TILE GROWTH
FACT OR FANTASY?
Richard Bowman

Tiling system failures are unfortunate events that provide the worst publicity for the tiling industry. Since property owners do not deliberately contribute to failures, they reasonably expect that somebody will provide restitution. However, it is exceedingly rare for any party to admit that they were at fault. The reality is that most failures have multifactorial causes, and need to be looked at accordingly to determine which factors have contributed to failure; and whether any of them have made such a significant contribution that the failure would ultimately have occurred if there were no other contributing factors. One should also assume common standards of workmanship rather than proscribed or desired levels that may be rarely attained.

It is important to distinguish between cosmetic and functional failures. The most catastrophic failures involve the debonding of tiles. While tiles falling from external facades have killed relatively few people, several have been injured after falling on ‘lifted’ tiles that have stuck out above pedestrian surfaces. ‘Pop-up’ failures, often initially detected as widespread drumminess, are more consequential than shading variations and staining problems.

Tile debonding is principally caused by differential movement (due to compression of the tiling layer because of shrinkage of the background or growth of the tiles). Naturally, the quality of the adhesive bond and the amount of adhesive coverage on the back of the tile will have a significant influence. Structural building movements (such as creep, inelastic column shortening, and deflection of concrete slabs) can cause compression of the background.

Almost all materials expand as they are heated and shrink as they cool. Many materials also expand as they absorb water and shrink as they dry. Timber structures and substrates, cement sheet products are a few examples of products that undergo short-term wetting and drying movements, including humidity changes. Unless a tiling system is appropriately designed and properly installed, such reversible moisture movements can be sufficient to induce failures.

Some materials also exhibit irreversible long-term moisture movement. Perhaps the best-known example is the natural phenomenon of concrete shrinkage. One practical application of this knowledge was the traditional requirement that tiling should not commence until after the concrete had been permitted to dry for one month for every 25 mm of concrete thickness. The rate of shrinkage will depend on the type of concrete, the exposed surface to volume ratio, and the prevailing climatic (temperature, relative humidity, air flow) conditions.

TILE GROWTH

Whilst ceramic tiles generally exhibit some moisture-related movements on exposure to moist air when cooling in the kiln, relatively few will undergo a significant amount of expansion once they are laid. This is increasingly the case, as porcelain tiles, the boom sector of the tile industry, have insignificant tile growth. Tile growth is less significant in small tiles: as the ratio of tile to grout decreases, there is more grout to take up any tile growth.

Moisture expansion is essentially due to the chemical and physical adsorption of water (as vapour) on the amorphous phases within the tile body. Glass phases are slightly reactive, but may become more reactive if alkali ions are leached out when the tile is wet. Crystalline phases are poorly reactive. The rate of moisture expansion will depend on how readily moisture can reach the various phases (a function of porosity and permeability), the reactivity of the phases, and the creation of new surfaces for further reaction (via microcracking and chemical modification).

The progress of moisture expansion with time is generally characterised by an initial rapid rise, which gradually slows down through a transitional region. The curve continues to rise steadily at a much slower rate, and the final part of the curve approaches to a straight line. The rate of natural moisture expansion can often be described by a logarithmic function of time (which can be useful for predictive purposes or forensic analysis). The rate of expansion is also a function of temperature and relative humidity. Put simply, the rate of growth will slow gradually.

While the kinetics of tile growth will vary with the type of tile body, the manner in which the tile is produced, and the extent to which it is fired, the nature of the fired product will determine its potential for expansion. One practical aspect of the growth kinetics is that a significant proportion of the potential expansion may occur before the tile is fixed. For example, perhaps 25% of the growth will have occurred if a tile is fixed 3 months after production.

HOW DO WE MEASURE TILE GROWTH?

Tile growth can be measured in the laboratory either as natural growth (over long periods of time), or it can be accelerated by boiling or autoclave pressure steaming. AS 4459.10:1999 Methods of sampling and testing ceramic tiles: Determination of moisture expansion, (equivalent to ISO 10545.10) uses a 2 hour reheat at 550°C reheat to condition the tiles (effectively reversing most of the natural moisture expansion). A 24-hour boil treatment is then used to induce accelerated expansion. This accelerated expansion is probably equivalent to the expansion that ‘conditioned’ Australian tiles might experience in 15 to 18 months of natural exposure. It should be noted that the 15-year tile growth could be twice the accelerated expansion.

