

'SLIP RESISTANCE – PLANNING FOR A GREEN FUTURE'



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1. PANEL DEBATE PARTICIPANTS

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2. ESTABLISHING THE DEBATE CONTEXT

I have prepared this introductory paper from a personal perspective to help provide some context for the debate. Rather than commencing with the abstract and concluding with some questions that arise from a consideration of the paper, it commences with the same questions.

3. A CONSIDERATION OF SOME OF THE ISSUES

While all should applaud the decision that flooring materials must retain sufficient slip resistance throughout their working life, have there been enough benchmarking exercises of the existing infrastructure to determine what levels of slip resistance might be deemed appropriate and adequate to satisfy any requirements that might be developed in conjunction with Construction Products Regulation No 305/2011 (the CPR)?

The CPR will effectively require tile manufacturers to (1) declare the long term slip resistance performance of floor tiles, and (2) assume responsibility for conformance with the declaration. This inevitably leads to questions as to what the declarations should be based on, and to what extent will prCEN/TS 16165 be suited for this purpose?

How can the tile industry ensure that the assessment procedures are suitable?

The CPR requires a consideration of accessibility and use by disabled persons. To what extent might overzealous limits require remediation of the existing public, private and governmental pedestrian infrastructure, in both interior and exterior situations?

To what extent must additional allowance be provided for sloping surfaces? Is there an agreed protocol for calculating such requirements?

If a tile is cleaned and maintained in accordance with a manufacturer's instructions but has failed to conform with the declaration of performance, to what extent might a manufacturer be liable for remediation of the surface or compensating those who might have accidentally fallen?

Assuming draft European Technical Specification 16165 adopts both the pendulum and the GMG 200 for measuring in situ slip resistance (as well as for laboratory testing of new and conditioned surfaces), what provision should be made for other procedures (in order to demonstrate long-term compliance with the CPR)?

Since the DIN 51130 oil wet ramp test mainly depends on a physical interlocking mechanism, is it largely redundant except when specifying for heavily contaminated workplaces where appropriately profiled footwear should be mandated?

Could appropriate surface roughness parameters, as used in the SlipSTD PAS¹, be used as a substitute for the DIN 51130 testing of highly profiled and structured surfaces?

What is required to overcome any perceived limitations with respect to in situ testing of heavily profiled or structured surfaces using the pendulum, GMG 200 and BOT 3000? What are the real limitations of each of these methods in such circumstances?

Are there agreed European definitions for profiled and structured surfaces? If not, should such definitions be based on optoelectronic surface topographic testing?

Could a 'soft' rubber wet pendulum test replace the DIN 51097 wet barefoot test?

Should there be a series of coefficient of friction (COF) limits which require various actions after tile installation? How might such actions affect the manufacturer?

Is the German unsafe limit value of 0.3 COF appropriate and/or acceptable for internal surfaces using the pendulum, GMG 200 and/or BOT 3000? Would a

¹ Parameters such as P_p and P_k , but not R_z

lower action limit of 0.25 or 0.2 COF be more sensible²? What limit/s should apply in external areas?

Many accidents are due to large differences in the traction available from adjacent surfaces. Although this may be less of an issue where there is sufficient traction, should there be some transitional requirements? How should any predicted loss of slip resistance be considered in terms of transitional slip resistance requirements?

Should specifications ultimately become based on the anticipated long term slip resistance performance³ rather than the initial ex-factory results?

Should the flooring material (ceramic, metal, wood, polymer) and its surface characteristics determine the type of conditioning procedure and whether it is required?

Does a linear or a radial motion accelerated conditioning procedure better simulate pedestrian wear? Which procedure provides the most homogeneous test area?

To what extent should quality control testing be necessary? Could optoelectronic surveillance be used to reduce the amount of physical slip resistance testing?

In the absence of American long-term slip measurements, might European declarations of slip resistance performance become accepted practice in the USA?

Employers can limit access to areas based on the type and condition of the footwear. Will shoe manufacturers ever be held accountable for the soling materials they use, and will workers or citizens ever be held responsible for the compromised condition of footwear?

4. PRE-CONFERENCE ABSTRACT

The new European Construction Products Regulation requires that (from 1 July 2013) flooring products must provide adequate slip resistance at the end of an economically reasonable working life. Sustainable slip resistance is an essential requirement on any environmentally sensible building project. Any premature use of remedial treatments might deface the tile, and destroy the life cycle performance credibility of ceramic tiles.

Since many tiles rapidly lose significant slip resistance, many current ex-factory indications of slip resistance are virtually meaningless. What tests should be

2 A 0.20 limit was initially adopted for the pendulum with the TRRL slider by the Greater London Council Architects' Dept.: Item 5 in Development and Materials Bulletin No 43 (2nd Series), GLC, London, March 1971.

3 Bowman, R. Desperately seeking green slip resistance test protocols. Int. Conf on Slips, Trips and Falls, 6-8 April 2011, Health & Safety Laboratory, Buxton, UK.

conducted in order to predict prolonged in service performance? How should specification practices change in order to be based on the anticipated slip resistance at the end of an acceptably long working life?

This panel debate is aimed at raising awareness of the apparent need to be able to warrant long term in service slip resistance performance, where manufacturers will have to almost immediately provide relevant data in a format that can readily be used by retailers and architects.

Although most ceramic tile specifications are based on maximising performance characteristics, slip resistance requires a customised approach: the maximum and minimum levels of required slip resistance vary according to the project. A process of optimisation is required, where the slip resistance is tailored to the anticipated operating environment and the proposed cleaning measures. Although the method of testing slip resistance is also relevant to the tile selection process, the proliferation of test methods and the lack of an ISO standard have created costly confusion (and inconsistent information in technical data sheets).

This panel debate will consider the key issues when focusing on new approaches to providing simplified specification solutions, including identification of assessment criteria for different service conditions, consideration of accelerated conditioning treatments, and alternative approaches of product characterisation. There may never be a test method that is appropriate for all products and situations, but might a comprehensive specification system, that is simple to use, suit everyone in terms of international trade? The European, American and Australian panel members will offer their solutions and suggested actions.

5. EUROPEAN CONSTRUCTION PRODUCTS REGULATION

We must recognise the intent of European Regulation No 305/2011 with respect to slip resistance. Annex 1 commences "Construction works as a whole and in their separate parts must be fit for their intended use, taking into account in particular the health and safety of persons involved throughout the life cycle of the works. Subject to normal maintenance, construction works must satisfy these basic requirements for construction works for an economically reasonable working life". Clause 4, *Safety and accessibility in use*, states "The construction works must be designed and built in such a way that they do not present unacceptable risks of accidents or damage in service or in operation such as **slipping**, falling, collision, burns, electrocution, injury from explosion and burglaries. In particular, construction works must be designed and built taking into consideration accessibility and use for disabled persons".

Since 'essential characteristics' are defined as "those characteristics of the construction product which relate to the basic requirements for construction works", slip resistance is an essential characteristic. Since manufacturers must take into

account the safety of persons throughout the life cycle of the works, sustainable slip resistance is more important than ex factory slip resistance; and the loss of adequate slip resistance might effectively define the end of the product life cycle. Furthermore, since construction works must satisfy these basic requirements subject to normal maintenance, one should presumably anticipate the occurrence of some soiling during the daily, weekly (or some other) routine maintenance cycle. While remedial treatments could also be considered to be a means of extending the product life cycle, such treatments may be short-lived, detract from the aesthetics, and/or weaken the tile surface.

