Ramping up the slip debate

This paper is an updated and much expanded version of a paper that appeared in issue 54 of ***Tile Today****. It provides notification of some important changes that should soon be made to the slip resistance standards. It alerts specifiers to some potential problems with ramp test classifications. It also considers some aspects of which test may be the most relevant primary slip resistance test to use, depending on the anticipated conditions. In addition, it reflects on some stone test results and considers 'What is an appropriate recommendation for the slip resistance of residential bathrooms?'*

An American colleague recently observed that the German slip resistance standards had very little impact on the choices of tile that were used in commercial buildings in the USA. Was this also true of Australia, where the German slip resistance requirements had been adopted as recommendations in Standards Australia Handbook 197:1999, *An introductory guide to the slip resistance of pedestrian surfaces*? We had also introduced the German ramp tests in AS/NZS 4586: 1999, *Slip resistance classification of new pedestrian surface materials*.

This question caused me to wonder whether the adoption of the German standards had reduced the incidence of slip-related accidents. Given that the Australian slip resistance standards, AS/NZS 4586 and AS/NZS 4663, *Slip resistance measurement of existing pedestrian surfaces*, are in the process of being revised[1], this is an opportune moment to reflect on the individual test methods and how they are used.

In this context, a particularly pertinent question would be "Do we place too much blind faith in the absolute accuracy of inclining ramp (or other types of) slip resistance test results?"

Proposed major changes

The proposed major change to the standards relates to the wet pendulum test, which will require that the rubber slider is prepared on a lapping film when testing smooth surfaces. This will bring the standards into line with BS 7976, *Pendulum testers*.

The draft AS/NZS 4586 Preface states "This revision incorporates an additional requirement for preparing rubber test feet when testing smooth surfaces. Research has shown that in some instances, where the Rz surface roughness of the pedestrian surface material is below 20.0 µm, a true reading of the wet slip resistance may not be obtained because the surface roughness of the rubber slider is greater than that of the pedestrian surface material. This inhibits the generation of a water film between the slider and the floor. A truer reading may be obtained by preparing the slider on a 3 µm lapping film as detailed in the standard. A slider prepared in this way is a closer representation of a worn and polished heel and may best reflect the lower slip resistance attributable to the contact of two smooth surfaces under water-wet conditions".

[1] DR 07066 CP Slip resistance classification of new pedestrian surface materials, and DR 07067 CP Slip resistance measurement of existing pedestrian surfaces, were available for public comment until 8 March 2008..

As reported in the December 2004 issue of *Tile Today*, in "Slip resistance and social responsibility", (issue 45, page 30) it had been anticipated that use of the lapping film would be adopted when the AS/NZS 4586 and AS/NZS 4663 standards were revised in 2004. Use of the lapping film yields a smoother surface on the rubber test foot, and mitigates against the pendulum test result being an artefact of the roughness of the rubber. Use of a smoother rubber test foot allows lower readings to be obtained on some smoother pedestrian surfaces. This effectively extends the critical bottom end of the pendulum scale, and allows better discrimination between very slippery and not so slippery products, which is an excellent outcome from a safety perspective.

While I still fail to understand why a few organisations cast negative votes that prevented adoption of the lapping film, I am confident that the revision will be fully supported this time. This is partly due to Robert Olsen, of Mirvac, who represents the Property Council of Australia on Standards Australia Committee BD-094, *Slip resistance of flooring surfaces*. Robert borrowed a pendulum and a surface roughness meter and undertook several tests on several different products, where he investigated the effect of rubber test foot preparation. Not only did he validate the results that I had published, but Robert also showed that there is a similar effect when the pendulum is used for dry testing of clean smooth surfaces.

One crucial outcome of the changed test foot preparation is that some products will receive a lower wet pendulum slip classification, where this is due to substantially lower results rather than having results that are close to the transition between classifications. Some products will fall from class X to class Z. This fact may explain why some people have slipped on floors that appeared to be safe, based on achieving a minimum coefficient of friction (CoF) of 0.4 when the floor has been tested.

A more extensive pedestrian flooring selection guide, based on minimum pendulum or ramp recommendations for specific locations, has been made available for public comment in Appendix H of DR 07066 CP. This expanded set of modified and simplified recommendations will become a focus of a revised HB 197, but is unlikely to be published in AS/NZS 4586. These proposed recommendations make use of the Y classification. However, any detailed discussion of them will be deferred until after receipt of public comment.

Extreme caution should be exercised with respect to the Appendix H recommendations. They relate to classifications that are based on the new method of rubber test foot preparation. If the intended wet pendulum recommendations are used in conjunction with the existing classifications, the consequences could be disastrous (if the product selected is one that would have a lower classification with the new method of rubber preparation).

It is anticipated that the new standards will be published at the same time as a revised HB 197. The need to check that test reports are relevant will be made most explicitly.

Most products that change classifications have an Rz surface roughness of less than 10 microns. Some test houses have been providing complimentary surface roughness results as they only take a few minutes to make. Those products that have an Rz surface roughness of 20 microns or more will continue to be tested using a rubber test foot that is prepared with 400# grit paper. For such products, existing test reports will remain valid. There will be an extensive publicity campaign once the standards are finalised and their publication date is determined.

