DEVELOPMENT OF CERAMIC TILE QUALITY SYSTEMS - KEEPING UP WITH CONSUMER EXPECTATIONS

by Richard Bowman

CSIRO Division of Building, Construction and Engineering
(Australia)

ABSTRACT

There is a wide range of «tile consumers» whose needs and expectations vary greatly. The proposed ISO Standards for ceramic tiles are a significant advance, and their promulgation will meet several of these needs and expectations. The activities of CERLABS member laboratories and other bodies should facilitate the introduction and consistent use of the Standards. Considering the diversity of consumersí interests, perhaps the litmus test for the ISO Standards may be in determining where the legal liability lies for failures of products that conform with the Standards, but are basically unsuited to the purpose for which they have been used. This will vary internationally, depending on the Standards for tile fixing practices and on the nature of the legal systems. This paper will consider the development of ceramic tile quality systems, paying attention to the different interests of tile and adhesive manufacturers, test houses, tile merchants, architects, builders, tile fixers, building owners and regulatory authorities.

INTRODUCTION

The above abstract is essentially the summary of a paper, «Will the proposed ISO ceramic tile standards meet consumer expectations» [1], given at the 95th Annual Meeting of the American Ceramic Society. That paper recognised that while the draft ISO Standards for ceramic tiles represent a considerable advance on existing national Standards, there would inevitably be some difficulties associated with their adoption during the transition phase. It was anticipated that these would mainly relate to adjusting to modifications in test procedures, becoming familiar with new test methods, and universal education as to the interpretation and application of the acquired results. These difficulties will hopefully be minimised by the proactive initiative that CERLABS, the European Network of National Ceramic Laboratories, has now instigated. Before detailing this, it is appropriate to consider the environments within which these and other Standards are applied.

MANAGING CHANGE

Pressure to improve quality and value is being experienced by all sectors of the community. The building industry, which is composed of a host of relatively small, independent organisations, is no exception. However, it has a unique problem since the processes of planning, design and documentation, and construction can involve hundreds of individuals and organisations, in thousands of decisions and actions, over extended periods of time [2]. At the 1st World Congress on Ceramic Tile Quality, Bowman and Leslie [2] sought international collaboration in developing a computer-based expert system in order to ensure the quality of ceramic floor tiling installations. They outlined a pilot study for the selection and installation of floor finishes with respect to the issues involved in planning for whole building quality and the management of building information. The proposed system, which was intended to support performance-based decision making, had two distinct but related stages. The first sought to assist the practitioner identify the most appropriate product(s) for a particular application. The second was to assure, once a particular product has been selected, that its potential «quality» is real by offering information on its installation and maintenance in accordance with the relevant installation Standards.

At the 2nd World Congress on Ceramic Tile Quality, the contents of the British installation Standards and the Council of America Handbook were detailed [3,4]. These were used as the basis for the Australian Standards [5,6], which sought to adopt the best features of the British and American approaches [7]. It is anticipated that the European installation Standards will further extend this strategy and accommodate regional differences in building practices, materials and climate, besides possibly considering local regulations. Such codes of practice recognise that it is the entire multi-layer system that must withstand the different types of applied stress, rather than the ceramic tile, and accordingly provide models for the composition of a system according to the specific requirements of the destined environment. These models respect two fundamental design criteria: namely that the materials used must have the necessary chemical-physical-mechanical characteristics to withstand the stresses they will be subjected to; and the materials must be assembled in such a way as to prevent any interference that would compromise the behaviour of the composite system.

Figure 1 summarises the process of designing a ceramic tiling installation, where it can be seen that the overall process comprises a number of sub-systems. Significantly, once the project requirements have been established, the design process may commence with a choice of either the materials or the bedding system, with any selection defining subsequent options. In the final analysis the compatibility of all selections must be verified. While a computer-based expert system can be designed to identify those products whose performance profiles match the performance characteristics selected by the operator, the adequacy of the advice depends on the relevancy of the methods used to characterise the products, and the consistent universal application and interpretation of such test methods. Furthermore, the composite expert system depends on the adequacy of the overall model. Accepted tiling systems have evolved from a process of refinement rather than on a detailed understanding of the behaviour of systems based on the reactions within and between the system components given specific operating environments. Such understanding essentially requires finite element modelling extensively refined through confirmatory studies of physical experiments.