WHAT DO THE RESULTS MEAN?

AS 4459.10 has an informative annex that states “The majority of glazed and unglazed tiles have negligible moisture expansion that does not contribute to tiling problems when tiles are correctly fixed. However, with unsatisfactory fixing practices and in certain climatic conditions, natural moisture expansion may aggravate problems, especially when tiles are directly fixed to inadequately aged concrete substrates. In these cases, a maximum limit of 0.06% moisture...
expansion is recommended when the test is used.’’

AS 4459.10 differs from ISO 10545.10 in that it has some additional variations that apply to exiting laid tiles. There is a second informative appendix ‘‘If the sample being measured is an old tile that is related to a differential movement failure, it is recommended that an initial two measurements be made on each prepared specimen prior to the refiguring procedure. The shrinkage that commonly occurs when aged tiles are reheated is highly indicative of the moisture expansion that has occurred since production of the tile. In trying to assess the degree to which tile moisture expansion has contributed to any differential movement failure, it should be noted that a large amount of the expansion may have occurred prior to installation of the tiles.’’ The test method also contains variations that establish a protocol for such reheat shrinkage measurements.

When CSIRO determines reheat shrinkage, the results are reported in an addendum, where it states there are no compliance requirements. However, an informative annex states ‘‘While this test method requires that specimens be reheated to 550˚C, it does not require that the reheat shrinkage be determined or reported. However, since a reheat shrinkage may be highly indicative of the moisture expansion that has occurred since manufacture, it is reported here. In trying to assess the degree to which tile moisture expansion has contributed to any differential movement failure, one should note that a large amount of the expansion will probably have occurred prior to installation of the tiles. The rate of moisture expansion generally decreases significantly with time. Where the reheat shrinkage is greater than 0.06%, one should consider attempting to determine how much of the expansion has occurred before fixing of the tiles and after failure of the tiling system. This could then be considered in the context of other system variables that contribute to such failures (unsuitable substrate preparation, inappropriate choice of fixative, inadequate application of fixative, failure to provide for differential movement, structural movement, etc.).’’

This informative text is followed by an important warning: ‘‘WARNING: Extreme caution should be exercised in the interpretation of this Informative Annex. Should you believe that you have a case against the tile manufacturer or some other party, you should consider instigating a consultancy. However, you should note that there are generally a number of contributing factors in most differential movement failures, and that it is not always possible to identify the primary causal factor.’’

WHAT DO I DO IF WE HAVE A FAILURE?

The first thing is to assess whether sufficient movement joints have been installed, and if they are functioning. Start with the perimeter joints, inserting a probe through the joint sealant to determine if the sealant goes the full depth of the tile and adhesive layer or if the joint contains rubble or adhesive that would stop it from functioning. While tiles can be lifted and the quality of workmanship assessed, whether or not porous tiles have grown requires an expert reheat shrinkage determination in a controlled laboratory environment.

SALT EXPANSION

Salt attack (the destructive drying expansion of soluble sodium sulphate and sodium chloride salts) may cause localised fracture of some porous-bodied tile surfaces, but may not affect the length of the tile. While some tiles have amorphous and glassy phases that will chemically react with some soluble salts causing tile growth, salt expansion is thought to be a relatively rare phenomenon.

CRYOGENIC TILE GROWTH

When a water-saturated moderately porous tile is frozen, there is about a 10% increase in volume when the water forms ice. The associated internal stress can cause fracture of a relatively small number of vitreous bonds on a microscopic scale, resulting in residual expansion. As the tile is exposed to a number of freeze-thaw cycles, the residual expansion will increase if the fracture-inducing freezing expansion phase induces a greater volume change than the thawing contraction phase. Localised frost damage may occur if saturated tiles are exposed to sufficient freeze-thaw cycles, but this will also be a function of the tile characteristics. Dry tile specimens do not exhibit permanent cryogenic growth.

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Classic pop-up floor tiling failure with multiple rows of tiles lifted, including at right angles to one another