Since some disabled persons have higher traction demands than able bodied persons, a sensible approach has to taken with respect to establishing appropriate requirements, learning from the difficulties experienced with the Americans with Disabilities Act (ADA) Accessibility Guidelines, where the compliance requirements were unrelated to any specific test methods.

Although the debate will not consider the minute detail of the new Construction Products Regulation⁴ (CPR), this background document allows the important recognition that the Declaration of Performance (DoP) is the key concept in the CPR. Manufacturers must draw up a DoP when a product covered by a harmonised standard (hEN) or a European Technical Assessment (ETA) is placed on the market. In this context, we must consider whether the proposed harmonised CEN Technical Specification 16165 for measuring slip resistance will be sufficient for declaring the long term slip resistance performance of ceramic tiles?

The manufacturer, by drawing up his DoP, assumes the responsibility for the conformity of the construction product with the declared performance. On the basis of the information contained in the DoP, the user will decide to buy, amongst all the products available on the market, the one which is fit for the use he intends to give to such product and he assumes the full responsibility of such decision⁵. In this context it might be simplest (during the debate) to assume that the user is an architect engaged to represent the building owner.

The DoP is thus intended to constitute the key element in the functioning of the construction products market by providing it with the necessary transparency and by establishing a clear system of allocation of the responsibilities between the relevant parties.

All the information supplied with the DoP is to be obtained by strictly applying the methods and criteria provided by the relevant harmonised standard or, in absence of an applicable harmonised standard, by the relevant European Assessment Document.

⁴ <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:088:0005:0043:EN:PDF>

⁵ http://ec.europa.eu/enterprise/sectors/construction/declaration-of-performance/index_en.htm

A European Assessment Document (EAD) is a document containing at least:

- A general description of the construction product;
- the list of essential characteristics, relevant for the intended use of the product as foreseen by the manufacturer and agreed between the manufacturer and the organisation of Technical Assessment Bodies;
- the methods and criteria for assessing the performance of the product in relation to those essential characteristics;
- principles for the applicable factory production control⁶ to be applied.

The European Technical Assessment (ETA) shall be issued by a Technical Assessment Body (TAB) on the basis of a European Assessment Document adopted by the organisation of Technical Assessment Bodies.

A request for a European Technical Assessment by a manufacturer for any construction product not covered or not fully covered by a harmonised standard and for which the performance in relation to its essential characteristics cannot be entirely assessed according to an existing harmonised standard can be addressed to a Technical Assessment Body (TAB) designated in the product area in question. Assuming CEN/TS 16165 is published, it might loosely be considered a standard, but it would seem to fail to fully cover the assessment of long term slip resistance behaviour.

The European Technical Assessment is issued on basis of an EAD and shall include:

- the performance to be declared, by levels or classes, or in a description, of those essential characteristics agreed by the manufacturer and the TAB receiving the request for the European Technical Assessment for the declared intended use, and
- technical details necessary for the implementation of the system of assessment and verification of constancy of performance.

Notification is an act whereby a Member State informs the Commission and the other Member States that a body that fulfils the relevant requirements has been designated to carry out conformity assessment according to a directive. Notification of Notified Bodies and their withdrawal are the responsibility of the notifying Member State. For example, the Health and Safety Executive is a British Notifying Authority that would seem to fulfil the relevant requirements with respect to slip resistance.

It should also be noted that "The responsibility of Member States for safety, health and other matters covered by the basic requirements for construction works on their territory should be recognised in a safeguard clause providing for

⁶ This is an important aspect that manufacturers should consider since once controls are identified, they should logically be implemented.

appropriate protective measures". Does this mean that there might be different sustainable slip resistance requirements in various countries?

Will Italy retain the Tortus for disabled access requirements? Probably not since the CPR states:

"Since it is necessary to ensure throughout the Union a uniform level of performance of bodies carrying out the assessment and verification of constancy of performance of construction products, and since all such bodies should perform their functions to the same level and under conditions of fair competition, requirements should be set for those bodies seeking to be notified for the purposes of this Regulation. Provision should also be made for the availability of adequate information about such bodies and for their monitoring" and

"In order to ensure a coherent level of quality in the assessment and verification of constancy of performance of construction products, it is also necessary to establish requirements applicable to the authorities responsible for notifying the bodies carrying out those tasks to the Commission and the other Member States."

Although the Regulation also states "Wherever possible, uniform European methods should be laid down for establishing compliance with the basic requirements set out in Annex I", there appear to be different national disabled access requirements.

6. PROBLEMS ASSOCIATED WITH MULTIPLE SLIP TEST METHODS

CEN/TC 339 sought to establish a standard for *Determination of slip resistance of pedestrian surfaces — Methods of evaluation* and is now trying to establish harmonised Technical Specification 16165. The most recent draft contained two laboratory tests (the German barefoot DIN 51097 and shod DIN 51130 inclining platform tests) as well as the pendulum friction and GMG 200 tribometer tests (two tests for both laboratory and in situ use). As it would more economical for tile manufacturers to only have to use either the pendulum or the GMG 200, there has inevitably been some competition. However, given existing requirements for their use, adoption of both would seem necessary.

Australians are familiar with the challenges posed by the adoption and use of multiple slip resistance test methods. AS/NZS 4586:1999, adopted the German barefoot DIN 51097 and oil wet DIN 51130 inclining platform tests, together with the wet pendulum and the dry (Tortus) Floor Friction Tester. We were aware that no test was perfect, and that each had some specific limitations.

We had to answer an immediate question with respect to use of dual or multiple tests: did the product have to comply with both or all tests? In the case of the

oil wet inclining platform test we were able to adopt as guidance the German regulation⁷, where this provided guidance based on the required R classification (from R9 to R13) together with (in some cases) a minimum displacement volume.

Australian experience has revealed a general failure: a disregard for the volumetric requirements, which should have been regarded as mandatory rather than optional. This aspect was highlighted by the inclusion of requirements for external areas in German regulation BGR 181(2003): architects could either specify that products be a minimum of class R11 or class R10 + V4 minimum displacement volume.

Standards Australia Handbook 197 provided a tabular pedestrian flooring selection guide, based on minimum pendulum or ramp recommendations for specific locations. The pendulum recommendations were extrapolated from the German ramp guidance by an intuitive process. While it was anticipated that there would be some modifications with the benefit of experience this has not been considered necessary. However, it is intended to change the recommendation for external colonnades, walkways and pedestrian crossings from R10 to R11. Even though R10 + V4 would probably be sufficient, the displacement volume requirements have too often been viewed as a nuisance rather than an aid.

Lower pendulum results should be expected when the rubber is prepared using pink lapping film. This film was first specified in BS 7976.2:2002, *Pendulum testers. Method of operation*, (superseded, withdrawn 31 October 2011); but has also been adopted in its imposed substitute, BS EN 13036-4:2011, *Road and airfield surface characteristics – Test methods. Part 4: Method for measurement of slip/skid resistance of a surface: The pendulum test*; and its potential eventual replacement, prCEN/TS 16165:2010. Since some class X, Y and Z results will be reduced by as much as 20 BPN, several modifications to the HB 197 guidance are anticipated when the sensitivity of the pendulum is increased at the lower end of the slip resistance spectrum.