DEVELOPMENT OF PRODUCT STANDARDS

Product technical literature commonly comprises analytical data predominantly determined in accordance with published Standards. The test methods in these Standards have essentially been developed from manufacturers' quality control procedures. The process of standardisation is based on the establishment of consensus, and this is obviously facilitated by the adoption of existing test methods. These tests were developed to provide a rapid indication of product quality so that the process could be quickly adjusted to maintain a consistent minimum level of acceptability. They accordingly typically determine properties that may only indirectly relate to product performance characteristics. Other accelerated test methods have been developed in order to fulfil consumer expectations with respect to

specific performance requirements. However, it is difficult to interpret some test results due to poor correlation between artificial accelerated treatments and the actual performance under various different environmental exposure conditions. Achieving better correlation is important, and increasing levels of consumer expectations are providing a constant driving force for the development of test methods which are more discriminatory. Innovative products that meet the needs of high-tech construction also compel evolving product and installation Standards.

Although consumer expectations represent quality parameters, there are different levels of expectations due to technological, sociological, cultural and environmental factors. Thus, some Asian countries have indicated that they want procedures to discriminate levels of quality, while retaining the right to determine acceptance. Thus, while the ISO Standards might establish the basis for international trade, regional trade might be based on less rigorous compliance criteria. This reflects the construction of several million dwellings that have been found adequate, even though some construction materials and practices would not comply with Western Standards. Conversely, local statutory regulations may impose more rigorous or alternate compliance criteria, particularly where safety issues are involved such as slip resistance. The development of criteria in such cases may require a multidisciplinary approach, involving perhaps a materials scientist, an ergonomist and a legal expert.

QUALITY SYSTEMS

A quality system may be defined as the never-ending attempt to bring a product into line with consumer expectations. This requires an identification of who the consumers are and a determination of their various expectations. Once these needs have been identified, the manufacturer must translate them into terms of production goals, which in turn are generally defined in terms of established test criteria. Since the process of product development ultimately requires consumer field assessment, it is to a great extent one of directed trial and error, where it may be necessary to establish the validity of a range of adjusted production goals. This process can obviously be applied to the production of Standards, but the lengthy process of revising drafts often requires that rather than being perfected, they are issued as the best consensus attained within a publication cycle.

CONSISTENT UNIVERSAL INTERPRETATION

One of the functions of technical product literature is to help us understand product quality, and this aim is poorly served through the inclusion of data that has little significance to product performance. Appropriate interpretation of such data is often within the realm of the specialist, since the suitability of a product will often depend on the specification of compatible materials and an applicable system. This is especially true of adhesives where there is often a one-way flow of information. The manufacturer promotes the benefits of a product to tile merchants, advising on the relevant areas of use and the most appropriate means of application. The tile merchant then advises the tile fixers, but the fixer rarely communicates his perception of the product to the manufacturer. Furthermore, little guidance is provided on how to adapt the preparation and application of the adhesive to cope with adverse situations and conditions. When such circumstances occur, time considerations or poor communication of the problem and its solution may result in inappropriate action, disposing the system to subsequent failure.

Although Australian manufacturers of tiling adhesives indicate the workability characteristics of their products, it is difficult to comparatively evaluate different manufacturersí products as they have established their own test methods given their omission from the relevant Standard, AS 2358 [8]. While this prevents sensible interpretation, a more serious problem arises from inconsistent interpretation of Standards. As shown in the following examples, this can occur for several reasons including imprecision or lack of direction within the Standards, the provision of alternative test methods, subjective visual interpretation of test specimens, and the application of different test methods and compliance criteria to

different products when determining the same characteristic.

AS 2358 [8] specifies the use of 1.5 mm stainless steel rods to achieve constant adhesive bed thickness. As part of the procedure for assembling thin-bed adhesive shear bond strength test specimens, it states:»After approximately 15 min, remove the spacing rods». As Table 1 indicates, pin removal time can have a significant influence on adhesive strengths, particularly when high water absorption test tiles are used. The presence of the setting pins prevents shrinkage of the adhesive as liquid is absorbed by the tiles, often resulting in shrinkage cracking at the tile perimeter. Interestingly, the tensile bond strength test states:»As soon as the adhesive or prepared mortar has set sufficiently, remove the spacing rods», however it gives no basis for determining whether the adhesive has set sufficiently.