When the European norms for the slip resistance of stone (BS EN 1341, BS EN 1342, BS EN 14231) were considered (March 2005 issue of *Discovering Stone*, "Beware of conflicting stone slip resistance reports"), they were found to be deficient, principally because of the lack of control over the rubber test foot preparation. The variable roughness of the rubber 'determined' the slip resistance of the product being tested. It is essential that we immediately adopt the use of lapping film for preparing rubber test feet when testing smooth surfaces. This should add a factor of safety to the processes of selecting products and monitoring their in-situ performance.

Other proposed changes

It is proposed that one will be able to use TRL rubber (also known as TRRL rubber and rubber 55) extend to the X, Y and Z classifications, rather than just classes V and W. It is known that use of different (Four S and TRL) rubbers may result in the one product receiving different classifications, but this situation has existed since AS/NZS 3661.1, Slip resistance of pedestrian surfaces, was first published in 1993. One could integrate the results in order to derive new classifications, but the need for the additional required testing is hard to justify.

Four S rubber is the rubber that is used in most wet pendulum tests of flooring surfaces. It is anticipated that the TRL rubber will be principally used for assessing coarse external paving surfaces and for auditing wet barefoot areas.

There are a number of new definitions including:

> **Profiled surface:** a surface with a designed raised geometrical pattern that provides volumetric displacement.
>
> **Structured surface:** an irregular surface, possibly produced to provide enhanced slip resistance.
>
> **Slip resistance value (SRV):** The SRV is the mean BPN value for the sample that has been tested, regardless of whether the surface was level or on a slope.
>
> **Slope design value (SDV):** The SDV is the mean BPN value required on a slope of a known maximum gradient. The SDV may be calculated by using the tables that are given in Appendix G, using the minimum SRV that is considered appropriate for a level surface.
>
> **Slope correction value (SCV):** When the slip resistance of a sloping surface of known maximum gradient is measured, the SCV is an adjusted SRV, giving a value equivalent to that of the equivalent SRV for a level surface.

It is hoped that widespread use of SRVs (as a new term) will help differentiate between the old (2004) and new (2007) test methods. The use of this term on product literature should indicate that it is up to date.

Appendix G contains tables that can be used to calculate the SDV and the SCV, as well as examples of calculations for wet pendulum and dry floor friction test results. It is hoped that this guidance will help prevent any calculation errors, particularly when selecting products for sloping areas, which are predominantly external. There have been some incidences in litigious matters where 'experts' have made errors that seemingly strengthened the case of their client. However, the exposure of one such error, together with a number of other questionable decisions, had devastating consequences.

If a periodical audit yields low SCVs, remedial treatment may be required.

AS/NZS 4586 also anticipates that some product standards might one day require that products are tested after a conditioning treatment. The scope of the wet pendulum test method states "If a product standard contains a requirement for the permanence of slip resistance, this requirement shall be determined after the appropriate accelerated ageing or wear testing procedure".

There are no significant immediately proposed changes to the ramp test methods, but the Committee felt unable to respond to some momentous external realities.

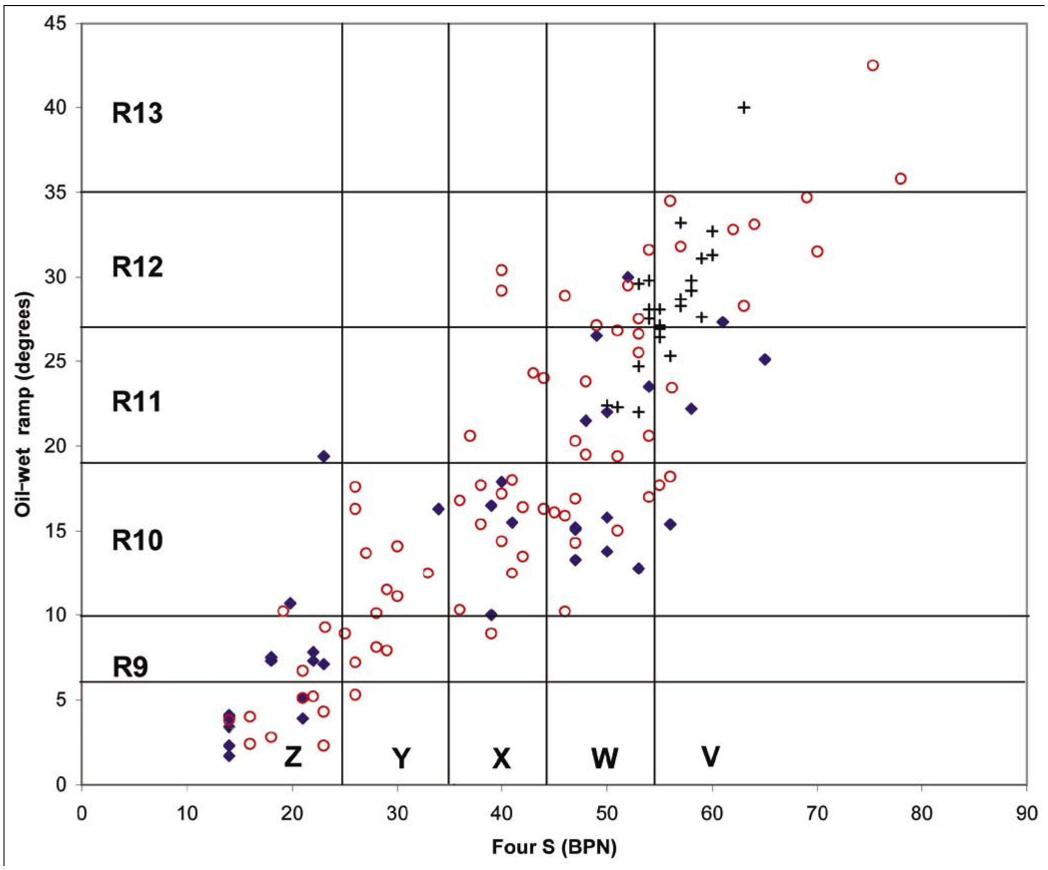

Figure 1 A comparison of oil-wet ramp and wet pendulum slip resistance results for some ceramic tiles, in the context of the AS/NZS 4586 classifications. Glazed tiles (♦) Porcelain tiles (○) And Terracotta tiles (+)

