Why get cross about spacers?

By Peter Hartog

In a recent review of the continuing revision of AS3958.1 - ***Guide to the Installation of ceramic tiles*** *(see* Tile Today, *September-October 1999), Colin Cass announced the drafting committee's decision to strengthen the proscription on permanent embedment of hard plastic joint spacers in wall tiling. He anticipates some opposition to any renewed emphasis on spacers as a potential cause of distress in tiling. Enforcement of a specification requiring removal of shallow cruciform spacers has already become a matter of dispute in a contract for re-tiling toilet walls of a commercial office building in Sydney. It may therefore be timely to elaborate on the brief caution under Clause 5.7.1(a) of the 1991 edition of the standard:*

NOTE: Hard, relatively incompressible spacers may impair the performance of the system if left in place.

Relative to what? Is impairment of the performance of the system equivalent to tiles delaminating and falling off the wall? The same clause refers to spacers *specifically designed to remain insitu.* I wonder if the manufacturers of the cruciform spacers widely used in Australia and now appearing in Southeast Asia are prepared to argue that their products are specifically designed for this purpose? At least one suggests so on it's packaging.

There are at least three defects associated with the permanent embedment of hard spacers in joints. The first is fairly obvious; thin joint grout over spacers cracks and flakes more easily than elsewhere, particularly when the layer of tiles come into high compression. A recent US handbook also warns of distinct colour differences in light-coloured grout directly above embedded plastic spacers.

A second set of defects is related to differential movement between tiles, substrates and structural elements. Unless embedded spacers are as soft as the surrounding grout, they obstruct even slight compression of joints. The need for tile-to-tile joints to be compressible is not recognised throughout the industry. In a long-running dispute over drummy and collapsing wall tiles in toilets of a high-rise office building, recently settled for over a $A 1 million, the head contractor's quality assurance manager was adamant that joints between tiles do not contribute to relief of stress from differential movement. He insisted that this Is common knowledge - or perhaps conventional wisdom - in the construction industry.

It is worth recalling the advice given in the CSIRO report *Failures of Wall and Floor Tiles - Their Causes and Prevention.* It recommended "very weak mortar with fine sand" to prevent compressive stresses "... being transmitted from tile to tile until they build up to such an extent that the tiles will split or whole sections will be torn from their bed". It cautioned that "...large grains of sand may prevent the collapse of mortar when the tiles are compressed". The report was first published in 1951. The tallest buildings in Australia at that time were ten to twelve storeys high.

In 1973 the CSIRO published a four-page *Note on the Science of Building* which recommended that joints in wall tiling '...should be filled with flexible material or crushable grout". It was republished in 1987. In 1991 the Royal Australian Institute of Architects produced a Cautionary Note that listed the causes of recent failures of ceramic wall tiling. These included:

- Use of hard (non-compressible) grout and/or too narrow joints.
- Non-compressible spacers.

The industry was already experiencing problems from use of spacer lug tiles with glaze-covered lugs. which did not crush as intended, that is, which prevented very fine compression of joint grout. AS 3958.1- *Guide to the installation of ceramic tiles* was issued the same year as the RAIA's note. The tallest buildings in Australia were then close to 70 storeys.

Why is the height of buildings relevant? Tall concrete structures shorten progressively during and after construction due to the combined effects of concrete shrinkage, creep and elastic shortening, so-called because it is theoretically reversible; knock off a few floors and what's left will spring up a few millimetres. These phenomena did not receive much attention until the late 1960s and early 1970s. Accurate data was obtained from long-term monitoring of strain in several high-rise concrete structures in Chicago, Miami and Sydney. The work is summarised in 1987 in **Column Shortening in Tall Structures - Prediction and Compensation** by Fintel, Ghosh and Iyengar. The following excerpts from their work are particularly relevant:

> In high-rise buildings, the total elastic and inelastic shortening of columns and walls due to gravity loads and shrinkage may be as high as 1 inch for every 80 feet of height [equivalent to 1.04 mm per metre]. The possibly large absolute amount of cumulative column shortening over the height of the structure of ultra-high-rise buildings is of consequence in its effects on the cladding, finishes, partitions and so on. These effects can be contained by providing details at every floor that would allow the vertical structural members to deform without stressing the non-structural elements...
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> The shortening of columns [and walls] within a single storey affects the partitions, cladding, finishes, piping and so on, since these non-structural elements are not intended to carry vertical loads and are therefore not subject to shortening. On the contrary, partitions and cladding may elongate from moisture absorption, pipes from high temperature of liquid contents, cladding from solar radiation and so on. Details for attaching these elements to the structure must be planned so that their movement relative to the structure will not cause failure.