Table 1. Effect of pin removal time on 7-day water immersion shear bond strength of a premixed commercial organic adhesive previously conditioned for 28 days.

Time of pin removal, min.	28-day shear strength, MPa
0	2,46
15	2,11
30	1,85
60	1,50

Although the relative absence of precise test procedural detail may lead to increased variation of results between laboratories, this will probably only be significant when products are close to the acceptance criteria for specific classes. A prime example would be that the primary classification of tiles may depend on the cooling rate adopted during water absorption determinations. Thus, such determinations may be influenced by the size and design of the boiling tank. For example, the CSIRO Division of Building, Construction and Engineering constructed a heavily insulated boiling tank to conserve energy, and this maintains specimens close to boiling temperature until forced cooling commences. ISO/TC 189 has purposely written the test methods to be as flexible as possible to allow for existing equipment variations.

ASTM C424 [9] provides two strategies for determining the crazing resistance classification of glazed products. One can either test specimens using the individual autoclave cycles, or one can consecutively subject the same specimens to each regime. Since the autoclaving treatment is intended to cause moisture expansion of the body, the latter strategy should cause greater cumulative expansion resulting in a lesser classification [10].

EN 154 [11] permits the abrasion resistance of glazed tiles to be determined using either the (so-called) PEI wet or MCC dry test methods. Unfortunately, the two test methods do not always result in the same classification. Australian producers exclusively use the wet test procedure. However, a few imported products, which are labelled as class IV on the basis of the dry test, only achieve class II or III when the wet test method is applied. Most ceramic tile technical specification sheets do not indicate which of the test methods has been used to determine the abrasion resistance classification. There appears to be a general tendency for Australian tile merchants to call a class IV tile a PEI IV tile, most probably because few people are aware of the occasionally used alternative test method. They have thus been advised [12] to check that imported tiles have been classified on the basis of the PEI method, since an incorrect assumption may leave them legally liable if the tile has poor abrasion resistance and has been classified on the basis of the MCC test. The draft ISO Standards for ceramic tiles do not recognise the MCC test method.

EN 154 [11] also relies upon a subjective viewing procedure. The identification of whether a product passes or fails this inspection depends on oneís interpretation as to whether or not the abrasion «can be readily distinguished» visually. Since the viewing conditions do not permit determination of a loss of gloss, which is often a cause of consumer complaint, Australian manufacturers have taken the most conservative interpretation of the viewing procedure, so that borderline products have been purposely downgraded.

EN 106 [13] and EN 122 [14] respectively determine the chemical resistance of unglazed and glazed tiles. Since EN 106 uses more corrosive solutions, specifiers have not always recognised that a tile that has passed EN 122 may have poorer chemical resistance than an unglazed tile that has failed EN 106. The draft ISO Standards have addressed this anomaly.

One should also consider the influence of the adequacy of the design of test equipment. There could be small design differences that could render some equipment more prone to unheralded malfunction that may prove hard to even detect. Some equipment is more operator-friendly and this may help eliminate operator-induced errors, either in the generation or interpretation of data. Furthermore, the trend towards increased reliance on instrumental results has also reduced the degree of intuitive feeling as to whether results are correct.

CERLABS INITIATIVE

As tiles are traded on the basis of their compliance with Standards, such inconsistent interpretations potentially threaten international trade. Bowman [1] thus proposed that CERLABS, the European Network of National Ceramic Laboratories, should adopt a proactive position with respect to the draft ISO ceramic tile Standards. CERLABS has decided that the first step in enabling consistent universal interpretation, is to publish a book detailing its consensus position. A discussion of each test method will establish its rationale, and to some extent the limitations of its application, for example, the test to determine crazing resistance is based on inducing moisture expansion within the body - it cannot predict the crazing resistance where stresses are induced by other movements within the tiling system. The book will then consider each test procedure drawing attention to factors that might influence the results, and providing direction to resolve any areas of potential ambiguity. An extensive pictorial approach is being adopted to assist in the definition of defects, and the determination of acceptability where subjective viewing procedures are used. It is intended that this book will be published in loose-leaf format. This will enable it to be updated as necessary, including references to recent authoritative papers. This approach will also minimise the cost of producing translated versions.

