CRAZING RESISTANCE

All glazed tiles shall pass the crazing resistance test, based on standard ISO 10545-11, before they leave the factory.

Crazing consists of rupture of the glaze in the form of hairline cracks that develop randomly on the glazed surface. This defect occurs because the glaze is subjected to tension, either at the kiln exit (immediate crazing) or after the tile installation (delayed crazing).

The test in the autoclave, at 500 KPa pressure and 160ºC, gives rise to that stress, which can lead to rupture of the glaze.

All first-quality tiles must pass the test. In special products that do not pass the test, the manufacturer is obliged to declare that the tiles may display crazing.

Good dilatometric fit between the ceramic body and the glaze assures crazing resistance. Most of today's tiles conform to the requirement.

However, tiles of group III that have a high coefficient of moisture expansion (exceeding 0.4 mm/m) may, under certain conditions, display crazing after an undetermined time. The following are contributing factors:

- Places regularly exposed to humidity or moisture
- Tile fixing with mortars rich in cement which, as a result, generate compression in the ceramic body and tension in the glaze
- Wall tilings installed without joints, subjected to compression

Crazing in BIII GL tile, at the juncture with the sanitary ware and change of plane

Autoclave for the crazing resistance test. Sebastián Carpi Laboratory (Castellón, Spain)

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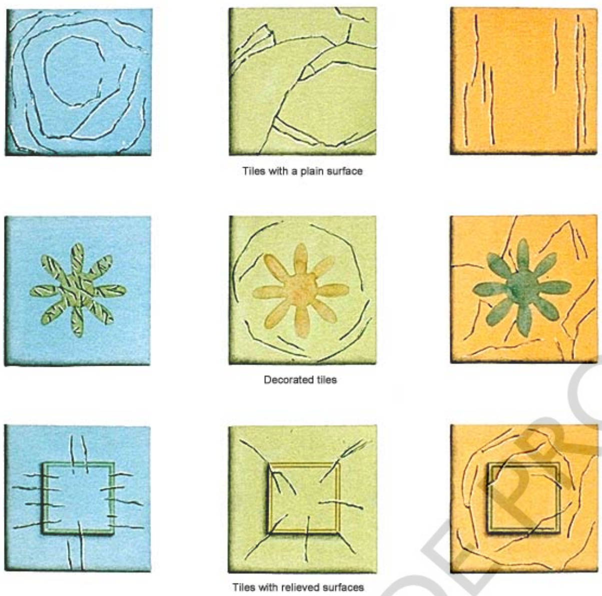
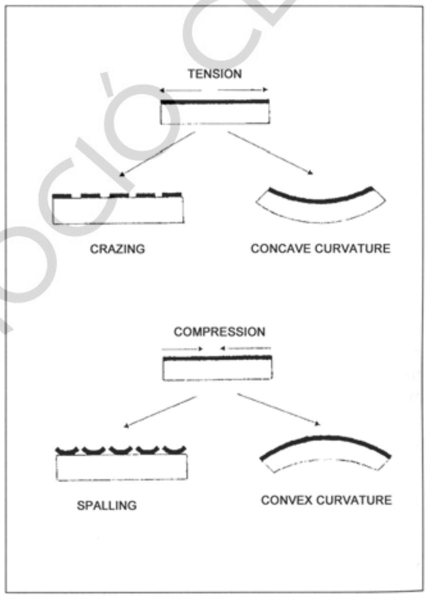
Crazing in glazed ceramic tiles

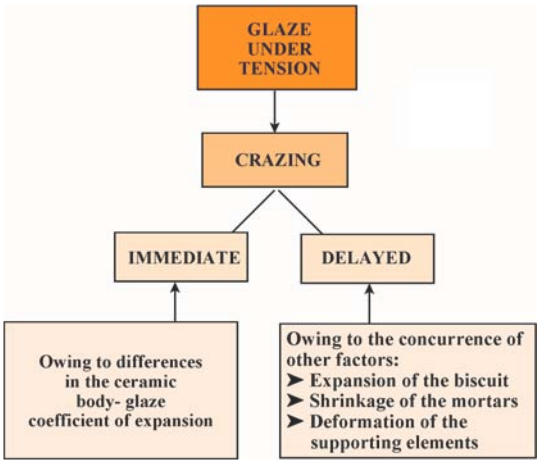
Glazed tiles have always displayed crazing when there was no dilatometric fit between the body and the glazes bonded to the body. *Immediate crazing* is the term given to microcracking by rupture of the glaze at the kiln exit or a few hours/days after the manufacturing process has ended, without there being any other intervening cause than the difference between the coefficient of linear thermal expansion of the body or biscuit and the glaze, in the range of temperatures between room temperature (23 ºC) and 100 ºC.