Even though a ramp test might cost three to four times as much as a pendulum test, architects prefer to use ramp classifications. This might be because several European tiles already have ramp classifications. Furthermore, the superseded BGR 181 provides more detailed guidance than is available for the pendulum. Many architects have made the hazardous mistake of assuming that the HB 197 guidance indicated equivalence between some pendulum and oil wet ramp classifications such that they (and some tile merchants) have converted some slip resistance classification for different test methods, for instance from pendulum class X to R10. As can be seen from Figure 1, there is absolutely no guarantee of equivalence. Using P400 abrasive paper to prepare a Four S rubber (Slider 96) test foot, Class R10 tiles cover all the pendulum classifications and could give pendulum results between 20 and 60 BPN.

⁷ ZH/1/571, October 1993, Floors in Workplaces and Areas with Increased Risk of Slipping. Superseded in October 2003 by BGR 181 (with same title).

The oil wet ramp test determines the physical-interlock-slip-resistance of profiled test surfaces using footwear with profiled soles. It is useful for determining the slip resistance where people might be wearing safety shoes with heavily profiled soles in contaminated industrial settings, but is much less useful where people might wear smooth soled shoes and water is the most likely liquid 'contaminant'.

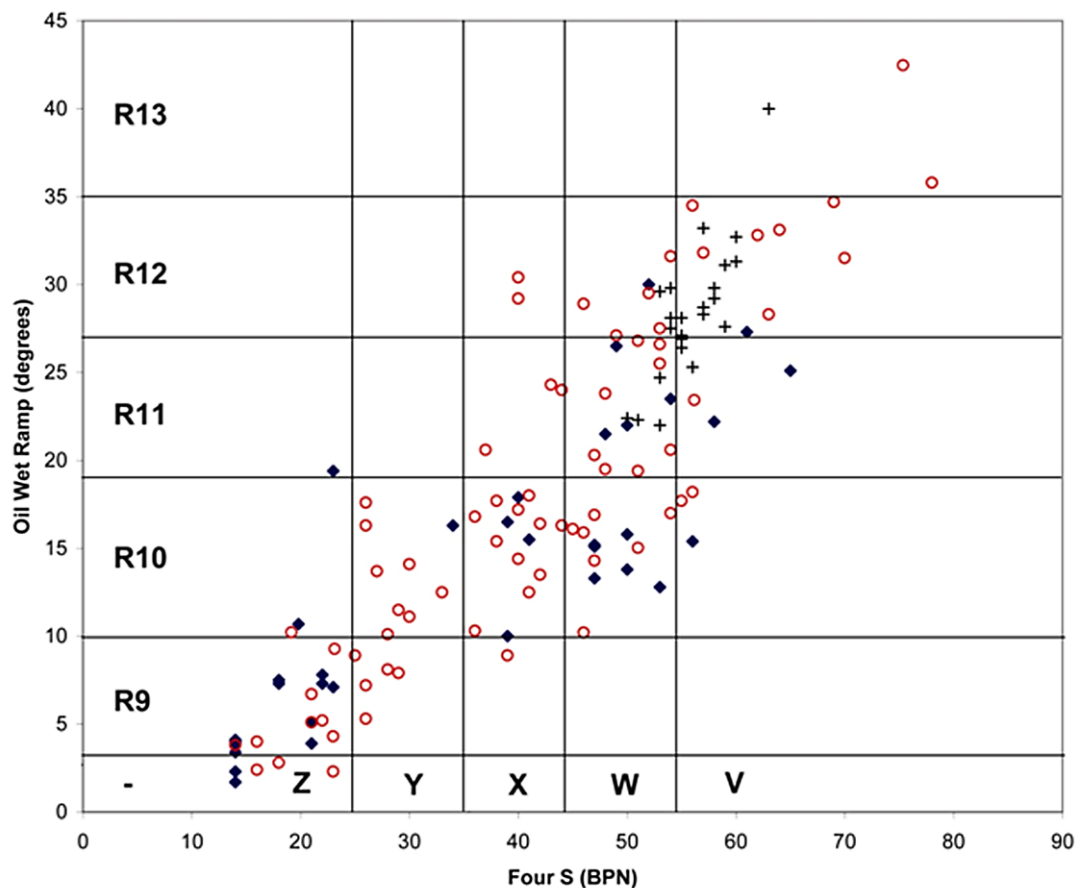


Figure 1. A comparison of oil-wet ramp and wet pendulum slip resistance results for some ceramic tiles, in the context of the AS/NZS 4586:2002 classifications: glazed tiles (◆); porcelain tiles (○); and terracotta tiles (+), where the Four S rubber slider was prepared on 400P abrasive paper.

Analysis of accidents has revealed that several falls have occurred where the tiles (selected on the basis of ramp classifications) never conformed to the HB 197 pendulum recommendations. The long asked question has been 'Should tiles conform to one set of recommendations or two?' There is obviously a factor of safety in complying with both sets. However, it is more a case of recognising the limitations of each test method and prioritising according to the test that is considered to be most relevant to the situation. Thus the pendulum test should be given priority when considering public areas where there is no control over footwear and water is the most likely slip contaminant. The wet barefoot ramp test should have priority in public swimming pool situations, but is sensibly supported by pendulum soft rubber (TRL slider 55) data. The oil wet ramp data should primarily be used

for the industrial and commercial applications for which it was originally devised (where employees wear appropriate safety shoes with profiled soles).

In preparing slip resistance recommendations for specific situations, we always assumed that we were making appropriate allowance for any loss of slip resistance due to wear, but, in the absence of an accelerated wear or conditioning test, this remained an assumption. However, periodic audits and accident investigations confirmed that the ex-factory slip resistance of products could change significantly in service. While some of the loss can be attributed to soiling, modest soiling should be considered to be an integral element of the life cycle in most situations, just as we expect tiles to be subjected to 'fair wear and tear'.

While Strautins' use of a linear reciprocating washability machine⁸ enabled artificial conditioning of ceramic tiles, the extent to which such conditioning represents the wear that occurs in service remains to be confirmed. We should expect that the wear will reflect the type of scratching dirt present, the volume of pedestrian traffic, the footwear worn, maintenance practices and other localised variations. Although the test predicts the long term performance of many products, pessimists consider there is too little (reliable agglomerated) data to develop detailed guidance.

Minimum pendulum and ramp recommendations should be considered to be the starting point for slip resistance design, not the final end point. There are many aspects such as lighting, slopes and drainage that can significantly affect the slip risk, together with footwear choices and behavioural modes. Few diligent architects have the confidence to use the existing guidelines as a basis for design. Many architectural specifications contain questionable slip resistance provisions. Natspec⁹ (2009) advises Australian architects to consider loss of traction at the design stage when specifying pedestrian surfaces. Anticipating that only a few will continue to seek professional guidance, we must again strive to condense our knowledge into a usable format without 'dumbing it down' too much.

One means of doing this would be to revert to the minimum acceptable results for a particular end use situation. For example, an OHS authority might find an industrial floor was insufficiently slip resistant if it obtained a mean Four S pendulum result of less than 39 BPN, or individual results of less than 35 BPN. Should manufacturers make declarations of performance based on the minimum predictable slip resistance during a particular type of anticipated life cycle, assuming that cleaning will be of the type and frequency that they recommend? EN 1341 required the stone industry to declare the minimum unpolished slip resistance value expected for individual specimens of fine textured stone as manufactured, to help ensure adequate slip resistance on installation. However, the DoP throughout a life cycle goes much beyond this.

