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# Slip Resistance and Wood Pedestrian Surfaces

Technical Design Guide issued by Forest and Wood Products Australia


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This work is supported by funding provided to FWPA by the Commonwealth Government.

ISBN 978-1-925213-46-1

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**Acknowledgements**
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First Published: November 2018

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# Contents

# 1 Introduction

**This guide is intended for designers, specifiers, producers, installers and end-users of pedestrian trafficable wood products—such as flooring, decking, boardwalks, steps, stairs, ramps and bridges.**

The guide provides a brief introduction to slip resistance; discusses the slip resistance suitability of wood with respect to location and use; describes methods for enhancing slip resistance; summarises relevant Australian obligations and recommendations; and outlines slip resistance testing methods.

The graphs and tables in Section 3 of this guide show slip resistance test results of various wood products and conditions. They are case studies and are not necessarily indicative of other instances of the products or conditions. Similarly, the table at the end of Section 3 provides a ranked summary of the case study test results, but it is for general illustration and is not necessarily indicative of individual cases.

Consideration and selection of wood products in terms of slip resistance should be based on product and application specific tests as discussed further below.

The Australian statutory and non-statutory codes are occasionally revised. Readers should asses the relevance of such revisions to this guide.

This guide does not address slip resistance for bicycles and wheelchairs or coverings such as large-area mats.

# 2 Complexity of slip resistance and its measurement

**'Slipperiness' and, conversely, 'slip-resistance' are commonly experienced phenomena and their implications for safety are readily appreciated: if a surface is slippery, possibly injurious falls may occur. But the simplicity of this characterisation belies the complexity of the phenomena and the difficulty in validly applying and comparing their measurement.**

Appreciating this complexity will facilitate realistic expectations about testing and achieving slip resistance, assessing slip and fall risks, and appraising the performance of wood products.

## 2.1. Slips and falls

Very small, frequently unnoticeable slips are a normal part of ambulation. It is when slips are longer or faster that falls can occur; the chance of this increases with the slipperiness of surface.

Slips can occur in forward and rearward directions: forward slips of the leading foot as it lands, and rearward slips of the trailing foot as it leaves the surface[1].

Forward slips of the leading foot typically occur between the rear of the heel (of feet or footwear) and the surface. Rearward slips of the trailing foot typically occur between the foresole and the pedestrian surface. It is a forward slip of the leading foot that is most likely to cause a fall[2].

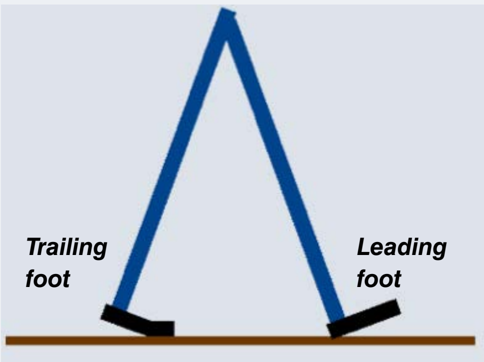



***Figure 2.1: Walking gait.***

*At mid-stride, the heel of the leading foot contacts the ground as the trailing foot rises on its forefoot preparatory to leaving the ground.*

*Slips can occur at heel contact and at 'toe-off', but it is typically at heel contact that slips are most likely to occur and that can lead to imbalance and falls.*

### 2.1.1 Reflexive downward rotation of foot for heel slip

When a heel slips, initiated by its rear edge, the foot typically reflexively and rapidly rotates downward to full-foot contact with the pedestrian surface. This helps arrest the slip and retain balance. However, if the reflex is retarded, slip arrest may not occur in time, or at all, to prevent a fall.

Consideration of the contact of the heel of the leading foot, especially at its rear edge, needs to be foremost in appraising and developing methods for slip-and-fall avoidance. A key issue is the typically very small area of contact between the rear edge of the heel and the pedestrian surface, with implications for installation of parallel slip-resistant fixtures as discussed below (see also Figure 3:29).

[1] *Rearward slips of the leading foot as it lands can also occur, but they are very small and undetectable.*

[2] *Rearward slips of the leading foot occur at the rear of the heel.*

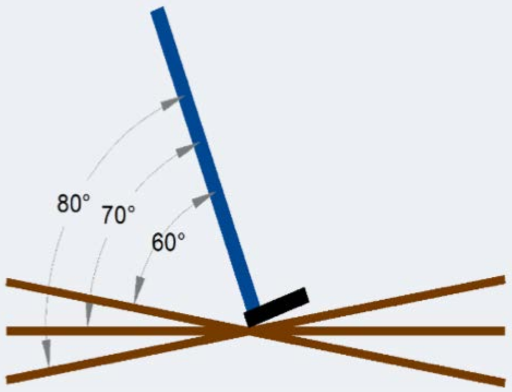



***Figure 2.2: Leg angles on sloped and level surfaces.***

*Generally, the greater the angle of the leg to the pedestrian surface, the less is the risk of slipping. Hence, for the leading foot, there is more chance of slipping going down a slope than going on the level and even greater than going up the slope.*

## 2.1.2 Slip length

People have been known to avoid falls for slip lengths as great as 300 mm. However, this can be considered rare. Falls can occur from slips much shorter than this. An assumption that significant fall risk is associated with slip distances of about 75-100 mm or less may be warranted – with implications for installation of intermittent attachments on pedestrian surfaces, as discussed below.

## 2.1.3 Slopes

Generally, a rearward slip of the trailing foot is more likely, and a forward slip of the leading foot less likely, during ascent than descent of slopes or on level surfaces. Conversely, a forward slip of the leading foot is more likely, and a rearward slip of the trailing foot less likely, during descent than during ascent of slopes or on level surfaces. In other words, slip and fall risk increases for descent travel. It also increases with increasing slope.

