shifting perspectives

We asked Richard Bowman for an update on ceramic tiling standards. In this first installation, he has provided some details of the Australian variations to the ISO 10545 ceramic tile test methods; some weaknesses of those test methods; and how the pursuit of sustainable development will require new standards that cover all ceramic tiles, not just first quality products. This will also impact on adhesives standards and codes of practice for fixing tiles, the topic of a subsequent paper.

Standards, by their nature, tend to be reactive rather than proactive. They are also evolutionary, and the process of evolution can take a long time (confounding predictions as to when particular standards will be published). This paper considers some of the internal and external drivers that can influence the development of standards.

'A preliminary introduction to the ISO ceramic tile standards', published in Issue 12 of *Tile Today* (August 1996), previewed the two ISO ceramic tiles standards: ISO 13006: 1998 *Ceramic Tiles - Definitions, Classification, Characteristics and Marking* (the product standard); and ISO 10545 *Ceramic Tiles - Test Methods*. That paper introduced each of the ISO 10545 ceramic tile test methods and reported that 14 of the 17 parts had then been published. The current status is given in Table 1. Several of these test methods have Australian variations that mainly clarify or improve the procedural details without affecting the test results. The Australian version of ISO 13006 should be published in mid-2000 with minor variations to clarify some of the terminology.

The governing committee, ISO/TC 189 *Ceramic Tiles*, last met in July 1992. Since then, WG 1, Ceramic tile test methods, has met to try to resolve difficulties with part 17, the test method for coefficient of friction. This slip resistance test method was dropped from the ISO list of tests in November 1999, but is being pursued within Europe as prEN 13552, with the same text as before.

ISO/TC 189 WG 3, Adhesives and grouts - test methods and requirements, has met several times whilst preparing new adhesive and grout standards (as detailed in Issue 21 of *Tile Today*). SAA Committee BD/44/2, *Ceramic Tiles Adhesives*, has recommended that these be published as interim Australian Standards as soon as possible.

Identified weaknesses

At Qualicer 2000, the world's most informative ceramic tiling congress, Bill Walters (of Ceram Research, the UK Cerlabs member) gave a paper 'Product standards their strengths and weaknesses'. He stated "The way some of the tests are written make visual assessment and characterisation difficult. Visual assessment is difficult anyway as can be deduced by the different results sometimes seen in the surface abrasion test. Some of the claimed performance results are very high - far higher than the real results. It is interesting to note that companies never claim performance results that are poorer than the real results. Whenever there is a difference the company result is always better than the independent results." CSIRO BCE would agree with this with respect to some imported tiles, although such comparisons are principally made when products do not perform in accordance with consumers' expectations. Australian manufacturers are generally very conservative in the claims that they make. However, it must be recognised that all manufactured products exhibit some variability in their characteristics, and the claims that are made are often based on the most recently obtained test results.

TABLE 1 RELATIVE ADOPTION OF ISO 10545 AND AS 4459 WITH BRIEF DETAILS OF INFORMATIVE (I) AND NORMATIVE (*) AS 4459 APPENDICES.

Part	ISO 10545 Test method	Adopted	AS 4459 details
1	Sampling and basis for acceptance	1995	1999 (I) - sampling of existing laid tiles
2	Dimensions and surface quality	1997	1999
3	Water absorption, porosity & density	1995	1999* Procedural improvements Additional reporting requirements
4	Modulus of rupture & breaking strength	1994	1997
5	Impact resistance	1996	1999* Unsuitability for non-flat tiles
6	Abrasion resistance - unglazed tiles	1995	1999* Procedural improvements
7	Abrasion resistance - glazed tiles	1996	1999* Procedural improvements Additional reporting requirements
8	Linear thermal expansion	1994	1997
9	Resistance to thermal shock	1994	1997
10	Moisture expansion	1995	1999* (I) - testing of aged tiles Refined measuring procedure
11	Crazing resistance	1994	1997
12	Frost resistance	1995	1999* Clarification of procedure
13	Chemical resistance	1995	1999* Clarification of procedure
14	Stain resistance	1995	1999* Procedural improvements
15	Extraction of Pb & Cd - glazed tiles	1995	1999
16	Small colour differences - glazed tiles	1999	To be published in 2000
17	Coefficient of friction	Dropped	AS/NZS 4586:1999