8 Strautins, C. Sustainable slip resistance: an opportunity for innovation. In QUALICER 2008, Castellon, Spain. <http://aulavirtual.camaracastellon.com/qualicerCD/pdf/0833123e.pdf>

9 Natspec Technote DES 001 (2009) Slip resistance performance. <http://www.natspec.com.au/Documents/TechNotes/NTN%20DES%20001%20Slip%20resistance.pdf>

7. MINIMUM COMPLIANCE REQUIREMENTS

Since a declaration of performance imposes a long term compliance requirement, is there a minimum acceptance figure that manufacturers should aspire to? Should this minimum be related to a mean result, the minimum result obtained, or should it be statistically determined?

Harper, Warlow and Clarke¹⁰ (1961) found that the mean peak utilized coefficient of friction (COF_u) was 0.17 for males and 0.16 for females when walking in a straight line. They determined that for safety the coefficient of friction (COF) between floor finishes and shoe materials should not be less than 0.4. This allowed for people turning (when there is a higher traction demand than walking in a straight line). Pye¹¹ used the same data to calculate that a COF of 0.24 represented a slipping risk to one in twenty people. Although Barnett¹² also used the same data when undertaking a more complex analysis of the risk of slipping, most people have no difficulty in adjusting their gait and traction demand to less than 0.24 COF when they are aware that a surface is contaminated or is likely to be slippery.

		SLOW		MEDIUM		FAST	
		Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Young	Females	.24 (.05)	.20 - .35	.24 (.02)	.21 - .28	.25 (.04)	.21 - .32
	Males	.19 (.04)	.14 - .30	.21 (.02)	.18 - .24	.27 (.03)	.23 - .31
Middle	Females	.24 (.04)	.16 - .28	.27 (.02)	.23 - .31	.26 (.05)	.18 - .34
	Males	.22 (.05)	.17 - .33	.26 (.06)	.20 - .39	.32 (.09)	.22 - .44
Senior	Females	.23 (.04)	.14 - .30	.22 (.03)	.18 - .26	.22 (.06)	.13 - .30
	Males	.19 (.02)	.17 - .22	.22 (.04)	.17 - .36	.24 (.06)	.17 - .37
Totals by Gender	30 Fem	.24 (.04)	.14 - .35	.24 (.03)	.18 - .31	.24 (.05)	.13 - .34
	30 Males	.20 (.04)	.14 - .33	.23 (.05)	.17 - .39	.28 (.07)	.17 - .44
Overall Total	All 60 subjects	.22 (.04)	.14 - .35	.24 (.04)	.17 - .39	.26 (.06)	.13 - .44

Table 1 – Peak COF_u values generated during walking at slow, medium and fast speeds, where each group consisted of 10 healthy subjects

10 Harper, F.C., Warlow, W.J. & Clarke, B.L. (1961). The forces applied to the floor by the foot in walking: 1. Walking on a level surface. NBS Research Paper 32, HMSO.

11 Pye, P.W. & Harrison, H.W. (2003). Floors and flooring – performance, diagnosis, maintenance, repair and avoidance of defects. Building Research Establishment Report 460, UK.

12 Barnett, R.L. (2002). 'Slip and Fall' Theory – Extreme Order Statistics. *International Journal of Occupational Safety and Ergonomics (JOSE)*. 8(2), pp. 135-158

Burnfield and Powers¹³ investigated the influence of age and gender on COF_U during walking at different speeds. The mean peak utilized COF values generated by all 60 subjects at slow, medium and fast walking speeds were $\mu = 0.22$, $\mu = 0.24$, and $\mu = 0.26$, respectively (Table 1). The highest and lowest values for single subjects, $\mu = 0.44$ and $\mu = 0.13$, both occurred during fast walking trials. Of the 180 data points, seven walks yielded peak COF_U where $\mu > 0.35$. While the mean peak COF_U may generally be about $\mu = 0.23$ for a comfortable walking speed, there is a high coefficient of variation.

While the subjects may not have been walking at their preferred speed, there are inevitably situations when lateness or involuntary group pressure cause speed modifications. Although the convention seems to be to aggregate data, this conceals the results of individual subjects, where the frequent occurrence of anomalous results in most studies (of small sample populations) suggests that idiosyncratic gait demands are more widespread than might have been generally anticipated. This would seem to suggest that when we are considering minimum safety requirements we should pay greater attention to the outliers who have higher traction demands. Although a consideration of those with low ambulatory function indicates that individuals must conform to the environment (develop a functional gait) if they want to be able to walk safely with minimal assistance, we must strike a compromise position without specifying highly slip resistant surfaces that may be difficult to maintain in a clean condition.

Burnfield, Tsai and Powers¹⁴ investigated the peak COF_U during different walking tasks in persons with and without a disability, selecting only subjects with relatively high ambulatory function, so they were capable of walking across level surfaces and on stairs with no or minimal physical assistance (a cane). When averaged across all subjects, the mean peak COF_U during level walking was $\mu = 0.23$. Values ranged from $\mu = 0.14$ for a person in the arthritic group to $\mu = 0.54$ for an individual in the stroke group. Peak COF_U was found to vary significantly across subject groups. However, the study suggested that persons with the select medical conditions are not at any greater risk for slip initiation than healthy older or younger adults during the tasks evaluated.

The higher COF_U values observed while descending stairs and negotiating a turn suggested an increased risk of slip onset compared to level walking and stair ascent. Recovery from a slip, however, is likely confounded by multiple factors including balance, muscular strength, power, and flexibility. Thus it is possible that once a slip is initiated, persons with a disability may have a more difficult time recovering from the event. The CPR stresses that construction works must be designed and built taking into consideration accessibility and use for disabled persons.

¹³Burnfield J.M., Powers C.M. Influence of age and gender of utilized coefficient of friction during walking at different speeds. In: Marpet M.I., Sapienza M.A., editors. Metrology of pedestrian locomotion and slip resistance, ASTM STP 1424. West Conshohocken: ASTM International; 2003. p. 3–16.

¹⁴Burnfield, J.M., Tsai, Y.-J. and Powers, C.M., 2005, Comparison of utilized coefficient of friction during different walking tasks in persons with and without a disability. *Gait and Posture*, 22, 82–88.

Ideally pedestrian surfaces should offer greater traction than pedestrians demand, although various slip resistance tests may provide different indications of the amount of available traction. Is a surface with a wet COF of 0.30 marginally safe such that it generally provides adequate traction? Does $\mu = 0.20$ represent an unquestionably unsafe surface and $\mu = 0.25$ a marginally unsafe surface? Who makes such decisions? Would use of a product on stairs require a re-evaluation of the limits or the declaration?

8. PROPRIETARY ISSUES AND TEST LIMITATIONS

Progress in developing slip resistance standards has often been diverted by proprietary issues, particularly relating with respect to tribometers. The proprietary restrictions that relate to the pendulum and the inclining ramp test methods relate to the rubbers, calibration boards, and footwear.

The TRL and Four S rubbers were both developed by RAPRA (now Smithers Rapra), who are unprepared to give away their intellectual property (the rubber formulations). These rubbers are now known as sliders 55 and 96 in accordance with their mean IRHD hardnesses, 55 ± 5 and 96 ± 2 respectively. This monopoly would seem to have led to the development of a rubber with a mean 59 ± 6 IRHD hardness. This rubber was adopted in a number of European standards as the CEN rubber (a decidedly European name). The CEN rubber gives different results to the TRL rubber, and the results are sensitive to the preparation of the slider. This aspect was ignored¹⁵ in EN 14231: 2003, *Natural stone test methods – Determination of slip resistance by means of the pendulum tester*. EN 14231 requires the reporting of the mean wet slip resistance value, where the slider preparation is again insufficiently defined: either the CEN rubber or some batches of TRL rubber might be used. The existence of several standards for pendulum measurements, albeit with small but significant differences, has impaired the perceived reliability of pendulum results.