Real world review

In returning to my opening remarks, it is hard to know exactly what impact our adoption of the German ramp tests has had. There has certainly been a marked trend towards R ratings to the detriment of pendulum results. Firstly, this is probably because of the ready availability of ramp ratings from many European manufacturers; and secondly, the wider range of areas detailed in the German regulations (Table 5 as compared to Table 3 in HB 197). Since nobody seems to have undertaken any follow-up research to determine whether use of ramp test classifications has reduced the incidence of slips and falls, one cannot assess whether their introduction has been successful.

Where the public is concerned, the most likely contaminant is water. One worst case scenario is somebody wearing shoes that have no tread. While the type of soling material can have a profound influence, the British Health and Safety Laboratory (HSL) has chosen to base their wet shod (PS SOP 12) ramp test on Four S rubber and potable water. Preliminary research results have indicated that Four S rubber shod shoes provide less slip resistance on water wet smooth surfaced hard finishes than footwear with a treaded pattern.

Although HB 197 states that the ramp test methods may be best in some circumstances and the pendulum in others, it shows no bias. Best practice is to base a specification on both pendulum and ramp tests. As Figure 1 shows, there is no correlation between these test results. Each test provides an indication of available slip resistance in different environmental conditions; oil being the contaminant with people wearing safety shoes for the oil wet ramp test; and water being the contaminant with people wearing flat shoes with hard rubber soles for the wet pendulum test. An R10 oil-wet ramp classification may not necessarily provide an indication of adequate wet barefoot slip resistance. When considering a hotel ensuite, one might prefer to specify class X where the pendulum has a TRL rubber test foot.

In considering primary test methods for anticipated environmental conditions, one should consider using the wet pendulum test for most normal public areas, the wet barefoot ramp test for wet barefoot areas, and the oil-wet ramp test for specific conditions such as commercial kitchens. It should be note that in Germany, products may have to comply with a volumetric displacement requirement as well as the oil-wet ramp classification. The volumetric displacement requirement is too often ignored by Australian specifiers.

Comparisons of the coefficients of friction obtained from Four S rubber shod water wet ramp tests and pendulum tests have generally shown reasonable agreement. The exceptions to this have generally been on surfaces that have been heavily textured and/or profiled. This leads one to question which test method is more suitable for testing structured and profiled surfaces.

Given that the wet pendulum results for tactile ground surface warning indicators are essentially a function of how the test specimen is positioned, it would seem that ramp tests are likely to be more appropriate for testing many structured and profiled surfaces. However, the geometry of tactile ground surface indicators is such that they are difficult to walk on upon the ramp.

While there appears to be a move towards Four S rubber shod water wet ramp testing in Europe, is this sensible if the test can only be conducted in the laboratory? If the results are generally in agreement with the pendulum, and the pendulum test can be conducted on site whenever required, and pendulum testing takes less time and costs less than ramp testing, where is the logic in switching to Four S rubber shod water wet ramp tests? The logical exception is certain profiled surfaces.

HSL has a high degree of confidence in the pendulum test method for assessing the slip potential of floors under fluid contaminated conditions, having previously conducted rigorous research on the pendulum test methodology. HSL determined that the pendulum was suitable for assessing pedestrian slip risk in contaminated conditions. The Health and Safety Executive then adopted the pendulum test as its preferred method for assessing the slip risk posed by floors for use during enforcement and prosecution.

If one believes in the accuracy of the pendulum test, one can accept ramp results that underestimate the coefficient of friction (CoF) of a water-wet floor compared to data generated by the pendulum test. A floor specified on the basis of the ramp results would tend to be 'fail safe', in that it could demonstrate higher levels of slip resistance when installed than might be expected based on the ramp results. However, those ramp results that overestimate the slip potential are a potential cause of concern.

Although there is no problem if the ramp-derived CoF is accurate, this implies that the pendulum result was inaccurate. As previously reported, the pendulum test may underestimate the slip resistance of warped specimens as the 75 mm wide test foot may make relatively little contact with the specimen. A shoe heel or a rounded sole may have a significantly higher proportion of the footwear in direct contact with a rounded surface. The same may be true of some profiled and structured surfaces.

There are some structured and highly profiled surfaces where more reliable indications of slip resistance may be obtained by using the pendulum fitted with TRL rubber. This more resilient rubber allows better contact with more of the walkway surface. The TRL rubber has also been found to provide a better indication of wet barefoot slip resistance than Four S rubber, and is thus often used for auditing wet barefoot areas.

Another important question is "How does this relate to the oil-wet and wet barefoot ramp tests?"