Frame shortening was recognised and well-documented in engineering journals by the mid-l970s. This quickly influenced the design of structures, cladding, lift systems and vertical pipework and the effects on mundane interior wall tiling were not widely appreciated. In sizing movement joints between storey-high curtain wall panels, designers in the early 1980s regularly allowed for long-term structural shortening of one millimetre per metre. Actual shortening was probably between half and one-third of this rate, say 0.35 to 0.5 mm per metre or 1.25 to 1.75 mm per floor. These values seem insignificant; If shared equally among narrow grouted joints between 150 mm high tiles in a typical toilet wall at the core of a high-rise building, compression in the grout amounts to 5% or less. Nevertheless, from direct observation I can confirm that obstruction of such minor strain by embedded spacers, uncrushable lugs and spillage of hard adhesives into joints, has contributed to widespread delamination of wall tiling in recent high-rise buildings in Melbourne, Sydney, Brisbane, Canberra, Singapore, Bangkok and Hong Kong.

In 1951 the authors of the CSIRO's report observed:

> A characteristic of tiling failures is the apparently haphazard way in which they occur. For example we find cases where tiling has suddenly failed after as many as 50 years of satisfactory service; or of one or two bad failures in a large number of walls or floors which have, as far as the builder can tell, been installed in an identical manner.
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> The reason for these apparently random failures lies in the fact that only rarely will any one cause be sufficient in itself to produce visible damage; the combined effect of two or more factors is usually required to produce stresses of sufficient magnitude to result in a failure. The immediate cause may well be a chance combination of circumstances which has raised long existing stresses beyond what the structure can withstand. As tiling may successfully resist for very long periods stresses only slightly less than those needed to produce failure, the change required may be quite small.

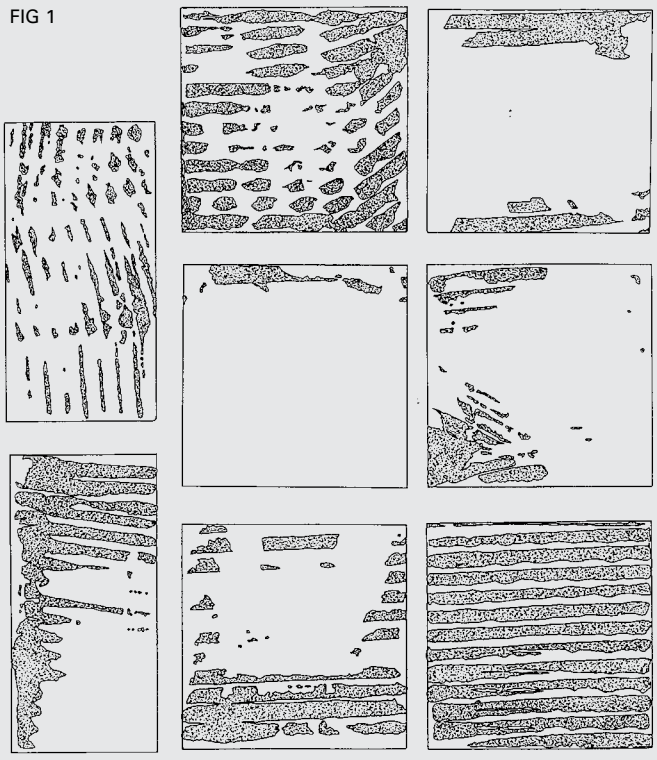
These observations have certainly been confirmed during recent investigations of tiling failures in high-rise and medium-rise buildings in Sydney and Singapore. Similar failures also occur in low-rise buildings if skirting level expansion joints are ineffective and gravity loads of suspended ceilings are transmitted to the uppermost course of tiles by rigid attachment of perimeter shadow-angles and trims.

We find that interior wall tiling is remarkably tolerant of overlapping and cumulative errors of design and installation. One investigation of widespread failures in a building of more than 60 storeys has identified no fewer than twelve defects which in some way contribute to recurring distress. Of course parties in dispute, as well as their lawyers and insurers, expect responsibility be apportioned according to the contribution of each defect, or even that a predominant cause be identified. That is rarely possible. It is possible, however, to identify a *sine qua non* factor, one without which the other defects would probably remain benign or latent. That concept is not always easy to grasp. It is not equivalent, by analogy, to the final straw that breaks the camel's back. It is the factor which synergizes or activates the rest. The *sine qua non* factor in many of the recurring wall tiling failures is obstruction of compression of joints by embedded cruciform spacers of hard plastic.

The third problem with cruciform spacers at corners is that they adversely affect adhesion of tiles **during fixing**, regardless of whether the spacers are embedded or removed before joint grouting. Conventional methods of wall tiling with thin-set adhesives require that each tile be pressed into the adhesive paste a few millimetres above and to one side of its final position. The tile is then twisted slightly and drawn downward and diagonally into place. Note: The purpose of this so-called *twist and slide* technique is to force ribs of adhesive to flatten, roll, spread sideways and merge. The technique also tends to drag and rupture any thin dessicated film that may have formed on the ribs during the working time of the adhesive. Skinned-over adhesive may not wet or bond to porous tiles. Premature drying of thin-set adhesives is a common problem in hot working conditions, on highly porous substrates and wherever tilers assume that adhesive manufacturer's published maximum working times are unnecessarily conservative.