EN 13036-4:2011 specifies a new rubber, slider 57 (with IRHD hardness range of 55 to 61). This seems to be an attempt to allow use of both the TRL and CEN rubbers, although many batches of TRL rubber will not comply. Even though the TRL Lübke resilience compliance requirements have been applied to sliders 59 and 57, there appears to be no published evidence that uniform pendulum results will be obtained. At 20°C, the permitted resilience range is 66 to 73%. A 7% change in rubber resilience (energy loss due to hysteresis effects) might be equivalent¹⁶ to a difference of 5 BPN on a surface that gives a result of approximately 50 BPN at 20°C.

¹⁵Bowman, R., Strautins, C. and Do, M.D. Beware of conflicting stone slip resistance reports. *Discovering Stone*, March 2005, 26.

¹⁶Giles, C.G., Sabey, B.E., and Cardew, K.H.F. Development and Performance of the Portable Skid-Resistance Tester, Road Research Technical Paper N0 66, 1964, DSIR Road Research Laboratory, UK

EN 13036-4:2011 contains two sets of verification values for pendulum operation, where tests are conducted on float glass, a reference tile, and a verification film. There is a note for slider 57: "If the values with slider 57 are outside the range, the verification may be repeated with slider 96. If this is in tolerance, the operation of the pendulum has been verified". FprCEN/TS 16165:2010 contained a similar table except that it was titled "Verification limits of the sliders", where a note indicated that it was anticipated that the verification procedure would be further developed during the CEN/TS period.

The FprCEN/TS 16165 (GMG 200) Tribometer test specifies the slider material as "SBR rubber, with a density of (1.23 ± 0.02) g/cm³ and a Shore D hardness 50 ± 3 ". The draft ANSI A137.1 standard requires SBR rubber to conform to the following specifications: " 1.23 ± 0.2 g/cm³ density, 95 ± 3 Shore A hardness, >10 MPa tensile strength, $>250\%$ flexibility, and <250 mm³ wear-ability."

Andrew¹⁷ considered the mechanisms involved in energy loss when a polymer test foot slides over a surface, where the energy loss was equal to the sum of reversible adhesion, disruptive adhesion, gross deformation, reversible micro deformation, abrasive wear, test equipment mechanical alignment, and viscous drag. The relevant significance of these mechanisms varies depending upon whether the polymer is a thermoplastic or an elastomer, as well as on the roughness of the test surface and other test condition variables. If the coefficient of friction is related to the hysteresis loss properties of a rubber, its Young's modulus, its abrasion resistance and other characteristics that can be quantified by existing test methods, why are these not being applied to better define and improve the consistency of existing or potential new slider materials?

EN 13036-4:2011 and FprCEN/TS 16165:2010 both fail to identify the reference tile or to specify its characteristics. However, FprCEN/TS 16165 required that the identity of reference test surfaces be reported if this information is known. I understand that a particular Pavigres porcelain tile is being used; and that if it is subjected to a conditioning procedure (using only 100 dry swings of the Pendulum) that it should give a reading of 34 ± 2 BPN and that the PTV should only drop by 1 BPN over the next 700 swings. While the standards permit a slider 96 reading of 34 ± 3 BPN, I understand that a few Pavigres tiles from within the reserved stock have yielded higher results in a controlled study.

Variation in calibration tiles and changes in the slip resistance of such tiles with use is a potential problem for the German inclining ramp tests, as is the change of the stipulated footwear in the case of the oil wet ramp test. Bowman et al¹⁸ found that when the Lupos Picasso shoes replaced the Bottrop shoes in the oil wet ramp test, there was a corrected mean difference of 0.4 degrees or less. It seems to be generally assumed that immediate initial or subsequent progressive

¹⁷Andrew, K.R. Energetics of transient contacts between polymers and inorganic substrates. PhD Thesis, Department of Physics and Applied Physics, University of Strathclyde, Glasgow, February 1997.

¹⁸Bowman, R., Strautins, C., Do, M.D., Devenish, D., Quick, G. 'Comparison of footwear for the oil wet ramp slip resistance test', Contemporary Ergonomics 2004, pp 33-37.

wear of the calibration boards and/or the proscribed safety shoes has no affect on the results obtained when testing products.

DIN 51130:2010 has now introduced Uvex Athletic 9452.9 footwear to replace the Lupos Picasso shoes and St-I, St-II & St-III standard surfaces to replace the E, P and R boards. Given an approximate €6000 cost for the new calibration boards, one would hope that they have consistent life cycle performance, but how does one determine that they are still performing acceptably? Bowman¹⁹ observed differences of between -5.5 and +4.7 degrees (or up to 0.11 COF) between the tests conducted by Sebald²⁰ and the results reported by the manufacturer. Are such differences normal and acceptable?

FprCEN/TS 16165 is similarly introducing new calibration boards for the wet barefoot test. While Bowman (2010) has drawn attention to some perceived limitations of the wet barefoot test, such as the progressive contamination of recirculated water during testing, such aspects have not been addressed in FprCEN/TS 16165.

NATA (National Association of Testing Authorities, Australia) is a recognised Notifying Authority²¹ under a Mutual Recognition Authority, although not (yet) for the CPR. However, one should consider the possibility that a laboratory that is accredited to conduct the wet barefoot test could supply problematic results that might have to be recognised within Europe, unless CEN/TC 339 takes action to prevent the test being conducted in ways that were not anticipated but are not expressly prohibited.

It should be noted that CEN/TC 339 recently introduced the following flatness criteria for the pendulum test:

"The measurement surface should be rejected if the deviation from a straight line over the length of the surface exceeds 2.0 mm (concave or convex) or if the deviation from a straight line over the width of the surface exceeds 0.5 mm. This should be checked in the middle of the measurement surface with the help straight edges and a feeler gauge set over the appropriate length (135 mm) or width (80 mm)".

It was also noted that although products with intended textures or profiles will generally not fulfil these flatness criteria, Pendulum measurements might still be possible for some products and the results might still be performance related. Surprisingly there was no similar criterion for the GMG 200 (which has a much larger slider footprint and should theoretically be more sensitive to surface deviations)

19 Bowman, R. Slip Resistance Testing – Zones of Uncertainty. In QUALICER 2010, Castellon, Spain, 2010. <http://aulavirtual.camaracastellon.com/qualicerCD/pdf/2010200.pdf>

20 Sebald, J., *System oriented concept for testing and assessment of the slip resistance of safety, protective and occupational footwear*, 2009, Pro Business, Berlin.

21 <http://ec.europa.eu/enterprise/newapproach/nando/index.cfm?fuseaction=na.main>

Giles *et al*²² considered that the pendulum was particularly well-adapted for use on the more rough-textured types of road surface. EN 13036-4 advises that when deciding the applicability of the pendulum to a surface which has non-homogeneous characteristics, e.g. containing ridges or grooves, or is rough textured (exceeding 1.2 mm mean texture depth), the small area of the test surface should be considered.