Bowman identified similar weaknesses in 'An Abrasive Open Letter' (Issue 11 of *Tile Today*, May 1996). As a consequence, the Australian variation to ISO 10545-7 notes that this test is also used with unglazed fully vitrified tiles, particularly those that have been surface treated (to improve characteristics such as stain resistance) or polished. It permits use of white corundum grit that is of nominal F80 size provided that the apparatus is appropriately calibrated (thereby removing the need to demonstrate particle sizing compliance). It permits an alternate abrasive load checking method (given that the one that was introduced, after WG 1 had concluded its discussions, is totally impractical). It specifies a grey colour shade for the interior of viewing box, and provides a definition of a darkened room. It provides rational requirements for the observation phase. However, most significantly, it introduces additional reporting requirements: "It is expected that where an independent laboratory conducts this test, that they will report whether there has been a significant gloss change, and, if it occurs, the abrasion stage at which the stain resistance of the tiles changes". While the gloss change may still be subjectively assessed, a proposal will be formulated for instrumental assessment.

Walters notes "In the chemical resistance test the guidelines for assessment are not really clear. Quite obvious changes to the glaze can fall into the category B and thus are deemed to have passed the test. This seems quite wrong. Despite removal of the surface, which would constitute a failure, the colour change itself should also constitute a failure since it is so obvious. The standard does not give this as an option to fail the tile". The Australian variation includes a comprehensive diagram to facilitate the chemical resistance classification of glazed tiles.

Problems also exist with testing the chemical resistance of unglazed tiles, where the classification is based on three options: no visible effect; visible effects on cut sides; and, visible effects on cut sides, non-cut sides and on the proper surface. In order to fail a tile, an internal cut edge must display a visible effect, where again "If the hue becomes slightly different, this is not considered to be chemical attack". Where 'protective coatings' (ultra-thin glaze films?) are applied to 'unglazed' tiles, chemical attack may change the appearance of the surface and external edges of the tile, but such a change will not occur on the cut edge because this surface was never treated. How pronounced does the difference have to be, and how does one know what is a slight difference and what is not? There is now a test method for determining small colour differences, but ISO 10545-16: 1999 restricts its use to plain coloured glazed tiles and notes that it should only be used when small colour differences are important in a specification. Should an unglazed tile receive a lower chemical test classification if it loses its gloss? Gloss can be easily measured instrumentally.

Walters states "In the dimension test, tolerances are given in % terms, but as tiles get larger the variations get so large that grout lines vary enormously between say 1 and 10 mm. This would give any tiled area a poor look. Companies get round this by having a range of up to ten different calibres for tiles of the same nominal (pressed) size. The problem with this arrangement, in UK at least, is that customers do not realise that tiles of the same nominal size can vary so much because of the calibre. It is possible, therefore, to buy a variety of sizes which cannot be used together".

On impact resistance, Walters notes that the ISO 10545 test "only reports on the coefficient of restitution. No reference is made to any surface damage to the tile which might be imparted by the ball bearing. In fact, this test on glazed tiles in particular can damage the surface. Such damage is often seen in normal use, but at present this problem is outside the scope of the standard tests". Actually, the standard requires that "any indentation or cracking of test specimens" be reported.