Existing problems

The oil-wet ramp test is dependent on the availability of the calibration boards and the specified shoes. The specified Lupos Picasso shoes are no longer available for sale. When the previously specified Bottrop boots became unavailable in 1998, it took 5 years before the Lupos footwear was formally accepted in Germany. CSIRO assisted BIA (Germany) and undertook a significant amount of confirmatory research, testing on the ramp and with the SATRA STM 603 robotic foot slip tester. The Lupos footwear tended to give slightly higher results, but generally within the 3 degree detection limit. Prior to this, a change in production parameters for the specified Bottrop footwear had caused several problems: laboratories were unable to obtain the correct results. BIAG (Germany) has again been testing various footwear. A decision on the proposed use of Uvex Athletic 9452/9 footwear will be made in Germany on

29 March. If accepted, it is hoped that any confirmatory research will be shared with BD-094, if it is not openly published.

At the beginning of February 2007, there was only one set of new oil-wet E, P and R calibration boards available for sale globally. These tiles were manufactured over 20 years ago. The supply of wet barefoot A, B and C calibration boards has been exhausted for over a year. SFV (Germany), suppliers of such boards for over 20 years, has been trying to identify new calibration boards for quite some time now, but without success so far.

To add to this, there are slight differences in engine lubricating oils of the specified SAE viscosity class 10 W 30. Such differences in the oil give rise to some differences between the untreated results, but it has always been hoped that these differences have been largely eliminated by using the calibration boards to produce corrected results. We also know that wear of the specified shoes may bring about some differences in the untreated results, as might wear of the calibration boards. It has again been hoped that the effect of such differences has been minimised by producing corrected results.

When one uses the calibration boards to determine correction factors, one would hope that any measured differences between laboratories would be relatively small. The reality is that there can be significant differences between individual walkers when the same calibration boards, oil and shoes are used. Some people are not well suited to conducting such tests. This may be indicated by a high level of inconsistency each time they walk on the calibration boards, or it may relate to a particular range of inclinations. This problem is more concerning with respect to the wet barefoot ramp test, where the calibration boards are not used to correct the results. My unpublished analysis of some past wet barefoot ramp tests indicates that this could improve the reliability of the final classification, while eliminating some confusion about the classification of borderline products, and providing a useful additional quality assurance aspect.

Further problems

There have been hearsay tales about the consistency of ramp test data, where manufacturers have received differing results when products from the same batch have been sent to different test houses. Specifiers don't seem to be too concerned about the relative position of a product within a class. If they are told it is an R10 product, they accept it regardless of whether it may have had a result of 10.1 or 18.9 degrees. There is obviously a significant difference in the slip resistance potential of such products. There may be no discernible initial difference in performance between products with results of 10.1 and 9.9 degrees, but one product is class R10 and the other R9.

I am concerned about the possible covert coaching of walkers during the conduct of tests to ensure that they are within the permitted limits for the calibration boards. Such coaching might improve commercial efficiency (by enabling a walker to test products that day). However, it would obviously invalidate the tests (if detected).

There are no proscribed compliance limits that qualify walkers to walk on the wet barefoot ramp calibration boards. However, if the walkers have significantly different results for any board, the walks have to be repeated, thus impairing commercial efficiency.

While parts C to E of AS/NZS 4586 are technically equivalent to the DIN 51097 and DIN 51130 German standards, parts C and D have a variation which permits tiles, other than mosaics, to be butted up against each other with no spacing required. This variation was permitted on the basis that, if a slip is initiated it will not be prevented once the foot has slid by more than 100 mm. Hence in the case of tiles larger than 100 x 100 mm, there is a rationale for eliminating joints that may prevent people from slipping. However, might differences in laboratory protocols result in differences in test results between laboratories?

Filling tile joints helps to prevent the loss of oil. However, any failure to fully clean grout from the face of specimens could lead to higher angles being reported. The use of silicone sealant to fill some joints could lead to lower angles being reported, particularly if any sealant should contaminate the walking surface. The need for filling joints is probably greatest where wet barefoot tests are conducted, since there must be a full flow of water across the lowest tiles.

I am concerned about the possibility of oil contaminating the water used in ramp tests if the same inclining platform is used for conducting both oil-wet and water-wet tests. As a precious resource, the water may be recirculated during the testing (which also facilitates addition of any required wetting agent, as well as helping to conserve it). The standard does not explicitly require that water is recirculated, but this might be implied from the requirement that the test solution (1 g wetting agent per 1 L potable water) shall be prepared shortly before the test. It also requires that “the test fluid shall be used within a period of 2 h of commencing any testing”. Thus, with a required flow rate of 6 ±1 L/min, one might also prepare a batch of 720 or 840 L of test solution.

I have sensed that the viscosity of the test fluid has changed during the course of a testing session. However, there is no requirement to monitor the viscosity, or to refresh the test fluid if its viscosity deviates outside a permitted range. There is a note suggesting that the temperature should be 23 ±5ºC. Depending on the season, there may be a significant change in the water temperature during the course of a 2 hour period unless the temperature of the room or the water is controlled. A change in water temperature will also affect the water viscosity. Viscosity control becomes an issue if there is a significant time interval between walking on the calibration boards and walking on the test board. This may occur if there are several test boards to be tested. One obvious solution is to install appropriate filters and temperature controls if water is being recycled, so that there is water quality assurance.

The wet barefoot standard does not require that the calibration boards be retested after each test board is tested. It does require that if a test board is within one degree of a calibration board, that both the test board and the calibration board shall be walked on again. The test is trying to establish whether a test board is more slip resistant or not than a particular wet barefoot calibration board. The calibration results essentially establish where the goal posts are positioned.