According to BS EN 14231:2003, *Natural stone test methods – Determination of slip resistance by means of the pendulum tester*, if the surface of the exposed face has a roughness greater than 1 mm it will be considered as not slippery, without any need to perform a pendulum test. This height difference lies between the EN 1341 definitions of fine textured (0.5 mm maximum difference between peaks and depressions) and coarse textured (more than 2 mm difference) stones. The kurtosis (sharpness of the surface profile) is undoubtedly more important than the profile depth. Where sharp angular peaks form part of the bearing surface, the slip resistance will decrease as wear rounds the peaks.

EN 14231 does not suggest what pendulum reading might indicate that a fine textured stone is safe or non-slippery, but EN 1341 indicated that unpolished slip resistance values of greater than 35 BPN can usually be considered safe.

While it might be intended that CEN/TS 16165 should eventually be the only standard for pendulum measurements in Europe, it will presumably be unable to directly replace the EN 13036-4 standard while it remains as a CEN Technical Specification. Although the existing inclining ramp test methods are being fine tuned, the draft CEN/TS 16165 recognizes that there is still a lot of work to do to improve the precision/ robustness/ repeatability of the pendulum test, and the quality control of the rubber and the reference materials. There may appear to be less work associated with the GMG 200 test procedure, but is this because it has not been as severely scrutinised by potentially biased critics (possibly due to their unfamiliarity with the equipment and its use)?

There appears to have been much pressure to rapidly finalise CEN/TS 16165, but will it be adequate to enable declarations of long term slip resistance performance, when products are tested in an ex-factory condition? One option is to use the pendulum and Strautins (2008) proposed specimen conditioning procedure. However, in the case of the three other CEN/TS 16165 test methods, the test surface area is approximately 100 cm x 50 cm in each case. The measuring distance of the GMG 200 tribometer test is at least 0.5 m in length, where the effective total footprint of the three individual 37.5 x 10 mm sliders is 170 mm long and 66 mm wide, and the five test runs may need to be conducted in multiple directions. Is there a convenient means of conditioning specimens that are 100 cm x 50 cm in size, or should one seek some other basis for declaring the long term slip resistance performance?

22 Giles, C.G., Sabey, B.E., and Cardew, K.H.F. Development and Performance of the Portable Skid-Resistance Tester, Road Research Technical Paper N0 66, 1964, DSIR Road Research Laboratory, UK

The principal limitation in adopting Strautins' conditioning procedure would be a lack of evidence that the process reproduces the type of wear that occurs in real world situations: such a limitation is an inevitable problem common to all methods attempting to simulate wear in order to be able to predict long term slip resistance performance.

The GMG 200 tribometer was adopted in DIN 51131:2008, *Testing of floor coverings - Determination of the anti-slip property - Method for measurement of the sliding friction coefficient*. Testing to DIN 51131 cannot be used to confirm that the products tested were in accordance with the ramp classification requirements of BGR 181 and/or GUV-I 8527. However, DIN 51131 has been adopted in BGI/GUV-I 8687:2011, *Risk assessment under operating conditions*, together with the 0.30 unsafe limit value and the 0.45 safe action value limits. Although I understand that special measures may be required when results less than 0.30 COF are obtained, I have been unable to find a reliable English translation of DIN 51131, BGI/GUV-I 8687²³ and of most of the recent related German research. As such I have been unable to form a fully informed opinion on the GMG 200 and its application. I suspect that others have had similar difficulty in accepting the adoption of the GMG 200 in prEN 16165. While I have no reason to distrust my esteemed German colleagues, a strategy of "Trust me" is unlikely to be highly persuasive or productive when foreign participants are seeking to maximise certainty in such a highly complex and uncertain subject area.

Vested interests have sometimes published malicious information about competing slip resistance test methods. Such information has sometimes been perpetuated by others who might have assumed that it was accurate. Buscher²⁴ has generally denigrated use of the pendulum, particularly for external surfaces: he suggested that the presence of a single grain of sand is enough to decisively influence the results of a measurement. The first swing of the pendulum should permanently displace and remove the sand grain if the area has been specifically tested in an uncleaned condition. Hence there is no problem, other than the misinformation. There are also far too many unsubstantiated 'facts' in the published literature, where preliminary conclusions that may apply when certain tests are conducted in a specific way on a limited set of specimens might have been inappropriately extrapolated to far broader situations and circumstances.

²³Assessment of the risk of slipping under operating conditions, January 2011, <http://publikationen.dguv.de/dguv/pdf/10002/i-8687.pdf>

²⁴Buchser, M. Revêtements de sol, Documentation technique 2.027 du bpa, 2007, p.21. http://www.bfu.ch/PDFLib/729_105.pdf

9. AMERICAN CONSIDERATIONS

The USA has long been a preferred export market for ceramic tile manufacturers. While there are several American slip resistance standards, the most important one from a ceramic tile manufacturer's perspective, is whatever standard is referenced after each periodic revision of ANSI A137.1, the American National Standard Specifications for Ceramic Tile. The current revision of ANSI A137.1 includes a proposal to delete the ASTM C1028 static COF test method and to replace it with a wet dynamic COF test method using the BOT 3000 automated drag sled testing device.

I understand that the decision to consider adoption of the BOT 3000 was based on the work of Sebald (2009), and further research at both the University of Wuppertal and at TCNA. This research implicitly accepts the German limit values.

The proposed ANSI slip resistance test method would use a test travel distance of 254 mm, except in the case of smaller tiles where the test shall be run with the longest possible travel distance that fits on the tile (with 101.6 x 101.6 mm minimum tile size). The use of such relatively short test travel lengths readily enables the potential use of the BOT 3000 with accelerated wear conditioning procedures.

As originally intended, Harper, Warlow and Clarke (1961) formulated the design criteria for an abrasion testing machine for flooring materials based on measurements of the forces applied to a floor surface by the foot, both in straight walking and turning on the level. While devices such as the Tribopod²⁵ are very useful for accelerating simulated pedestrian wear, the process is too slow to use as an accelerated conditioning procedure.

The limitations of the ISO 10545.7 surface abrasion test have been recognised²⁶ in that the corundum media is so abrasive as to cause wear and colour change that does not occur in service. Attempts are being made to improve the reliability of such tests, based on the Spanish abrasion method UNE 138001²⁷. However, considering conditioning procedures, would a linear reciprocating or rotating motion best model the pedestrian wear pattern? Which type of motion produces more homogeneous wear?

Given the importance of the environmental impact of building materials and the need for sustainability, one might assume that it will only be a short while before there is a need to state or demonstrate the long-term slip resistance perfor-

25 Barbera, J., Usó, J., Enrique, J.E., Felú, C. and Silva, G. Durability prediction of ceramic tile subject to abrasion processes from pedestrian traffic. In QUALICER 96. Castellon (Spain). p .453-465. <http://aulavirtual.camaracastellon.com/qualicerCD/pdf/9623012e.pdf>

Silva, G., Muñoz, A., Felú, C., Ibáñez, M.J., Barbera, J. and Soler, C. Abrasion Resistance of Ceramic Flooring in Actual Heavy Traffic Conditions, In QUALICER 2002. Castellon (Spain). p . 79-82. <http://aulavirtual.camaracastellon.com/qualicerCD/pdf/0232170e.pdf>

26 Simpson, K. Tile Abrasion: ASTM C1027 and Possible Upcoming Changes, Tile Magazine, Sept/Oct 2009, p 32. http://www.tileusa.com/Articles/TileAbrasion_Simpson09.pdf

27 UNE 138001 IN: 2008. Abrasion Resistance of Ceramic Tile to Pedestrian Traffic. Recommendations for Selection According to Use.

mance of flooring materials in the USA. Is there any competing flooring industry or test method that is preferentially placed to fulfil such a requirement? Might the European declarations be recognised and accepted without the need for further testing? Should such declarations be based on the Environmental Product Declaration (EPD) standardized manner of reporting?