Different types of crazing illustrated in standard ISO 10545-11



Glazed tile curvatures as an expression of stresses



This defect was present in the manufacture of tiles with lead silicate-based glazes, with coefficients of linear thermal expansion exceeding those of the biscuit, affecting both (white body) earthenware tiles and (red body) majolica tiles. In the European standard of 1982, crazing resistance was already considered a fundamental characteristic that first-quality glazed tiles had to pass, unless the manufacturer provided information to the contrary or products were involved that, owing the forming process, were not included in the standard (current group **C** of standard EN 14411).

At present, all first-quality glazed ceramic tiles that invoke standard EN 14411 shall pass the crazing resistance test according to the method put forward in standard ISO 10545-11. This test assures good performance of the tile with regard to immediate microcracking, since there is dilatometric fit between the body and the glaze in the aforementioned range of temperatures between 23 ºC and 100 ºC.

In most current products, glazes are usually under slight compression before the tiles are installed; however, this situation can change radically when tile expansion (caused by humidity or moisture, and shrinkage of the cement agglomerates in bonding mortars and intermediate layers) overlays this. The appearance of microcracks with a random geometry, at an undetermined time after the tile has been installed, is termed *delayed crazing*.

This crazing mode cannot be foreseen from a manufacturing standpoint. Even when the assumption is made that there is dilatometric fit between the different layers that make up the ceramic tile, and with the foresight of providing slight compression of the glazes at room temperature, it is difficult to predict the tensional state of the tile once it has been fixed to the background surface. As a result, this type of defect usually appears at present particularly in tiles with an intermediate/high water absorption capacity (group **III** according to standard EN 14411), which in turn have a high coefficient of moisture expansion (above 0.4 mm/m according to the test method laid down in ISO 10545-10).

In that sense, current standard EN 14411 has meant a step backward with regard to the previous European standard, which required a coefficient of moisture expansion of 0,6 mm/m or smaller. Now, it is envisaged as an optional, voluntary characteristic for the manufacturer and, in (informative) Annex P of that standard, this characteristic is only mentioned as featuring in particular tile installation situations (without these being specified).

The present situation of risk occurs especially in screeds (flooring) and renders (wall cladding) on which tiles are fixed a few days (fewer than 7) after these backgrounds have been prepared, during the time such layers shrink most, especially with high temperatures and environmental dryness. Note moreover, particularly in screeds, that mortars with a high water/cement ratio (exceeding 0.5) are being used to facilitate mortar application and levelling, as a result of which the shrinkage is even greater. Usually the concurrence of these factors leads to much more serious defects than delayed crazing on isolated tiles, defects that include buckling and widespread cracking in flooring.

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Prevention of the defect

The Ceramic Technician must know the coefficient of moisture expansion of GL tiles of Group III, especially in sizes larger than 900 cm^2. Coefficients above 0.4 mm/m may constitute a contributing factor in the appearance of *delayed crazing* in butt-joint tile installations with cement agglomerates.

If there is the certainty that the tile glazes are under slight compression when they leave the factory, the measures for the prevention of this irreversible defect need to be adopted in tile installation. Such measures include:

- Respecting the 28-day hydration process for the intermediate layers installed with cement agglomerates (wall renders and floor screeds), which constitute the fixing surface for the ceramic tiling.
- Using cement mortars with low shrinkage, for both intermediate layers and bonding mortars. In this last case, it is always advisable to use mortars with a cement and lime mix owing to their greater deformability.
- Always arranging perimeter joints at the juncture of the tiling with other materials, in order to avoid subjecting the ceramic tile to compressive stresses that will cause tensile stresses in the glazes. Tile installation with an open joint can also contribute to the liberation of compressive stresses, particularly if the grouts are minimally deformable.