Since the results are not corrected, as in the case of the oil-wet testing, the mean angles have less relevance. There seems to be greater variability between individual walks when a walker walks on the calibration boards. The walks at the end of a test session may be quite different to those at the beginning of the session. This might be due to a change in the water quality, a change in the condition of the sole skin, fatigue, or a combination of these and other factors. It is thus important that any test board should be properly related to the relevant calibration board. It would thus be inappropriate for each walker to walk on each calibration board eight times at the start of testing, in order to try and avoid the need to retest the calibration boards later in the session. Unless one tests the calibration boards at the end of the session, one cannot confirm the final position of the goal posts.

The test method requires that the arithmetic mean is calculated from the eight individual values, but that if any individual value deviates from the mean, the test shall be repeated and the mean calculated from 16 individual values. If the results between the initial walks on a calibration board are significantly different from those when it is subsequently walked on, there is an argument for discarding the initial results with respect to that test board.

AS 4586 calls for specimens that are approximately 1000 x 500 mm in size, but makes no allowance for significant deviations from this. There may be a problem with placing large specimens on the inclining ramp. It is possible to test smaller specimens, but there should be at least 800 mm to walk on – one only stands on the top 200 mm of the board. The specimen cannot be so narrow as to affect the required gait rhythm. Most importantly in the case of oil-wet testing, the amount of oil used must be adjusted in accordance with the specimen size.

AS/NZS 4586 also permits materials to be tested without being adhered to a board if they are ‘self-supporting’. This was intended to permit the testing of large stone and concrete slabs that are quite thick and have flush edges. However, there have been anecdotal reports of small thin tiles (150 x 150 mm dust pressed tiles with bevelled edges, and 230 x 110 mm split extruded tiles) that have been tested without being fixed to boards. Such tiles are often not completely flat. Any under foot movement must be of concern, as it will disrupt the gait rhythm and add to the uncertainty as to whether it is safe to continue walking on the tiles. Such movement has probably resulted in lower angles being reported for some products.

A consideration of the following scenario indicates the need for more explicit guidance. A tile merchant imported a 300 x 300 mm natural porcelain tile with a structured finish from a respected manufacturer on the basis of its wet barefoot B classification. He submitted a sample to a local laboratory to be told that it failed to obtain a classification. The merchant advised the manufacturer that he was quarantining the tiles as they were not fit for purpose. The manufacturer submitted a second sample from the same batch to a respected Italian laboratory, to again be told that the product had received a low B classification, with the individual walkers obtaining mean results of 18.7 and 19.1 degrees.

The merchant then asked the laboratory he used for his raw test data. This indicates that walker 2 found that the tile should have been class A, but walker 1 did not. In fact, as Table 1 shows, the test board was within 1 degree of the A calibration board. The Standard required that further walks should have been conducted, but this did not occur.

The tile manufacturer, not having been paid, made a claim on their credit insurer. The repercussions made it hard for the tile manufacturer to purchase Italian tiles on credit.

The tile merchant then resubmitted further tiles from the same batch and asked that they be retested, specifying that the tiles were to be fixed to boards, with the use of a 5 mm grout joint. The results are in Table 2. Walker 1 now found that the tiles were definitely class A. A new third walker found that they were almost class B.

Table 1 Inconsistent wet barefoot ramp results from one laboratory for the same tile

	Mean ramp angle, 4 walks			
1st test	Board A	Board B	Board C	Test tiles
Walker 1	13.08	18.20	25.63	11.78
Walker 2	11.83	17.85	25.98	12.95
Mean	12.45	18.03	25.81	12.37
2nd test				
Walker 1	12.80	17.33	26.48	15.45
Walker 3	11.83	17.03	25.58	16.80
Mean	12.32	17.18	26.03	16.13

The merchant then sought an explanation from the laboratory as to why the results were so different. Did the use of a 5 mm grout joint cause the difference, or might there have been some grout haze on the second set of tiles?

By this time, the original tiles had been discarded, despite the merchant having put the laboratory on notice, by making several enquiries about the unexpected results. The merchant has still failed to obtain a satisfactory explanation, having consistently found it very hard to get any information.

The last explanation that the merchant received was that the last batch of tiles had been tested with the pendulum, and had been found to have a mean result of 32 BPN. When the first set of tiles had been tested, the individual results had been 30, 24, 29, 28 and 27 BPN, with a mean of 28 BPN. The laboratory thus concluded that the second set of tiles must have been more slip resistant. It is disconcerting to think that that these tiles were all from the same batch. It is most unusual to take two random samples of five specimens, only to find that the specimens in one sample perform differently from the specimens in the other sample. Did the specimens really differ so much, or are we placing too much faith in the accuracy of pendulum results?

AS/NZS 4586 requires that "After the apparatus has been calibrated, regular internal checking shall be conducted on a set of control specimens and the results recorded. When results obtained from the control specimens vary from the values established following calibration by more than 5 units, the apparatus shall be partially or completely recalibrated".

Is the Standard effectively saying that a ± 4 unit variation is acceptable? This would mean that if a set of control specimens had a mean result of 28 BPN after the pendulum had been calibrated, then any subsequent result from 32 to 24 BPN would be acceptable.

