RECURRENT SYSTEMIC SLIPS?

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In reviewing recent developments in slip resistance standardisation and building regulation proposals, it becomes obvious that there are many reforms that still need to be made in order that premises remain sufficiently slip resistant throughout economically reasonable working lives. When will bureaucrats stop slipping up?

Introduction

Should minimisation of slip-related injuries be a global priority? Has anyone determined how many non-occupational falls on the level are due to environmentally caused slips, having determined the available traction, and at the time of the incident? Has any country benchmarked the available traction that is available in publicly accessible and residential settings? The European Union has sensibly legislated that floors should be safe at the end of an economically reasonable working life, but which flooring providers can reliably indicate the anticipated long term slip resistance of floor finishes over multiple environmental usage scenarios? Since slip resistance will decrease due to wear and soiling, do published recommendations for new floors overestimate the required slip resistance? Can mandated floors be cleaned as expected? What guidance exists for the realistic interpretation of slip resistance audits? Many residential and hotel bathrooms have a wet coefficient of friction of less than 0.18 – if the theoretical risk of slipping is 1 in 2 when walking on a level surface with a coefficient of friction of 0.19, why do relatively few bathroom accidents occur? Is there a realistic scientific basis for establishing slipping risk that factors in relevant accidental circumstances? Do expert reports in litigious matters provide sufficient information to help judges make appropriate decisions? When most falls in the elderly are related to biomedical causes, are governments well advised when told the elderly need highly slip resistant floors (that promote stumbles)? Is government falls prevention research funding sensibly directed? Surely slips and falls conferences should start to focus on some of the bigger issues in order to develop collaborative research efforts? What, if anything, is done differently now than five or ten years ago? If we were to address the recurrent public slip resistance challenges what initiatives should be implemented?

The Cost of Slips, Trips and Unintentional Falls and the Regulators' Responses

The high costs of falls injuries has caused Governments great concern due to a perception of epidemic hospitalisation costs associated with the ageing of the population. Significant funding has been provided to delay the onset of biomedically induced falls, essentially trying to improve the balance, strength and fitness of the elderly, through voluntary participation in appropriate activities. Limited home modification assistance has also been provided so people can remain at home, but any associated slip resistance evaluations are subjective rather than objective.

The Australian Building Codes Board (ABCB) commissioned Monash University Accident Research Centre (MUARC) to undertake a study of the incidence of slips, trips and falls and the design and construction of buildings. Ozanne-Smith *et al* (2008) produced MUARC report 281, "*The relationship between slips, trips and falls and the design and construction of buildings*". While this was a useful first step in publicly understanding the dimensions of the problem and costs of falls in Australia, the epidemiologist researchers and the project's 'expert panel' lacked specialist slips, trips and falls expertise. Such expert knowledge should have identified the critical issues that might then have enabled the ABCB to best determine the provisions that would reduce slips trips and falls in buildings. Hence the understanding necessary to improve the safe use of buildings is still missing, as well as some required data.

The most common falls hazards MUARC identified included: the wide range of allowed stair riser/going measurements and the often insufficient illumination found in many domestic stairways; the possible absence of handrails for stairways in domestic buildings; and a lack of definitive measurement or requirement for slip resistance for flooring surfaces.

In 2010, the ABCB proposed five falls prevention changes to the Building Code of Australia (BCA) including a handrail requirement in private stairways; and stair riser and going dimensions to be subject to a narrower range with a minimum going of 280 mm. A regulatory impact statement (ABCB, 2011) only found the new handrail requirement to be cost effective.

Ozanne-Smith *et al* (2008) identified that 80% of stair accidents occur during descent and that the narrow going width currently permitted by the BCA could potentially encourage falls during descent. However, they found little detailed relationship between slips, trips and falls and the design and construction of buildings. The available Australian accident data was predictably pitiful from a falls prevention perspective: hospitals seek and keep no data on stair geometry in their case files. The ABCB (2011) concluded that "No research has been conducted to identify the contribution that individual building components make to the incidence of slips, trips and falls relative to other contributing factors or how specific changes to some building components can reduce the incidence of slips, trips and falls". Although regulators need to identify the extent of fall and injury reduction that can be attributed to any proposed change, Ozanne-Smith *et al* (2008) failed to include the need for such research in their recommendations.

While Ozanne-Smith *et al* (2008) referenced the work of Roys & Wright (2003), they failed to highlight its most significant findings: "The effect of going size on slipping is so dramatic that it should be possible to walk with a reduced chance of slipping, even on highly contaminated stairs, if the going is large enough"; and "Where the going is less than 300 mm, the material and design of the nosing contributes to the likelihood of a slip".