Walters is most concerned about the proposed slip resistance tests (that are likely to again become a draft ISO standard if the Europeans can resolve their differences). "Firstly, there are four vastly different methods of measurement, all giving results which do not necessarily correlate. There is no guidance - and this is crucial to specifiers and architects - on limits although there is information outside the standard. The different methods can give different results as to suitability when reference to the guidance information is made. Most commonly, wet Tortus results can suggest a tile is suitable whereas the wet pendulum results will say the opposite. This is an impossible situation for a specifier. All the proposed tests are for shod conditions only - no barefoot test is included. For this latter condition the German barefoot ramp test has to be used. Finally, I am a firm believer that none of the tests so far advocated can cope equally with all types of surface texture and profiling and all types of footwear and that anomalies arise because of this". The British, led by the national Health and Safety Executive, have voted negatively on prEN 13552 because it contains a wet Tortus test.

Australia is perhaps fortunate to have AS/NZS 4586 - 1999, *Slip resistance of new pedestrian surface materials*, and SAA/SNZ HB 197 - 1999, *An introductory guide to the slip resistance of pedestrian surface materials*. AS 4586 incorporates the German barefoot ramp test and excludes the Tortus wet test. HB 197 provides guidance to architects and specifiers. It rejects the concept of a universal minimum slip resistance threshold value that is both practical and safe. It states that "In equating safety with a coefficient of friction, one has to consider all the relevant variables, as well as whether the result has been unduly influenced by the method of slip resistance measurement". HB 197 recognises that all the test methods have inherent limitations and provides some cautionary advice. Unpublished CSIRO research is indicating where the wet Pendulum test may be under- or overestimating slip resistance. One shouldn't expect all the test results to correlate, but should choose the appropriate test method.

Walters recognises that "There are many innovative processes now in use in tile production which modify the surface in any number of ways. The standard only recognises glazed and unglazed and it is quite difficult in many instances to decide which category the tile falls into. This of course is very important to the different wear tests for each category. We at CERAM have sometimes performed the wrong test. This is usually the surface test because our feeling is that the surface layer is different from the rest of the tile when the manufacturer claims that this is not the case and therefore, the deep abrasion test should be done. Perhaps the most obvious instance of tiles with a modified surface is the polished tile. This is regarded at present as unglazed, but in fact this surface is far more like a glazed surface. So should the surface wear test be performed? It is also a fact that polished tiles can be less stain resistant. This is because micropores are opened up in the polishing process."

When voting negatively on the adoption of ISO 13006 in 1995, because of the coefficient of friction provisions, Standards Australia noted several weaknesses. While the definition of a polished surface - "surface of an unglazed tile which has been given a glossy finish by mechanical polishing as the last stage of manufacture" - was appropriate, there was "no indication as to whether a polished tile must be tested as an unglazed tile, or whether it may be tested as a glazed tile". Since manufacturers are now polishing the surfaces of glazed tiles, the definition is now inappropriate. In 1998, CSIRO suggested that SAA might have to provide appropriate information in the form of a local variation when adopting the standard. However, such changes should not be made unilaterally if they might cause greater confusion.

ISO/TC 189 needs to reconvene to uniformly address the recognised weaknesses. Standards Australia has already taken a lead in this by adopting some local variations to the

test methods However, there is another spectre that must also be addressed.

The pursuit of sustainable development

In Europe, the Construction Products Directive (CPD) mandates that any construction product, which is covered by the CPD, shall have such properties that the building or structure is able to fulfil specific essential requirements regarding:

1. mechanical resistance and stability
2. safety in case of fire
3. hygiene, health and environment
4. safety in use
5. protection against noise
6. energy economy and heat retention.

Ceramic tiling is covered by European Mandates M/119 Floorings, M/121 Internal and external wall and ceiling finishes, and M/127 construction adhesives. Walters states "The mandates refer to all forms of cladding not just ceramics. Hence, about 12 technical committees are all putting forward work programmes independently. The fact that compliance is required from all material used means that products not of first quality must be included for the first time in terms of tile standards".

The CPD interpretative documents include the statement "Where provisions concerning the durability of works in relation to the Essential Requirement are connected with the characteristics of products, the mandates for the preparation of European standards and guidelines for European technical approvals, related to these products, will also cover durability aspects". The Europeans, who dominate the ISO/TC 189 Committee, are clearly somewhat limited with respect to adoption of new ceramic tile standards, since most of the test methods relate to aspects of durability, safety or hygiene.