A study that I organised in 1998 revealed some interesting results Twenty-seven laboratories tested six sets of ceramic tiles with a Four S rubber slider. Twenty-two of these laboratories also tested the same tiles using a TRRL rubber slider. An earlier American study found that repeated tests with the pendulum showed a standard deviation of 1.0 BPN unit. While my study found similar *repeatability standard deviations*, this statistical measurement did not indicate the magnitude of the range of results. The largest result was typically 30% above the mean, and the smallest 15% below. Thus if a tile had a mean of 40 BPN, the results might range from 34 to 52

BPN. When the results for six outlying laboratories were variously withdrawn for each tile, most of the results fell within 10% of the mean. Where a result of 39 units indicated an AS 3661.1 pass and 38 units a failure, it seemed that too much emphasis was being placed on the accuracy of this instrument. We thus moved to AS/NZS 4586 and AS/NZS 4663.

This was not the first time that the merchant had experienced a significant difference in results between these laboratories. There appears to be little that one can do in such situations unless the laboratory concerned is NATA accredited, or has a positive open policy with respect to the swift resolution of problematic situations. The merchant suffered financial loss but decided not to resort to litigation, which can be a very costly last resort.

Domestic bathrooms and stone surfaces

The Local Government and Shires Association of New South Wales has a Slips and Falls Prevention Working Party and is represented on Committee BD-094. Local governments certify that new buildings (both domestic and commercial) are fit for occupancy. The inclusion of provisions aiming to reduce the incidence of slips and falls in and around buildings should ensure that all new floor surfaces are slip resistant, which is an obvious and relatively easy way to improve safety.

Thus some Councils have Development Control Plans which include provisions such as “All new floor surfaces and finishes to have a slip resistant classification which complies with the relevant location criteria set out in Table 3 of the Standards Australia Publication HB 197: 1999 An Introductory Guide to the slip resistance of pedestrian surface materials”.

The Local Government and Shires Association of New South Wales has thus been keen to have locations such as domestic bathrooms included in Table 3 of HB 197. While we may feel we have the right to decorate our homes as we see fit, we are required to fit smoke detectors in new homes, just as we are required to wear car seat belts and bike helmets.

A communiqué from the 2007 Sustainable Materials in the Built Environment Conference urged governments to use their purchasing power to further drive the commercialization of innovative sustainable materials across all product categories. “Governments at all levels must recognise that it is insufficient to merely support sustainable new technology research and commercialization. This must be followed by active procurement of products and services incorporating these technologies to enable their establishment in the market place”. In a similar way, Councils can play a proactive role in regulating the type of floor surfaces and floor finishes used, to contribute to the reduction in the number of falls and associated costs.

Since the BCA has a functional statement, “A building is to provide safe access for people to the services and facilities within”, and requires that some floor surfaces must have a non-slip finish, there is an argument that it is necessary to require slip resistance testing to determine whether “safe access” has been provided to the public.

In the case of residential bathrooms it was proposed that the HB 197 recommendations for residential bathrooms should be either a (modified) pendulum classification of Y, or a ramp classification of A or R9. Several ceramic tile merchants have expressed their concern that this will prevent the sale of products that have traditionally been used in residential bathrooms. Others have stated that they could not afford to pay for independent testing of all their floor tiles. Although some have said that the proposed recommendations will result in the use of tiles that cannot be readily cleaned, where is the factual data to support this position?

From a stone industry perspective, I represent the Australian Stone Advisory Association (ASAA) on the Committee. I am awaiting instructions as to how ASAA will vote on this issue. However, let us consider some of the data published in *Discovering Stone* in "Practical aspects of the slip resistance of stone" (issue 2, page 16) and in "Beware of conflicting stone slip resistance reports", (issue 7, page 26).

Some raw data for the grey granite is given in Table 2. It can be seen that the honed (180 and 220 grit) granite would be classified as Y with the proposed test method, and could thus be used in a domestic bathroom. The polished (400 and 600 grit) granite would be classified as Z. The TRL results have not been classified as the rubber was not conditioned on lapping film, as the proposed standard would require.

Four walkers were used for the wet barefoot ramp test: reliable R; self-confessed unsuited U; enthusiastic inconsistent I; and experienced E. All of the walkers got the calibration boards in the right order, and close to the expected values. This is probably due to the nature of the boards, but it could also be a learned experience. It can be seen that R managed to get the boards in the same order as the pendulum, with or without shoes, but the other walkers did not. Walker R classified the honed tiles as A, again indicating their suitability for a residential bathroom.

Table 2 Some pendulum and water wet ramp slip resistance test results (in BPN and degrees) for a grey granite

	120 grit	180 grit	320 grit	400 grit	600 grit
Pendulum, Four S, 400#	39 (X)	38 (X)	36 (X)	32 (Y)	27 (Y)
Pendulum, Four S, 3M	33 (Y)	27 (Y)	19 (Z)	15 (Z)	11 (Z)
Pendulum, TRL, 400#	27	23	22	19	15
Wet barefoot ramp - R	16.8 (A)	13.7 (A)	11.2 (A)	10.2 (-)	9.8 (-)
Wet barefoot ramp - I	12.5 (A)	13.2 (A)	12.5 (A)	12.8 (A)	14.1 (A)
Wet barefoot ramp - U	4.7 (-)	4.0 (-)	4.9 (-)	3.3 (-)	6.3 (-)
Wet barefoot ramp - E	16.7 (A)	17.1 (A)	20.6 (B)	15.8 (A)	16.3 (A)
Rz, µm	14.1	10.0	6.4	6.0	11.7
85 degree gloss, %	34.3	39.0	58.8	60.4	71.1
Wet ramp, Four S - R	16.0	12.0	7.9	5.9	4.2
Wet ramp, Four S - I	5.5	5.7	4.3	4.2	5.4
Wet ramp, Four S - U	3.7	5.1	7.6	8.2	10.8

In looking at the black granite results in Table 3, it would appear from most of the results as though the 220 grit stone had been over-polished, and that there was a quality control problem. Walker R failed to detect this. Given walker E classified all of the granite as A or B, all but the 600 grit granite would receive an A classification when the results for both walkers were used, as the Standard requires. This would allow all but the 600 grit black granite to be used in a domestic bathroom. Conversely, only the 120 grit granite could be used according to the proposed pendulum recommendation.