Assignment of the defect

Although crazing has been extensively dealt with in the literature, the survey we conducted found no documentary sources that conclude on the fundamental factors in the appearance of *delayed crazing*. Here, we are inclined to assume that moisture expansion in the ceramic tiles, shrinkage of the cement agglomerates, and fixing surface and background movements concur.

For the first contributing factor, the Ceramic Technician is familiar with the complex phenomenon that governs the increase in volume of a ceramic body caused by water, in a liquid or vapour phase. It should be borne in mind that two independently developing actions superimpose themselves: one involving an reversible increase in volume owing to the physical absorption of water, and another, of a chemical nature (chemisorption), which develops by the hydration of amorphous aluminosilicates, glass, and amorphous silica, in a process of volume growth that prolongs itself in time, independently of whether the humidity or moisture supply stops or not.

Although there are no strict correlations, the greatest coefficients of moisture expansion occur in high-porosity tiles with the presence of capillaries, where the specific surface area on which chemisorption takes place is greater and where, obviously, water transfer can also be greater.

When other contributing factors overlie the natural phenomenon of ceramic tile expansion, resulting in strong compression on the biscuit, microcracking of the glazes can occur if glaze tensile strength is exceeded when the tile is subjected in its entirety to flexo-compression. The following contributing factors are involved:

- Shrinkage of the cement agglomerates or compositional variations of the mortars.
- Movements and strains generated by the fixing backgrounds, particularly deflections in decks and shrinkage of construction elements containing cement-based compounds during the hardening process.

The loss of volume of cement agglomerates depends on various factors (compositional variables of the agglomerate and, among these, the cement/aggregate and water/cement ratio, particle size distribution of the aggregates, and environmental humidity and temperature conditions during the hardening process). In a 1:4 volumetric composition this may be set at 0.4 mm/m in a semi-dry mortar with a water/cement ratio below 0.5 up to shrinkages exceeding **1.2 mm/m** in agglomerates with a low consistency and high cement content.

The hardening of intermediate layers that make up the base underlying the ceramic tiling, in line with the remarks made in the previous paragraph, can also become an important contributing factor in the manifestation of delayed crazing. For example, this can appear in particular areas of thin-set wall tiling on a render with high shrinkage or in correspondence to reference areas and screeds installed with rapid-setting mortar, and may even lead to complete cracking of the tile.

The concave deformation of horizontal supporting elements (deflections in decks and differential shrinkage in screeds) usually leads to greater malfunctions than delayed crazing, though the latter may be present.

The appearance of crazing in particular tiling surfaces deserves special mention (e.g. in tiles at junctures with sanitary ware, kitchen benchtops, tiles bordering carpentry, etc.). In these cases, localised microcracking appears, caused by strong compression of the tile that abuts rigid elements and, in some cases, is subject to variable stresses, as a function of the presence of water or linear thermal expansion of the abutting materials.

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Crazing resistance in ISO 10545-11

This part of standard ISO 10545 establishes the test method for determining the resistance to crack formation in glazed tiles (**GL**) by putting the tiles under vapour at high pressure in an autoclave, with subsequent visual examination, after applying a stain on to the glazed face.

The standard defines *crazing* as the manifestation of cracks that appear as capillary lines restricted to the glazed surface of the tile. The standard includes a figure that is intended to illustrate different types of crazing.

Procedure

After visual examination of the tiles before the test, also with the help of a methylene blue stain (solution at 1% by volume, with the addition of a wetting agent) that is spread over the glazed surface with a cloth in order to detect any crazing before testing, the process below is followed using entire tiles:

- Refiring of the test tiles up to 500 ºC, in a heating process of 150 ºC/h, holding peak temperature for at least 2 h.

- Arrangement of the pieces in the autoclave, in order to subject them to heating (up to 159 ºC) and increasing pressure [up to (500 ± 20) kPa in one hour] in a humid environment. The maximum pressure is held for two hours. Once that time has elapsed, the vapour supply is shut off and the pressure is lowered as rapidly as possible until atmospheric pressure and room temperature are reached.

- After the methylene blue stain has been brushed on to the glazed surface, this is wiped of with a damp cloth and the surface is visually analysed (at 25-30 cm, with lighting of 300 lux) to detect the presence of any crazing. The presence of hairline cracks in the surface of a single tile will entail a negative report in regard to crazing resistance.