Where spacer crosses are already embedded at the top corners of one course of tiles, their upward-protruding arms interfere with twist and slide action during setting of tiles in the next course. Many tile-fixers have overcome these obstructions by lowering the bottom edge of each tile directly onto the horizontal arms of spacers in the preceding course. They then rotate or hinge the tile on the spacers, press it flat against the adhesive ribs and beat it lightly enough so as not to disturb surrounding work. This technique can be very fast, but it significantly degrades contact coverage and adhesion. It tends to flatten ribs without forcing them to merge. It does not rupture or tear the surface of skinned-over ribs, particularly in the centre two-thirds of the tile. I believe the

FIG 1



evidence from BDAP's studies is incontrovertible. We have examined thousands of tiles and can reliably correlate different tiling techniques with patterns of coverage, reduction of initial adhesion and excessive working times. When the *hinge and thump* technique is combined with skinned-over adhesive, coverage rates typically range from nil to about 20%. We can also confidently distinguish adhesives that have been retrowelled after expiry of their effective working times. Shallow D-shaped recesses occur along the ribs. Some recurrent patterns of inadequate coverage are recorded in the illustration featured in fig 1.

If the BD/44 Committee's proposed proscription of permanently embedded spacers and cruciform spacers recessed at corners becomes contentious, I suggest that the proponents of these spacers sponsor the CSIRO to measure the relative merits of twisting and sliding and hinging and thumping. Meanwhile, side-by-side comparison of notched-trowel tiling onto frosted glass or plastic sheet, a simple method of demonstration used in Britain and Germany, may enlighten the doubters.

NOTE: The corresponding advice occurs in AS 3958.1 in a note under Clause 5.6.2(a)(i)

The front page of the Sydney Morning Herald chronicles newsworthy trivia. In June 1997 it reported:

Nature called yesterday while John Davis, of North Curl Curl, was visiting the Building Services Corporation's new offices in Castlereagh Street. In the men's toilets all the tiles were peeling off the wall. Whoever did the job sure chose the wrong place.

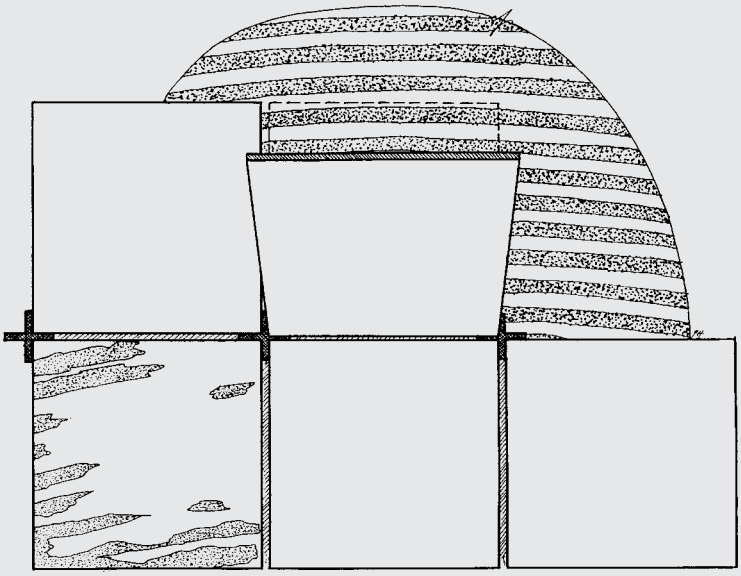


FIG 2 THE ALTERNATIVE *HINGE AND THUMP* METHOD OF TILE-FIXING ENCOURAGED BY THE USE OF CRUCIFORM JOINT SPACERS

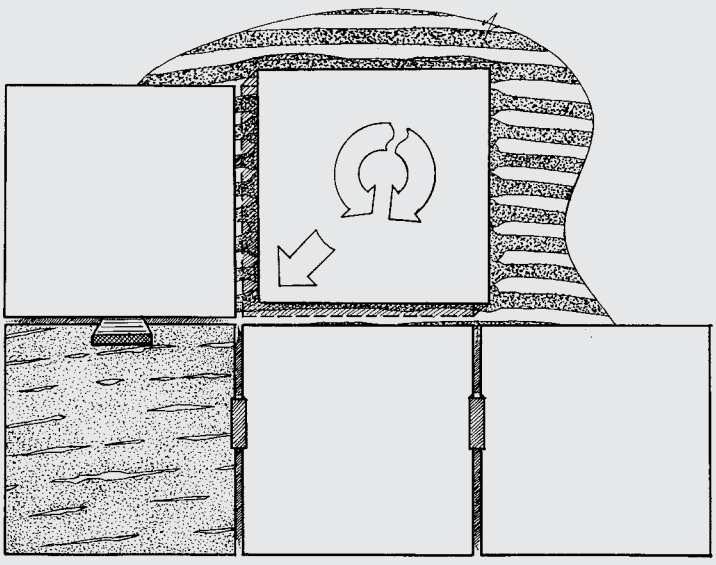


FIG 3 THE CONVENTIONAL *TWIST AND SLIDE* METHOD OF FIXING WALL TILES WITH THIN-SET ADHESIVE