While the impact of the CPD has still to be determined, the New Zealand Building Code has, since 1992, contained quantitative requirements for the service life of various parts of buildings and for construction products. Clause B.2.3 commences "From the time a code compliance certificate is issued, building elements shall with only normal maintenance continue to satisfy the performance of this code for the lesser of; the specified intended life of the building, if any, or:" (as far as ceramic tiles are generally concerned) "For other fixings of the building envelope and attached structures, the building envelope, lining supports and other building elements having moderate ease of access but which are difficult to replace: 15 years".

The pursuit of sustainable development reflects environmental concerns and will essentially require the production of performance-based standards. Before considering how this might be achieved, one will need to differentiate between functional performance and aesthetic issues. The gradual accumulation of scratches on floor tiles might be unsightly, but it may not impair their performance. There is a need to predict service life, recognising that this will depend on several factors.

The ceramic tile standards have traditionally relied upon simple measures of characteristics, both quantitative and qualitative. Although some of these measures have been hard to relate to in-service performance, they have had a logical basis. However, it is hard to predict durability when products may be subjected to an extreme range of conditions, where the performance might be more related to other system components than the intrinsic characteristics of the product. For instance, the impact resistance of a floor tile is influenced by the resilience of the adhesive and the substrate.

Accelerated qualitative ageing tests (for instance the ISO 10545-7 surface abrasion test) can make some products look good (light coloured tiles) and others bad (dark coloured tiles). However, soiling of the tiles in-service will accentuate any degradation of a light coloured product whilst tending to mask it in a dark coloured product. While extended surface abrasion test cycles will remove the surface layer of products, the process is one of polishing rather than of grinding or scratching. The latter processes are more commonly encountered in-service externally, or where coarse hard particles are introduced into an internal environment. This is not to say that the simulation is fundamentally flawed, since it is impossible to simulate all possible degradation mechanisms and weathering stresses in the laboratory. A part of the problem is that there have been very few studies of how products perform in-service, where the degradation factors are measured and any degradation in the product is quantitatively determined. Given vast product ranges, and the short life cycle of some products, such studies are unlikely to be widely undertaken.

Designers need to have information on durability to meet the building owners' requirements and to develop a rational policy for the durability of the tiling system. Such information should logically be obtained from:

- experience in the use of traditional materials and fixing systems
- certificates assessing the performance of products
- research publications
- predictions of the service life of products provided by their manufacturers

It should be noted that there are relatively few recent research publications since there is little competitive advantage for manufacturers in conducting individual studies, and the mechanisms for joint commissioning of independent studies are poor.

It should also be noted that relevant test certificates are not always available from some manufacturers, particularly where tiles have been imported. Several manufacturers state that products comply with the various quantitative test methods rather than providing a specific figure. Some manufacturers will state that their products exceed a specific figure where this is more demanding than that required by the standards. Other manufacturers will report a value, but this provides no indication of variability, and some degree of variability must be expected in any manufactured product. Such differences in reporting make it hard for an expert to make a meaningful comparison between products. One presumes that architects and specifiers are only expected to ensure that products comply with the standards rather than using such data for design purposes.

The situation is also uncertain with respect to tests based on qualitative assessments, given the breadth of possible

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interpretations, and the fact that some claims are exceedingly conservative whilst others might best be described as optimistic. This may partly reflect cultural differences, both with respect to consumer expectations and the propensity to litigate. Experts can have great difficulty in making a meaningful comparison between products based on technical data sheets. Unless some tests are again conducted, any inappropriate subjectivity will remain unrecognised.

Where the service life of a tile or a tiling assembly has to be predicted, this could logically be based on a principle of demonstrated effectiveness where identical assemblies have been successfully used in the same environments. Where the environment is moderately different, some modelling of any deterioration process may be required. Where proven components or assemblies are to be used in significantly different environments, or where innovative components and assemblies are to be used, some modelling and testing is likely to be required.