Table 3 Some pendulum and water wet ramp slip resistance test results (in BPN and degrees) for a black granite

	120 grit	220 grit	320 grit	400 grit	600 grit
Pendulum, Four S, 400#	34 (Y)	29 (Y)	32 (Y)	31 (Y)	31 (Y)
Pendulum, Four S, 3M	23 (Y)	14 (Z)	22 (Z)	14 (Z)	16 (Z)
Pendulum, TRL, 400#	20	17	20	15	20
Wet barefoot ramp - R	16.6 (A)	13.1 (A)	11.2 (A)	10.3 (-)	9.2 (-)
Wet barefoot ramp - E	19.4 (B)	14.8 (A)	18.8 (B)	15.7 (A)	12.3 (A)
Wet barefoot ramp - both	18.0 (A)	13.9 (A)	15.0 (A)	13.0 (A)	10.7 (-)
Rz, µm	9.5	5.8	6.9	6.1	7.0
85 degree gloss, %	46.2	62.7	54.3	62.8	67.0
Wet ramp, Four S - R	14.5	12.2	10.5	7.6	5.4

In comparing both sets of results, it can be seen that the black granite tends to be smoother and glossier, as well as having lower results. Given that the 220 grit results are inconsistent with the other results, producers should be wary of relying on the processing alone. Gloss results appear to offer a more suitable secondary test than surface roughness (where Ra, Rz, Rv, Rt and Rp were all determined). However, any secondary test, such as gloss or SlipAlert readings, needs to initially be well correlated with the primary test method for each specific product.

In comparing the wet pendulum and wet barefoot ramp test methods, it appears quite obvious that the pendulum is the more reliable test method because it lacks the subjectivity of the walkers. While some walkers are more dependable, even reliable walker R failed to detect the anomalous slip resistance of the 220 grit black granite.

Experienced walker E seems to have detected the slipperiness of the 220 grit black granite, but overrated the 320 grit grey granite. He otherwise failed to observe any significant difference between the grey granites. He also obtained far higher results than the other walkers. While some walkers are clearly unsuited to such testing, there are some significant difficulties in identifying potentially suitable walkers and in training them. This aspect is not covered in the ramp test methods.

The test methods also fail to address the issue of walkers getting vastly different results. In the case of the grey granite, is any possible combination of walkers acceptable, or are all of the possible combinations of walkers acceptable? The classification would vary depending on who is selected. No matter how well intentioned a walker might be, some people will admit to being unsuitable for one reason or another: others will not; some will not realise it.

In the instance of these granites, the results for walker R were published. Some results for basalt are given in Table 4. It can be seen that the Australian basalt is more slip resistant than the dense imported basalt when both products are saw cut. The nature of the stone and the manner of its dressing determines its slip resistance classification. The basalt could be used in a domestic bathroom unless it was tested with the pendulum with Four S rubber. Since TRL rubber is considered a better rubber for assessing wet barefoot resistance, the polished basalt would appear to be suitable for use in a domestic bathroom. Walker R found that the polished basalt was in the bottom portion of class A.

Table 4 Some pendulum and water wet ramp slip resistance test results (in BPN and degrees) for two basalts

Test method	Australian			Imported
	Sawn	320 grit	Polished	Dense sawn
Pendulum, Four S, 400#	69 (V)	46 (W)	21 (Z)	52 (W)
Pendulum, TRL, 400#	73 (V)	50 (V)	23 (Y)	53 (V)
Wet barefoot ramp - R	35.7 (C)	22.0 (B)	13.2 (A)	21.6 (B)
Wet barefoot ramp - E	39.0 (C)	37.2 (C)	30.3 (C)	18.4 (A)
Wet barefoot ramp – R & E	37.3 (C)	29.6 (C)	21.8 (B)	20.0 (B)
Wet barefoot ramp - I	-	26.9 (B)	19.7 (B)	-
Rz, µm	80.7	45.3	52.3	28.2
Wet ramp, Four S - R	39.6	27.7	15.8	26.2

Class V diamond sawn has long been used to pave Melbourne’s sidewalks. The wet slip resistance of a few bluestone pavers in the Melbourne CBD was recently tested and found to be around 30 BPN (Four S rubber). Given the apparent low incidence of slips and falls on wet days, it might be inferred that worn pavers provide adequate traction. A higher result was obtained with TRL rubber (around 40 BPN). The sustainability of slip resistance is an important issue that will need to be addressed in the next revision of the Standards.

Apart from some honed granites and basalts, what other stones might comply with the proposed Y recommendation? Exfoliated granites are typically class V. Sandstones and saw cut stones are typically class W or X. Honed limestone and travertine may receive a Y classification, but polished limestone and marble will have a very low Z classification. True marble generally receives a very low Z classification.