10. A CERAMIC ENGINEERING PERSPECTIVE

The slip resistance of ceramic tiles is initially dependant on the macrostructure of the tile and its microtexture, but may then change primarily due to localised abrasion and soiling. The macrostructure will largely be determined by the forming process, while selection of the raw materials, the method of body preparation, the firing cycle and any surface treatment will determine the microtexture and characteristics such as wear and erosion resistance of the different crystalline and amorphous phases. While bonded composite materials might be formed with a specific content of exposed wear resistant angular material that is strongly adhered to the surface, ceramic manufacture is based on the process of vitrification, which involves the inherent full or partial dissolution of materials during the heating phase, together with the possibility of nucleation and crystal growth during cooling. In order to develop tiles with sustainable slip resistance, not only does one need to define several control parameters and to optimise process control, but also to recognise what new characterisation techniques might be required, as well as understanding the relative limitations of any applied slip resistance test method. How many of the existing test methods are capable of recognising that a product has adequate long-term slip resistance for specific environmental operating circumstances?

Diagnosis is the first step in solving any problem. Since there are many different types of wear and friction, and many types of ceramic tile surfaces with varying physical characteristics, simplification of such a complex systemic problem is necessary, even if the outcomes might not be universally applicable.

11. THE SLIPSTD CONSORTIUM PROJECT

The SlipSTD consortium project: Development of Slip Resistant Standard Surfaces for a Safer Environment originally²⁸ had three objectives:

- establish fundamental knowledge concerning the influence of surface characteristics in various environments on the slip resistance of ceramic tiles;
- assist end-users in the selection of appropriate tiles;

²⁸Engels, M. and Tari, G., The SLIPSTD European Collective Research Project: Development of Slip Resistant Standard Surfaces, QUALICER 2008, p. 135; <http://aulavirtual.camaracastellon.com/qualicerCD/pdf/0832260e.pdf>

- promote better understanding of slip resistance issues for manufacturers of ceramic floor tiles and end users to enable them to meet their legislative responsibilities;

and two intended deliverables:

1. A Publicly Available Specification (PAS); and
2. A set of calibrated surfaces with different slip resistance characteristics.

The project's only output appears to be the SlipSTD Publicly Available Specification²⁹. The SlipSTD PAS provides a slip risk assessment based approach for the selection, maintenance and control of hard flooring materials in pedestrian areas, taking into account its usage and foreseeable contamination. It also lists the responsibilities of manufacturers, architects/specifiers, installers and users. However, the following stated responsibilities of duty holders are more idealistic than realistic:

- Maintain and clean the floor covering in accordance with the manufacturer's recommendations and recognised good practice.
- Maintain and clean the floor covering to retain the original slip potential values.
- Monitor the slip potential of the floor covering by regular testing.
- Manage and control the other main variables affecting the occurrence of slip accidents in foreseeably contaminated areas³⁰.

It is generally impossible to retain the original slip potential values. The SlipSTD PAS itself recognised:

"Wear and abrasion degrade all floor covering surfaces over a period of time. The rate of degradation depends on the installation environment and usage. There is no current standard or officially recognised test method that simulates surface wear and predicts service life for floor coverings' surface technical characteristics, including slip resistance. Therefore, it becomes the duty holder's responsibility to establish a control plan to monitor the condition of the floor covering to determine the acceptability of its slip resistance. The control plan should take into account the environment, working conditions and any information derived from previous experience of using the flooring surface in question".

²⁹ SlipSTD PUBLICLY AVAILABLE SPECIFICATION (SlipSTD PAS) Classification of hard floor coverings according to their contribution to reduce the risk of pedestrian slipping. Prepared by : Giuliano Tari with contributions by Brassington, K., Tenaglia, A., Thorpe, S., and Engels, M. July 2009 (Version 6, revised) <http://www.slipstd.com>

³⁰ Just as much control is required in "foreseeably clean and dry areas" since unintentional contamination is not entirely avoidable: accidents happen.

Duty holders, whether shop owners, building managers or cleaning contractors, are unlikely to have 'previous experience of using the flooring surface in question' or the expertise to establish a bespoke control plan. They would prefer to know that a product has suitable sustainable slip resistance so that they do not have to budget for testing. Furthermore, tile manufacturers generally fail to give sufficient cleaning recommendations that can be universally applied, particularly from a green cleaning perspective. The SlipSTD PAS recognised that there is no universal product suitable for all situations and recommended following the cleaning product suppliers/manufacturers' guidance on cleaning methods and compatibility with floor coverings.

Where correctly maintained, smooth flooring with a lower susceptibility to contamination can sensibly be used, reducing the need for aggressive or frequent cleaning, and bringing about obvious sustainability advantages. This should avoid the over-specification of structured or profiled tiles that may be more difficult to maintain.

A key project objective was to overcome vested national interests in traditional slip resistance test methods and to define common "European" minimum slip resistance requirements for ceramic tiles based on defined and measurable surface properties, and objective information relating to the intended use of the floor. The SlipSTD PAS promotes a novel approach to surface characterisation, using optical white light to generate three-dimensional surface topography parameters such as Pp and Pk. These are more representative of the surface and more reliable than the Rz (averaged and filtered) two-dimensional roughness values.

The project proposed a simple three value classification system that takes into account the anticipated type of contaminant, the existence of slip-reducing control measures and the cleaning regime. Hard floor coverings are categorised into the classes (Table 2) according to the existence and implementation of any or all these policies:

- The likelihood of the floor covering to become contaminated in the environment in which it is used.
- The existence and implementation of a restorative plan to deal with unintentional and avoidable floor covering contamination.
- The existence of control measures to reduce the risk of slip accidents.

The SlipSTD PAS explains the scientific background to this new approach and includes an optical topography test method to determine the classification of products. This simple laboratory test is carried out on a floor covering sample or a moulded duplicate surface of an installed product. The SlipSTD Consortium believes the classification system need not be restricted to hard surfaces, but could be extended to other floor coverings. It could presumably also be extended to external areas.

The SlipSTD research program also involved slip resistance measurements (oil wet ramp to DIN 51130; wet barefoot ramp to DIN 51097; the Pendulum with Four S and TRRL sliders according to BS 7976; and a biomechanical friction tester) on 18 tiles that had been previously assessed as having low, medium or high slip resistance, where the tiles either had a smooth surface (Group 1), a non-profiled micro-rough (gritty) surface (Group 2) or structured or profiled surfaces (Group 3).

	Suitable use areas	Proposed surface characteristics
Class 1	Areas that are foreseeably clean and dry and are routinely maintained as such.	No requirements Groups 2 and 3 not advisable
Class 2A	Areas foreseeably contaminated with water and/ or dry contaminants.	Group 2: $P_k > 50 \mu\text{m}$ and $P_p > 90 \mu\text{m}$ Group 3: $P_k > 100 \mu\text{m}$ and $P_p > 200 \mu\text{m}$
Class 2B	Areas foreseeably contaminated with other liquid contaminants with a viscosity higher than water, such as oil or grease.	Groups 1 and 2 not applicable Group 3: $P_k > 150 \mu\text{m}$ and $P_p > 300 \mu\text{m}$

Table 2. SlipSTD classes for hard floor coverings used in internal pedestrian areas

Various roughness data parameters were each correlated with the slip resistance data leading to the proposed surface characteristics for hard floor coverings for internal pedestrian areas, ex-factory and post installation.