The second stage will be for CERLABS members to promote this consensus position within their own countries and regions, through appropriate educational activities such as training courses for laboratory staff from the manufacturers and other test houses, and seminars for architects, specifiers and tile merchants.

CONSUMER EXPECTATIONS

There is a general expectation that Standards will provide guidance, that products passing Standards are suitable, and that manufacturers and design professionals will provide suitable guidelines. Given the varying size of projects and differences in contractual arrangements, the following partial list of expectations is not exclusive to the parties to which they have been allocated. It is recognised that on several projects some persons may have multiple roles or responsibilities, not all of which are necessarily listed or mutually compatible. For instance, the design professional, who is initially responsible for determining, addressing and resolving the demands of codes, Standards and other regulations, may have a conflict of interest, in the case of a design omission, if he is ultimately responsible for inspecting the work and declaring it to be acceptable.

Regulatory authorities expect that the Standards will be sufficiently extensive so that they can prescribe particular requirements for specific types of facilities. These may be based on federal or local building regulations, or on health and safety requirements. They are starting to expect that Standards and building codes be performance based.

Government departments expect that specifications will cover function, performance, material and technical details. They should allow suppliers the maximum opportunity to compete for business on the basis of value for money. This entails providing an accurate description of requirements in a readily understandable manner, and this relies heavily on accepted Standards that establish material, engineering, workmanship or technical limitations and applications. They expect that suppliers can provide quality assurance, all those planned and systematic actions necessary to provide adequate confidence that goods or services will satisfy given requirements. They do not expect biased specifications written around a particular product or service.

Building owners expect a perfect, durable system. They expect that they will be supplied with suitable products and adequate advice. This may extend to being asked sufficient questions to enable them to have adequate information to make a decision about a general requirement that they may have defined poorly. Tiles are widely perceived to be a safe, durable, environmentally friendly, low maintenance product offering limitless decorative possibilities.

Architects hope that their clients have correctly and comprehensively communicated their requirements and expectations. They expect that manufacturers not only know the limitations of their products, but will also help them, as designers, service their clients.

Specifiers anticipate that they will have been provided with all of the information that they require in order to specify a functioning system. This includes the amount of movement that can be anticipated. They expect that tile fixing Standards are sufficiently comprehensive to cover the majority of situations that might be encountered. They also expect that product suppliers can give them accurate, reliable and timely information about their products and how they should be installed. They expect that new tiling systems have been adequately and extensively tested, particularly prefabricated exterior cladding. They may expect that manufacturers will be able to provide independent verification of test results.

Tile manufacturers expect that their products will be appropriately installed in a suitably specified system, and that specific guidance will be sought as required. General advice must be to use the Standards and to follow the adhesive manufacturers' recommendations.

Adhesive manufacturers expect specifiers and tile fixers to consult them or their literature regarding the most relevant selection and appropriate use of their products. They expect that ancillary products will be used in accordance with their recommendations. They accept that in installing tiling systems, one is unlikely to have ideal conditions, substrates or workmanship, but hope that there is an adequate factor of safety to compensate for this and to tolerate any subsequent structural movement and service exposure conditions.

Tile merchants expect that the ceramic tile and adhesive product Standards will provide adequate discrimination of products based on a reliable representation of their fitness for specific situations. Where the Standards do not reliably indicate fitness of purpose for specific situations, they expect that the manufacturer will provide them with sufficient data that they can provide guidance to their customers. They not only expect that products will comply with Standards, but are also starting to expect that the manufacturers have adequate quality assurance procedures that will assist them in developing their own quality assurance procedures in order to fulfil.

A builder expects that those expectations and requirements, which the building owner expressed to the architect, have been adequately and responsibly communicated to him in the form of specifications and

drawings, and that any crucial aspects that must be observed have been brought to his attention as specific instructions, such as what constitute adverse weather conditions and how to protect against them. He does not expect manufacturers to couch the limitations of a product in ambiguous terms hidden within a product warranty. He is not surprised to receive a general specification that has not been customised to the project in hand, effectively requiring him or the tiling contractor to assume responsibility for the tiling system design and materials specification.

