials, such as natural stone, asbestos-free pressed fibre cement sheets, sheets of thermostable synthetic resins, and even sheets of large-size porcelain tiles, has grown. Some of these materials, particularly the thermo-hardened resin sheets, are being increasingly used as cladding in the partitions of wet domains in dwellings and in the areas or places of transit of public use, although the adhered ceramic claddings continue maintaining their primacy in these applications. With regard to ceramic flooring, its unquestionable preference by a wide spectrum of users does not prevent the use of terrazzo from returning in important promotions of residential buildings, or parquet

being chosen, and the application being studied of alternative materials in buildings destined for public services.

6. CONCLUSIONS

- Some of the usual ceramic tiling solutions, particularly the external claddings of facades on a thin layer of adhesive material and interior floorings on flat concrete decks, are subject to recurring manifestations of damage stemming from very different causes, which frequently act together. Of these causes, the deformability of current backgrounds, the tendency towards large tile sizes and narrow tile-to-tile joints, as well as the difficulty of achieving optimized tile installation conditions, are the most influential.
- Certain increasing possibilities of selection and use of alternative solutions to ceramic materials for external and interior claddings have been noted, with equivalent or improved performance and smaller levels of accident risk or presence of damage.
- The foregoing indicates that with regard to adhered ceramic tilings, to achieve comparable levels of confidence to those of other alternative solutions, it is necessary to increase quality assurances in all the stages of the process, particularly in those ranging from the selection of the products to their appropriate application and installation on the background on site.

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