When walking down stairs, the first contact between the shoe and the step is with the toes or midsole of the shoe. An overstep is twenty thousand times more likely to occur when the going is 250 mm compared to 325 mm. Although it can be calculated {based on Roys & Wright (2003)} that an increase in the going from 250 to 280 mm should reduce the incidence of large oversteps by 94%, the effectiveness of the stair riser and going dimensions proposal was assumed to be only 30% (ABCB, 2011) although no data was provided to support this assumption. Even though 63% of new residential stair goings appear to be less than 280 mm (Di Marzio, 2010), the proposal for a minimum going to 280 mm was dismissed on the perceived cost benefit analysis (ABCB, 2011). Expert reanalysis of the data by a falls specialist would seem most appropriate. The only successful (handrail) proposal was assessed with an assumed 30% effectiveness, where that assumption was based on a published study.

Stair Nosings

Since the ABCB has dismissed the stair geometry proposal, the pressure for stair safety is now literally on the stair nosing, and how its slip resistance may change due to wear, even if these aspects might not be effectively determined by the new Australian slip resistance standards.

The highest risk of a dangerous slip occurring on a stairway will generally be due to that of overstepping of a nosing during stair descent, particularly when the stair has a high pitch (high risers and short goings). As the going decreases, it becomes harder to place a substantial part of the foot on the step, leading to potential oversteps in descent. With goings less than 300 mm, people tend to rotate their feet in descent to ensure that enough of the foot remains on the tread. However, some continue without sufficiently rotating their feet on stairs with smaller goings; this increases the amount of overhang and hence the risk of slipping. While there are various nosing geometries, the position of slip resistant nosing should extend from the step tread up to the vertical front face of the nosing, as Hunter (2013) has confirmed.

The ABCB (2013) now proposes to quantify "slip resistance". The proposed changes to "slip resistance" also apply to the terms "nonslip", "non-skid" and "slip-resistant" in the National Construction Code (NCC) – the new title of the BCA. It is proposed that the existing slip resistance code requirements for stairways, landings and ramps be changed from the format "The surface of a {*ramp*} must have a non-slip finish" to "The surface of a {*nosing strip*} must have a slip-resistance classification complying with Table 1 when tested in accordance with AS 4586". The nosing strip requirement would apply to all building classes and stair geometries. A change to the wording "The surface of a {*nosing*} must have a non-slip finish (such as a slip-resistance classification complying with Table 1 when tested in accordance with AS 4586)" would sensibly allow appropriate alternative design solutions, such as longer goings, contrasting nosings and safer illumination provisions. This phrasing would also enable recognition and application of the work of Hunter (2013) on nosings, a term that the ABCB has yet to define.

Table 1 Proposed NCC 2014 Slip-Resistance Classifications

Application	Surface conditions	
	Dry	Wet
Ramp steeper than 1:14	P4 or R11	P5 or R12
Ramp not steeper than 1:14	P3 or R10	P4 or R11
Tread or landing surface	P3 or R10	P4 or R11
Nosing or landing edge strip	P3	P4

New Australian Standards

AS 4586:2013, *Slip resistance of new pedestrian surface materials*, and AS 4663:2013, *Slip resistance measurement of existing pedestrian surfaces*, have both adopted the use of lapping film for preparing the rubber test feet. This provides better differentiation between surfaces at the slippery end of the slip resistance spectrum, since the floor surface results are no longer dominated by the rubber slider roughness. The old class X products (35 - 44 BPN) will now variously fall into new classes P3 (35 - 44 BPN), P2 (25 - 34 BPN) and P1 (12 - 24 BPN). In practical terms the difference between a P3 floor surface that has a 35 BPN mean and a P2 floor surface that has a 34 BPN mean, in terms of the risk of someone slipping over, is virtually nil. Yet there is a real risk that the proposal will declare there to be a significant difference.

Merchants and consumers have still to re-educate themselves that some class X products they perceived as being safe are unlikely to now be regarded as safe, even though their intrinsic slip resistance remains the same. The converse view is that this reorientation explains why slips would sometimes occur on products that were deemed safe (≥ 39 BPN) by AS/NZS 3661.1:1993, *Slip resistance of pedestrian surfaces: Requirements*. AS/NZS 3661.1 is still the basis of the slip resistance provisions in the New Zealand Building Code. However, the Accident Compensation Corporation (ACC), which provides comprehensive, no-fault personal injury cover for all New Zealand residents and visitors to New Zealand, is currently investigating "good practice" for testing the slip resistance of bathroom and kitchen flooring.