Tile contractors expect that they have been provided with all the information that they require to successfully complete an installation, including the locations of control joints on drawings. Where specifications appear inappropriate, they may consider it unnecessary to seek approval for varying them. Where a proprietary adhesive has been specified, they anticipate that the manufacturer can provide proper guidance for its use, including detailed instructions on how to adjust its use to accommodate extreme environments and job-site conditions. Where such data has not been provided, they anticipate that it can be readily obtained from the manufacturer, his agent or the tile merchant who supplied it. While they also expect that preceding construction will have been performed in a proper manner, they must check the quality of workmanship associated with tiling substrates as their commencement of work is essentially an indication of the acceptability of preceding work. They also expect that there will be a sufficient number of skilled operatives who can competently install the tiles. This expectation extends to a knowledge of how to tile in adverse weather conditions, and specifically, proper mixing of the adhesive, placement of sufficient adhesive, replacement of worn notched trowels, placing of tiles before the adhesive skins, application of sufficient force to bed the tiles recognising that this is dependent on the size of the tile, and allowing for the installation of flashings, movement joints, etc.

Tile fixers expect that they will receive adequate remuneration for their services, and that contractors will recognise that the quality of their workmanship is partly dependent on the time allowed for completion. They do not expect their work to be closely supervised. They expect that their efforts to protect new work will be respected. They are aware that due to the nature of their work, that once the tiles are installed, there are relatively few non-destructive tests to accurately determine the quality of their workmanship.

Building inspectors expect that the workmanship under the tiles will be acceptable, and that if the tiling is well set out and without obvious defects, and appears solid when struck, that it is acceptable.

Building managers expect a safe, durable system and hope that it can be easily maintained with low life cycle performance costs.

Test houses expect that the Standards which they test to will be expressed in precise terms so that there is no ambiguity about procedural matters, and that where acceptance is based on a subjective visual inspection, sufficient guidelines have been provided in order to make consistent decisions. They expect that some clients will be unable to articulate their actual requirements, and anticipate that they may have to provide guidance in the selection of appropriate test methods, as well as interpreting the data.

Some people expect that concrete floors do not deflect, that cracks become stable with time, that movement joints may be safely omitted if they will compromise the aesthetics of an installation, etc. We all have dreams: unfortunately some may be rudely awoken by the harsh reality that costly failures may occur if our expectations are ill-founded. Clients may expect buildings to be designed using the latest advances in technology, to tight budgets, to be constructed as quickly as possible, and to last indefinitely without formal maintenance programs [2]. Unfortunately, the building industry has been unable to realise these expectations, due mainly to problems of information management. Furthermore, while it is widely expected that suppliers should have registered quality systems, it is often not recognised that two registered companies manufacturing the same product may have widely different degrees of quality. Registration only requires that whatever procedures are used are documented in accordance with the ISO 9000 outline. Thus, the auditor verifies the company is following its written procedures, not whether these procedures

are producing a quality product. However, the integral corrective action procedures should improve quality through the elimination of defects.

RESPONSIBILITY IN THE CASE OF FAILURES

While this is a highly complex and contentious area, a few simple guidelines can be given for resolving responsibility. Have the parties involved in the commissioning, design and construction of the installation acted in accordance with their responsibilities and reasonable expectations, and were the products of acceptable quality?

There is general consensus that the cost of failures due to poor tile installation practice is far greater than the cost of problems caused by poor selection or design, and that relatively few problems are caused by the tile or the adhesive [15]. However, it is often difficult to obtain restitution from tile fixers due to difficulties in locating them and getting them to accept that they were responsible for the failure, even in part. Litigation is sometimes a dubious proposition as the tile fixers may have insufficient financial reserves to make restitution, particularly after legal expenses. In some circumstances, «innocent» manufacturers have been ordered to contribute to rectification due to their perceived capacity to pay, and in other cases have done so as a cost-effective means of protecting their reputation. Not only do manufacturers benefit from improved levels of workmanship, but so does the industry as a whole. Poor publicity from one failure can lead to several decisions to use alternate products.