While such considerations may influence the evolution of tile and tiling standards, there is an immediate need to provide architects and specifiers with better guidance. This will partly be achieved through the revision of AS 3958, details of which will be provided in a continuation of this paper. In 1996, BRANZ published *Good Tiling Practice*, which provides a useful adjunct to AS 3958 even though it contains some conflicting advice and outdated data. The Australian Tile Council is looking at producing an updated version of this as a Handbook.

The Spanish have provided the most logical approach to developing guidance for architects and specifiers, as evidenced in the presentations that Dr José Luis Porcar made at Qualicer 98 and Tilex 98, and in a "Ceramic Tile Guide", available (in Spanish) at **http://www.ascer.es/es/gbc.pdf**. This involves a functional tile classification, which gives two numerical identifiers and up to three alphabetical identifiers based on the dimensional characteristics, mechanical characteristics, and additional characteristics (chemical, frost and slip resistance). Tiles are selected for specific building domains (rooms and areas associated with different classes of buildings), where each domain establishes minimum requirements for either floor or wall tiling (based on the desired grout joint size: less than 3 mm, or 3 mm and greater). It also provides guidance on finding the appropriate tile installation technique, considering the intrinsic characteristics of the backgrounds, substrates, movement joints, bedding technique and materials, type of tile, and selection of grout and back-up materials. Related software is being developed where inputting the domain details will provide the best tile installation solution, without the fixer or merchant having to remember tile characteristics, as these are implicitly expressed in the tile code.

This system could be readily adopted in Australia. Although it uses wet (Tortus) Floor Friction Tester results for determining whether or not a tile is slip resistant, it would be relatively easy to provide additional slip resistance requirements using SAA HB 197 (once expanded to cover domains such as hotel bathrooms).

The Spanish system imposes more stringent dimensional tolerances than the ISO standards, particularly on large format tiles. It recognises the need for testing stain resistance and gloss loss after determining abrasion resistance of glazed tiles. However, it also requires some characteristics that are common to all uses, such as crazing resistance, stain resistance, and a maximum moisture expansion of 0.06%.

Consideration needs to be given how such a system might be extended to include second quality tiles. Tiles that have a large moisture expansion potential can be successfully used after being aged. However, this may require that the standard be varied to accommodate a test where the tile is not reheated prior to artificially inducing accelerated expansion. The informative appendix to AS 4459-12 already permits a most significant variation: '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 refiring 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 moisture expansion has contributed to any differential movement failure, it should be noted that a large amount of the expansion will may (sic) have occurred prior to the installation of the tiles'. The word 'may' is likely to be replaced with the word 'probably'.

The pursuit of sustainable development is based on the need to conserve material and energy resources. Condemning a product because it may craze or stain would be counterproductive. When mechanical stresses induce crazing, tiling systems are not condemned, although recognition of such defects may bring about plans for renovation. Second quality tiles might be used in temporary buildings or in facilities that have a short design service life. Standards and national building regulations will need to accommodate the sensible use of second quality products.

In conclusion, ISO/TC 189 needs to reconvene to formulate a policy for modifying the ISO 10545 ceramic tile standards. In the short term, it must address any recognised weaknesses, particularly where these have resulted in national variations. It must also tackle how to revise the test methods in order that the results might provide better service life predictions.

Richard Bowman is Chair of the Standards Australia committees on ceramic tiles, fixing of ceramic tiles, ceramic tiling adhesives, and slip resistance of pedestrian surfaces. He leads the Standards Australia delegation to ISO/TC 189. He is also a past President of both the International Ceramic Federation and the Australasian Ceramic Society, and is on several international advisory committees. Richard is a Principal Ceramic Scientist and leads the Optimisation of Tiling System Performance and Smart Slip Resistance Systems Projects at:

CSIRO Building, Construction and Engineering,
PO Box 56, Highett, 3190
Fax: (03) 9252 6244
Tel: (03) 9252 6021
e-mail: Richard.Bowman@dbce.csiro.au.