Since class P3 might be regarded as non-slip and class P1 as noticeably slippery, the greater differentiation between 'non-slip' and 'slippery' products will enable new design guidance to be provided. However, Standards Australia Handbook 197 (Bowman, 1999) is still current (with its dubious notional interpretations of the "contribution of the floor surface to the risk of slipping when water wet".

The proposed Table 1 (above) would require a product to have either a R10 oil wet classification or a wet pendulum class P3 (35 - 44 BPN) for a dry residential stair tread surface (that is not normally wet or likely to be made wet by an accidental spill). While either option appears excessive, class R10 products have been found to yield pendulum classifications from P5 (≥ 55 BPN) to P1. Given that the pendulum is used to conduct audits and accident investigations, it is somewhat nonsensical to rely solely upon oil wet ramp classifications for public locations (and particularly private homes) where smooth soled footwear is worn. The oil wet ramp test requires the use of profiled footwear to determine the physical-interlock-slip-resistance. Singular reliance on oil wet ramp classifications entails a frequently observed risk that pendulum results would subsequently indicate a specified product was never fit for its intended purpose.

AS 4586 still requires that stair nosings and treads be tested in a direction that is normal to any strips, grooves and profiles, even though a similar requirement for tactile ground surface indicators (TGSIs) has been amended to require an offset of 10 degrees to prevent grooving of the rubber test feet when testing linearly profiled directional TGSIs; and an offset of 30 degrees to ensure that only the chamfered edge of the rubber test foot contacts the warning TGSIs.

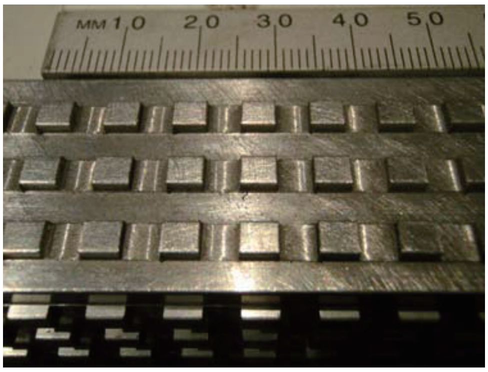

Figure 1   A castellated metallic stair nosing

Figure 1 shows a castellated metallic stair nosing that rapidly grooves and shreds Four S rubber test feet (slider 96), such that the nosing needs to be tested at an offset angle in order to get reliable consistent results. There are other hard ribbed nosing profiles that also destroy the chamfered edges of pendulum test feet. While manufacturers may engineer nosing and tread designs in order to obtain high slip classifications, pendulum testing is based on the principle of testing in the direction that gives the lowest results. There is an unstated assumption that any testing will be consistent with the correct pendulum operational principles, where the rubber test foot condition is fundamental to the hydrodynamic theory of squeeze film formation.

AS 4586 also now allows carpets to be tested with the pendulum in both wet and dry conditions. While it is desirable that other surfaces should also be permitted to be tested with the dry pendulum, the use of the wet pendulum classifications for the dry carpet pendulum test results is mystifying: materials that have very low wet pendulum results typically have dry results that are much higher than materials that have high wet pendulum results. Although dry results are best considered in the context of wet results, separate classification schemes are required to avoid any confusion between P5 and $P5_{dry}$.

Specification of slip resistant pedestrian surfaces

The European Construction Product Regulations (CPR) now require that products will be **safe (i.e. slip resistant) at the end of an economically reasonable working life**. This position recognises that slip resistance tends to decrease, and is consistent with occupational health and safety (OHS) needs and sensible risk management practices.

Various approaches can be taken towards specifying the slip resistance of pedestrian surfaces. The German occupational health and safety (OHS) system requires that new workplace floors comply with prescribed oil wet ramp slip resistance and volumetric displacement requirements. These requirements were published as recommendations in Standards Australia

Handbook 197 (Bowman, 1999). Unfortunately some flooring manufacturers have chosen to ignore the volumetric displacement requirements, overlooking the fact that German practice is to require a higher classification if the volumetric displacement requirements are not fulfilled.