There is a very real possibility that failures may occur due to products that conform with the Standards, but are basically unsuited to the purpose for which they have been used. It might be assumed that this is due to the performance of the best quality tile being compromised by inappropriate specification, but this is not necessarily so. Pressed wall tiles are commonly installed using thin-set adhesives. The Standards permit Group BIII tiles to have a maximum +0.5% centre curvature, related to the work size diagonal, or +0.8 mm in the case of spacer lugged tiles. If a 300 x 300 mm tile, with an «acceptable» 2.1 mm centre curvature, is fixed using a thin-set method, it is quite possible that a significant proportion of the tile back will not be in contact with the adhesive bed. This presumes a moderate amount of tile wear and a 30% reduction in applied bed thickness due to the trowel being held at an angle of 60 degrees to the wall. Many builders consider that the AS 3958 requirements for maximum variation in plane of background are somewhat unrealistic. For thick and thin bed application of wall tiling adhesive, a maximum variation of 4 mm to 2 mm is permitted. If the tiling system fails, initiated by moderate differential movement of either the tile or the background, where should the responsibility lie? In practice, the tile fixer will generally be held accountable as the adhesive coverage requirements of AS 3958 states that: «The adhesive manufacturers generally recommend a minimum of 65% coverage for general areas with perhaps more than 80% or 90% for floors and specialized areas such as shower compartments. Many tiling installations are, however, successful and meet their performance requirements with contact coverages as low as 35%. Expressing contact as a percentage alone presents some problems. For example, 80% coverage on a floor tile which leaves 20% of one edge without any adhesive is not generally acceptable». In the absence of specific instructions from adhesive manufacturers, AS 3958 provides figures to show examples of what would normally be considered satisfactory and unsatisfactory coverage. The latter are due to large «missed» areas or low overall coverage. The resolution of such problems becomes more complex as the moisture expansion of the tile increases, or if the movement of the substrate is appreciable and this has not been conveyed to the tiling contractor. Such movement may particularly occur in the structural core walls in high-rise office blocks, where washrooms are frequently located.

PRODUCTIVE RESPONSES

Failures are bad publicity that can reduce the overall demand for the installation of tiling systems. Thus the industry also benefits from initiatives that facilitate improved design and selection procedures.

Commendable initiatives include adhesive manufacturers providing computer programs to assist architects in writing specifications and selecting the correct adhesive, particularly where this is based on the appropriate selection of an accepted installation procedure. The Tile Council of America has established the Tile Industry Research Foundation which is studying «Thin-set ceramic tile installations on floor slabs subject to bending or deflection». This project is using finite modelling to enable the development of improved specifications. The German tile industry has produced a comprehensive set of lecture notes for distribution to lecturers in German technical colleges. These are organised into sections on building materials science, construction and design. The subsections include ceramic tiles in the renovation of old buildings, ceramic facade coverings, ceramic tiles in the construction of swimming pools, etc. The purpose of this initiative is to offer tertiary lecturers practical assistance in passing on the fairly complex specialised knowledge for planning and installing ceramic tiling systems to architectural and building industry students in a comprehensive and competent way. Thus, improved design and selection procedures essentially relate to both the development of new industry Standards and the continual upgrading of a variety of focused continuous educational programs.

Continuous improvement cycles are based on the concept that one must be accountable for the results of a process. One has to develop and apply meaningful measures of assessing and evaluating the process in order to find the root causes of any problems so that solutions can be identified and the effect of modifications monitored. The incorporation of such monitoring tools allows the accountable parties to ensure process conformance or to detect deviations that can then be addressed. While it is easy to visualise such processes relating to product development, they also apply to Standards preparation and the operation of test houses.

Standards may not be well regarded within the industry if they do not provide sensible results, although it is often the test house that may be held to blame [16], for instance when a glazed tile passed an abrasion test, even though the glaze was visibly removed, because the weight loss was insufficient for the tile to fail the test. However, test houses which undertake irrelevant tests, for example determining the crazing resistance of unglazed tiles, deserve their poor reputation. This raises an important fundamental issue - to what extent may a test house be liable for a failure on the basis of the data it has provided? In considering abrasion resistance of glazed tiles, EN 154 has been criticised for several reasons including the fact that it provides no indication of loss of gloss and that it does not reveal which products will become susceptible to cleaning problems due to the opening of pores within the glaze [1, 12, 17-22]. Several CERLABS members have developed secondary testing procedures to better characterise products [12, 18, 20, 21, 23]. The draft ISO Standard for abrasion resistance of glazed tiles contains provision for class V tiles which must pass a staining test after a greatly extended abrasion cycle (12 000 revolutions). In order to fulfil clients' expectations of being provided with all the information required to make a well-informed decision, CSIRO routinely adds a staining procedure to determining the abrasion resistance of all glazed tiles. If there are any problems with staining or loss of gloss at the last abrasion stage at which the tile is assessed to have complied with the viewing requirements, the client will be informed. They will also receive the duplicate tile from that stage. Not only might this fill a gap in the client's understanding of the basic test, it also effectively transfers legal liability.