Stones are available with several finishes. The degree of macrotexture and microtexture imparted by these man-made finishes to the natural product have varying degrees of effectiveness and longevity in terms of if and when they will become slippery in use; in months, years or decades.

If Councils convert the HB 197 Table 3 recommendations to requirements, to what extent will they relax the requirements, if there are aspects of the building design or usage that significantly mitigate the risk of slipping? Although this remains to be seen, it must be noted that such factors are an integral aspect of determining whether an area is a wet, dry or transitional area.

While the stone industry has some data to base a decision on, is it useful in helping to resolve whether the proposed domestic bathroom recommendations are appropriate for other types of traditionally used materials?

Perhaps the answer lies in looking at the proposed recommendation for supermarket aisles (other than in fresh fruit and vegetable areas). The recommendation is for a minimum of class Z or R9, where there is a note ‘values of less than 12 BPN with the Four S rubber would be most inadvisable’.

Such supermarket floors are commonly polished sheet vinyls. Newly applied polishes on vinyl and terracotta floors typically yield values of around 12 BPN when tested wet with Four S rubber. Class Z products are considered suitable for dry areas – those areas in which appropriate control measures ensure an area remains dry and clean when in use. The onus is on the supermarket manager to ensure that liquid and solid spills are rapidly detected and corrected. The wet slip resistance may increase to 25 BPN before the polish is stripped and reapplied.

Does the use of a bath mat and sensible behaviour achieve an equivalent outcome in a residential bathroom? The socially responsible position may be to impose provisions to accommodate the lowest common factor, but civil liberty principles dictate that we should have the right to make fully informed decisions. In this situation, use of a class Z product in a bathroom might be acceptable if the owner is aware of the risk that is being taken, and that he is obliged to communicate this risk to potential users of the bathroom, and that this onus extends to fully informing potential purchasers of the building.

A compromise position might be to have a similar note advising that values of less than 15 BPN with the Four S rubber would be most inadvisable. However, since this is a wet barefoot area, and there is a higher risk when people are stepping out of baths and showers, perhaps the TRL rubber should be specified.

While there is very little slip resistance test data in Australia concerning TRL rubber prepared using the lapping film, there may be some British data. However, one should be wary of using foreign stone test reports as CEN rubber may have been used, and the rubber test foot may have been prepared to give a rough rather than a smooth surface.

It thus seems likely that there will be a need to test imported products for use in bathrooms, unless they have received an A or R9 classification, or better. The proposed recommendation for hotel ensuites is a minimum of class X, or A, or R10. Hotels and hospitals cater for people from all backgrounds with varying degrees of impairment.

The elderly may consider falls prevention advice to be useful in principle, but not personally relevant or appropriate. Such advice may be regarded as common sense, only required for older or more disabled individuals, and potentially patronising and distressing. It may also be a potential threat to their identity and autonomy. The provision of a slip resistant floor minimises the risk to patrons and workers.

There are certainly some ceramic tiles on the market that will achieve an X classification, while also being readily cleanable. Their slip resistance may be illusory, in that it may rapidly decline after installation, but that’s another issue.

In conclusion

This review is intended to provoke comment and to initiate debate throughout the flooring and slip resistance communities, as well as in several other international standards committees. My responsibility is to ensure that the process of standardisation is as transparent as possible.

Some contracts contain a ‘Warranty of slip resistance by the manufacturer’ clause, which may require: “The manufacturer shall warrant in writing that the product(s) used in the Works that their initial ex-factory slip test rating shall be capable of being sustained at that minimum level for the perceived working life of the product(s), nominated at 10 years, subject to the manufacturer’s maintenance recommendations being followed”.

Since the projects get completed, such assurances are presumably provided. However, few slip-resistant hard surfaces retain their ex-factory slip resistance. Stone can be honed just enough to become class R10, but a little bit of foot traffic will polish it back to R9. Whether or not products retain their rating (as in classification rather than declared result) is another issue. In the case of product that has been specified in terms of ramp classifications, it is arguably impossible to determine whether the classification has changed unless a section of the floor is removed. Determining the sustainability of slip resistance is the next big issue that has to be addressed.

My experience is that architects and tile merchants tend to consider published slip resistance classifications as akin to insurance policies. Greater regulation of the ramp test procedures might ensure that they are conducted in the intended spirit, so that any unbridled faith in the results might have a firmer foundation.

When considering the impact of ramp tests on the provision of an improved slip resistant environment, we have yet to develop a means of capturing the necessary data. We need to consider the effects of wear, contamination and maintenance, as well as how we relate any pendulum audit data back to the original ramp test data, which may often lack the desired specific detail in terms of the actual ramp angle.

Since the projects get completed, somebody is presumably providing such assurances, although most data indicates that few slip-resistant hard surfaces retain their ex-factory slip resistance. Whether or not they retain their rating (as in classification) is another issue. In the case of product that has been specified in terms of ramp classifications, it is arguably impossible to determine whether the classification has changed unless a section of the floor is removed. Determining the sustainability of slip resistance is the next big issue that has to be addressed.

Given that the pendulum is well suited to quality control testing of product, and that it can be used to monitor slip resistance after installation, greater faith in pendulum results would seem appropriate.

With respect to revising the slip resistance standards, immediate adoption of the use of lapping film, for preparing rubber test feet when testing smooth surfaces, should add a necessary factor of safety to the processes of selecting products and monitoring their in-situ performance.

We can formally resolve any issues associated with ramp testing at a later stage, since most people seem to have been blissfully unaware of any problems until now.

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