The SlipSTD Consortium recognised that this innovative SlipSTD classification system was unlikely to quickly replace the ramp and pendulum classification methods. There has since been a general failure of manufacturers to declare SlipSTD classes for their tiles. However, the global financial crisis probably undermined any initial momentum. While there has been no further technical data published since Qualicer 2010³¹, this does not mean that manufacturers have abandoned the initiative. In fact, optical topography offers huge potential for sustainable slip resistance: such measurements should enable understanding to be developed of any wear that causes slip resistance changes.

As the classification system focuses on objectively measured parameters, it potentially enables a surface roughness based approach to the development and control of sustainable slip resistance. An understanding of any changes in macro-roughness or microroughness supports the analysis of actual slip measurements, independent of the method/s used. Optical topography can also be used to validate accelerated wear conditioning procedures by determining the actual changes in surface characteristics. This knowledge can be transferred to design new surfaces with enhanced slip resistance properties. The scope of such implementation ex-

31 Engels, M., Tenaglia, A. and Tari, G. The Classification of Hard Floor Coverings According to Slip Risk: A New Approach for Ceramic Floor Coverings; QUALICER 2010, <http://aulavirtual.camaracastellon.com/qualicerCD/pdf/2010101.pdf>

tends to all hard floor coverings, e.g. natural stone, and can also support the discussion on comparability of slip resistance test methods. Any correlation between the results of slip resistance test methods, and the applications to which products are best suited, is likely to depend on the detailed surface topography of “product groups”.

This approach, which is still under development, will be discussed by the panel using examples and case studies including a German approach to accelerated wear conditioning of tiles. Optical topography is a significant objective tool for quantifying surface characteristics and their influence on slip resistance and its durability. It thus has the potential to support cleaning and maintenance guidelines and control regimes, as well as the design of durable surfaces. Optical topography can give tile manufacturers information in terms of one or several parameters, which the manufacturer might use for quality control procedures, as well as ensuring that the correct products are appropriately selected.

12. THE ULTRAGRIP PROJECT

Gonzalo Silva (ITC) kindly drafted the following introductory material for the panel debate

New initiatives have been continuously pursued since 2007 with a view to recasting the standards applicable to the construction sector in order to incorporate sustainability-related criteria into standard documents, particularly with relation to durability under foreseen service conditions. The definition of the intended use of a standard product is, in fact, pre-requisite to defining the sustainability indicators in the future harmonised standards in the frame of the Construction Products Regulation (CPR), though at present many standards do not yet include this information.

Although the standards may be the appropriate instruments for addressing this new sustainable approach in the field of construction, as far as the problem of slipping is concerned, they have unfortunately been a barrier to progress. Since the establishment in 2002 of the horizontal standardisation committee CEN/TC 339, whose objective was to unify the vision of all types of flooring materials in relation to slip resistance requirements, it has not even been possible to reach an agreement with regard to the test methods for evaluating anti-slip performance. In my view, this absence of results largely stems from the focus of the work, which has targeted the evaluation of the test methods instead of seeking to standardise the assessment criteria for different service conditions. In fact, the absence of recommendations on the application of the four proposed methods for the different service conditions in draft prCEN-TS 16165 was the main reason for the negative vote of the Spanish delegation on this committee.

In this same sense, a Spanish collaboration initiative between the flooring and the footwear sectors, with a view to jointly addressing the problem of slip, has also laid the seed for the European project 'Development of a high grip designing tool (ULTRAGRIP)' funded by the Seventh Framework Programme of the European Commission (FP7 -SME-2010-1.262413). This project involves a comprehensive approach to the factors of influence that condition the slip/fall risk, and includes companies that manufacture different types of flooring (ceramic, natural stone, wood, and polymers) and footwear (professional, sporting, and conventional), and it is principally aimed at developing tools for designing optimised flooring and footwear for different real applications (service conditions, pollutants, ergonomic requirements, etc.)

This objective obviously requires the generation of knowledge of all the variables of influence, so that, as partial results, it is sought to obtain correlations between the test methods in the simulation of different service conditions and types of footwear, the study of the durability of their performance in different environments, harmonisation proposals of requirements for flooring and footwear in accordance with their real applications, etc. As a whole, the project seeks to increase the useful life of anti-slip solutions, limiting the need for subsequent maintenance treatments and reducing the risk of user slip/fall injuries.

Muñoz et al conducted an associated study³² simulating real pedestrian wear in external conditions, by adjusting the operating conditions of a semi-industrial polishing head fitted with a quartz based scouring pad. The correlation was validated using an in situ wet pendulum study, where the slip resistance results decreased from 50 to 30 BPN in the first year before tending asymptotically towards a practically constant value after six years exposure (250,000 pedestrian traffic passages). However, only the central portion of the abraded area fulfilled the homogeneity requirements that are necessary when using conditioning processes for making predictive friction measurements.

The ULTRAGRIP research program involved slip resistance measurements (oil wet ramp, DIN 51130; wet barefoot ramp, DIN 51097; the Pendulum; and a biomechanical friction tester) on 20 different types of materials that variously had polished, smooth, rough or profiled surfaces using several flat and profiled rubber and polyurethane sole materials that had different hardnesses. Preliminary conclusions include:

- Good correlation between the methods from 0.15 to 0.50 COF when using flat soles/sliders and water on floors that are not profiled;
- No linear correlation between flat and profiled soles;

³² Muñoz, A., Noguera, J.F., Domínguez, R., and Gilabert, J. Analysis of the life span of the anti-slip performance of ceramic flooring, In Qualicer 2012.

- Decreasing dependence with shoe design from polished and smooth floors to rough and profiled floors;
- No linear correlations between contaminants (water, water + SLS, oil);
- We will need to establish different test conditions for simulating each of the relevant actual conditions of use.

13. CONCLUDING THOUGHTS

In 2000, Dr Grout³³ produced the following humorous definitions

Slip resistance: Valuable quality, now capable of empirical measurement using Tortus, Pendulum or Ramp tests to guarantee that laboratory rating bears no resemblance to performance in real life. None however, compare to the tiler's tried and tested "banana skin" test.

Specification: Pointless document (or equivalent).

Standard: The lowest common denominator, expressed in terms unintelligible to all.

While other persons' slips and falls might often be the cause of relieved laughter, slip resistance has always been a serious matter for ceramic tile manufacturers, even if some might have regarded it as an intractable problem that could be disregarded for the time being. The required Declarations of Performance might help to focus upon proactive solutions that advantage the industry, recognising that competing materials that have sustainable slip resistance are unlikely to require accelerated conditioning procedures.

Any failure to comply with the declared slip resistance performance could be costly, not just for the companies concerned, but for the reputation of the ceramic tiling industry. It might be anticipated that the introduction of the CPR will lead to widespread and important improvements in the accessibility, safety and performance of all new and upgraded buildings. However, we should remember that every prescription has two parts: the medicine and the method of ensuring correct use. Greater attention will have to be paid to diverse cleaning and maintenance issues.

The time for joyful laughter is when we develop an optimised long term solution to the immediate problems associated with slip resistance. However, a longer term goal should be to incorporate slip resistance into building information modelling.

³³Dr Grout, Tile UK, Vol. 5 No 3, Summer 2000, page 69.