HB 197 also makes some recommendations for new floors in terms of the now superseded pendulum classifications. These recommendations contain some safety factor, to allow for slip resistance lost due to the polishing wear of foot traffic, although the amount of slip resistance lost varies considerably between materials. This causes over-specification of slip resistance: property owners have difficulties cleaning floors that are rougher than desired, whereupon aggressive cleaning practices can then significantly reduce the inherent slip resistance.

Another approach is to specify a minimum long term performance requirement based on the anticipated use of a facility and the intended risk management approach, bearing in mind that the slip resistance of the floor is only one component of safe pedestrian surface design. Thus if 25, 30 or 35 BPN was specified as the nominal limit for an area in service, a manufacturer would need to indicate that a product would have sufficient slip resistance at the end of a reasonable working period, on the basis that the floor would be maintained in accordance with their instructions. This minimum acceptable slip resistance approach provides a basis for interpreting periodic audits. As the floor nears the specified limit, any workplace controller must obviously obtain staff feedback to ensure that existing safety provisions are adequate, whereby values less than the specified limit might be found to be acceptable.

Appropriate accelerated wear tests (AWT) can provide a basis for determining the likely long term slip resistance. Such tests need to be standardised where pads that contain highly abrasive media need to be used with caution. There has been some European research using commercial scouring pads for accelerated wear conditioning of ceramic tiles, even though one would not expect these pads to be used for tile maintenance procedures, Bowman (2012).

Building codes should not rely on regulations that provide transitory slip resistance for new buildings. They should require economically reasonable life cycle slip resistance performance. It is anticipated that in 2014 the ABCB will propose mandatory slip resistance for most floors.

Interpreting Slip Resistance Test Data

With the change in rubber test foot preparation, the slip resistance of some polished porcelain tiles has fallen from 26 to 11 BPN, i.e., from class Y (25-34 BPN) (that was considered too unreliable to use in terms of HB 197 recommendations) to P0 (< 12 BPN). While the measured slip resistance may have fallen, the inherent slip resistance is unchanged. Such tiles would have been considered to make a high contribution to the risk of slipping when water wet, or a very high risk (20 BPN) in the unlikely event of 100 cycles of AWT being commissioned.

Should Australia now adopt the UKSRG (2011) criteria, for high (< 25 BPN), moderate (25 – 35 BPN) and low (> 35 BPN) slip potential? These criteria were based on Pye's analysis (1994). This suggested that for unencumbered, reasonably active pedestrians aged between 18 and 60, a pendulum result of 36 BPN or above represented an acceptably low risk (one in a million) of slipping when walking in a straight line on a level surface. A 24 BPN result has been equated with a risk of 1 in 20, and 20 BPN with a risk of 1 in 5. Since much lower results would seemingly predict epidemic accident levels (that have not occurred), do such analyses provide an appropriate basis for determining slip resistance design (or liability in the case of accidents)?

Burnfield & Powers (2003) determined mean peak utilised coefficient of friction (COF_U) for a medium walking pace was 0.23 for men and 0.24 for women. The considerable difference between their data and that of the Building Research Establishment {0.17 for men and 0.16 for women, Harper, Warlow & Clarke (1961)} is probably due to measuring protocols. Burnfield & Powers found the peak COF_U for their 60 subjects ranged from 0.13 to 0.44 when walking fast.

Chang, Matz & Chang (2013) have undertaken extensive new walking trials and force plate studies, where their calculated statistical slip probabilities differ slightly from those of Pye. There is a 5% risk of slipping with a 0.26 COF for people under the age of 55, and a 0.25 COF for people over the age of 55. How do we best apply these findings to real world situations?

Since the mean slip resistance in many domestic bathrooms has been determined to provide available traction of 0.12 to 0.17 COF (13 to 18 BPN according to AS/NZS 4663:2004), and AS 4586 and AS 4663 will tend to yield results lower than these, why aren't more residents falling over? The residents have obviously modified their gait and reduced their traction demand. Since they are no longer walking freely (as asked of the force plate study subjects) the analytical outcomes of such free walking studies rapidly become of diminished relevance in residential settings, where familiarity with the surroundings induces gait restraints.

Closing remarks

Why so many introductory questions and so few definitive answers? Sometimes we need to ask many questions to determine we know the real facts, rather than assuming that some seemingly established facts are universal truths. While nations should invest funds to protect their elderly from biomedically induced falls, there should be a greater investment in protecting the whole community from environmentally caused accidents, as there is a far greater cost associated with the temporary and permanent disability of younger productive people, particularly workers and home carers. If only Governments were to seek to become better informed about how to interpret slip resistance and falls related data when investing funds and drafting regulations.

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