Such situations can be avoided or minimised through the development of more relevant Standards. For instance, an innovative AICE investigation simulating abrasion in floor tiles due to pedestrian traffic [24] recognises that the EN 154 test procedure does not adequately model wear process in some environments, say Perth in Western Australia where the soil is very sandy. When coarse sand particles are trodden upon, concentrated point loads result and this may cause significant opening of pores within the glaze that are close to the tile surface.

It is anticipated that not only will CERLABS enable a consistent universal interpretation of the forthcoming ISO Standards, but that it will also provide a forum for the discussion, initiation and evaluation of enhanced test methods prior to the official review of the Standards. This should obviously facilitate a short effective revision process.

Developers of new Standards should recognise the widespread trend towards the development of performance-based Standards, particularly as a result of the European Community Construction Products Directive. The draft European clay masonry units Standard thus embodies a «declaration system» for the specification of product characteristics, requiring that some properties (dimensions and tolerances, geometry, gross dry density, compressive strength, frost resistance, soluble salts content) be declared in terms of numerical values or class levels, whereas other properties may be declared (net dry density, water absorption, initial rate of water absorption, dimensional stability). This approach will facilitate the development of a masonry construction code. It should be noted that while masonry codes generally address accommodation of movement as a design matter, tiling codes have yet to fully address this aspect.

Tiles, while serving several functional purposes, are often selected on the basis of aesthetics, even to the extent that necessary performance requirement considerations are sometimes unfortunately overlooked. Although the draft ISO ceramic tile Standards have been framed with some consideration of the relatively recent Construction Products Directive, some revisions may ultimately be considered desirable. For instance, there is only a single compliance requirement for crazing, which may lead to the adoption of classes similar to those of ASTM C 424 [9]. The Essential Requirements of the Construction Products Directive concern not only the tiles, but also the jointing materials used between tiles and the methods of laying tiles. It has been proposed that the draft European Norms for tile adhesives and grouts, and also for the laying of ceramic tiles and tiling systems, should establish the framework for subsequent ISO Standards.

European Norms for ceramic tiling adhesives are currently being drafted, and some effort has been made to enable countries such as Australia to provide comment. Such Standards all permit the optimum strength to be achieved through the use of favourable environmental conditions, 23± 2° C, 50± 5% R.H. and an air velocity of less than 0,2 m/s. Given the fundamental role that adhesives play, some parties are questioning the relevance of such adhesives Standards, particularly with respect to conditions under which samples are prepared, and the tests that are conducted. How do the adhesives' characteristics vary when subjected to different, more demanding application and curing conditions? How do they change with time, when used in different thicknesses, and when used with materials with different characteristics? Such material does not appear to be available in the open literature. One is thus forced to rely upon the manufacturersí guidance. This however does not permit adequate evaluation of which of several products may be best for a specific application as there is no direct basis for comparison. Do we know whether adhesive manufacturers are determining the most relevant characteristics, and at the appropriate times? Do all of the adhesive manufacturers know the relevance and the limitations of what they are doing? Such aspects are being studied to some extent in a number of experimental and theoretical projects, including some based on finite element modelling.

SUMMARY

The cost and responsibility of ensuring that the right information is available to the right people at the right time, and in a form that will facilitate understanding and application, must be shared by industry as a whole. However, seeking to initiate wholesale changes in the way that the industry operates is not a realistic option. CERLABS has adopted a proactive position to enable the consistent universal interpretation of the forthcoming ISO ceramic tile Standards. Each tiling industry segment has traditionally focused on its own sector and perhaps without sufficient consideration to the consequences in other areas. A tiling system functions best when all components operate in harmony with one another and their designated environment. Each industry segment should be contributing what it can to the continual development and management of tiling information, as well as informing and collaborating with other industry sectors. Communication of international differences will facilitate the further understanding of tiling system issues and facilitate the development of better products, systems and Standards.

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Figure 1. Flowchart of the process of designing a ceramic tiling installation.