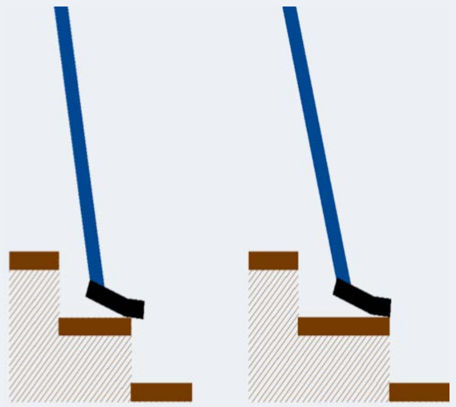


***Figure 2.3: Leg and foot angles during stair descent.***

*The angle of the leg to the surface is considerably less on stair treads than on other pedestrian surfaces. It decreases slightly with increasing tread going, especially if the rise of the treads also decreases, which may increase slip risk although, in this circumstance, there is less likelihood of the foot projecting over the nosing and therefore less risk of an overstep slip on it.*

## 2.1.4 Stairs

During stairway ascent and descent, contact and the possibility of a slip generally occurs between the sole of the foot and the stair treads and/or bottom and mid landings. An exception is that, if misjudgement occurs at the top landing just prior to descent, contact and the possibility of a slip can occur between the heel and the landing. At top stairway landings, the risk of a slip and fall can therefore be greater than for elsewhere on the stairway. Contact and the possibility of slips can also occur when the foot lands too far forward on a tread or top landing during descent. If this happens, the foot can slip over the nosing of the tread or landing.

Slips and falls are less likely on stairways than on slopes or on the level but, particularly during descent, if falls do occur, they are likely to be more injurious.

### 2.1.5 Slips and slip resistance factors

Slips and slip resistance, as discussed further below, are an outcome of three factors: the interaction of the underside of the foot (or footwear) with the ground (or floor); any matter between the two surfaces; and gait characteristics (the manner of walking or running). Consequently, for a given surface, it is difficult to predict whether a slip will be inevitable; even more difficult to predict whether falls will occur because of a slip; and impossible to do so without reference to all three factors. Moreover, the change of these factors with time also needs to be considered, whether on the scale of minutes (e.g. after rainfall or spillages) or months or years (in terms, for example, of wear and weathering).

## 2.2 Slip resistance measurement

Results of slip resistance testing devices and methods can be very precisely expressed, but they are specific to the tribometer and test method, to the surface sample and to any matter on it. Moreover, the heterogeneity of wood, at least in its natural state, frustrates the generalisability of test results for the same type of wood, especially with respect to surface change over time.

Additionally, the diversity of naturally occurring surface matter means that instances of it will affect slipperiness and its measurement differently, in many cases quite differently to water and oil – the surface matter used for testing under Australian slip resistance testing standards.

The variability of human gait and footwear also frustrates the formulation of broadly applicable slip resistance requirements.

Unless testing is conducted for a specific combination of factors, slip risk assessment becomes a risk management exercise and it is in this context that Standards Australia's guidelines on slip resistance is useful (see Non-statutory codes below).

The test pads of most tribometers can be regarded as poorly replicating footwear and its diversity, and their action as very poorly replicating human gait and its diversity. Nevertheless, the standardisation of tribometers and their operation (such as under Australian standards) enables a reliable and consistent comparison of surfaces, including between different wood products, and between wood and non-wood products.

Apart from the three types of tribometer addressed by the Australian slip resistance testing standards, there are other types that can be validly and valuably used in the development of new products; in the analysis of slip and fall incidents; for establishing 'alternative solutions' under the performance provisions of Australian codes; and in circumstances where the use of tribometers under the Australian standards are impracticable. A complicating factor, however, is that results with these other types of tribometer will not necessarily correlate strongly with results from the tribometers covered by the Australian standards.

Descriptions of the tribometers covered by the Australia standards are given in Section 7.

# 3 Slip resistance suitability of wood

## 3.1 Wood species

The primary relevance of different wood species to slip resistance is their response to wear and weathering and their retention of slip resistant fixtures and coatings. Generally, the slip resistance of denser hardwoods will be more sustainable indoors and outdoors than less dense hardwoods, and more sustainable than softwoods. For internal applications, differences between species becomes less important to the extent that they are coated or otherwise covered, in which case as noted below, the coatings or coverings become the slip resisting attribute.

More information about wood species can be found WoodSolutions website, in the Species and Materials section: woodsolutions.com.au.

## 3.2 Location and use

Slip risk and the need for slip resistance depends on where and how a surface is used, i.e. the nature of activities and of human gait on it and, particularly for outdoor settings, environmental conditions. It is also influenced by the susceptibility of the surface to wear from traffic and, for outdoor settings, weathering.

### 3.2.1 Activities and gait

The relevance of "activities" here is their possible contribution of surface matter such as mud, grease, food, oils and cleaning products, and spilt water such as from swimming, bathing and showering and from water fountains.

Gait refers to whether people are running or walking and, if walking, whether quickly or slowly and, in either event, whether abrupt changes in direction occur. People are more likely to slip when running, walking quickly or abruptly changing direction. Examples of where abrupt changes of direction can occur are at intersections or bends in footpaths and corridors, and anywhere that activities predispose to abrupt directional changes, such as in recreational, sports and employment settings.

***Figure 3.1: Well-worn heel.***

*This heel was removed from a shoe worn by a person who slipped going down a wet ramp of boards laid across the ramp. It was surmised that the smoothed and rounded rear edge of the heel from long-term wear was a key factor in the slip. For the leading foot, the rear of the heel is critical in forward slips (or avoidance of them).*

Slip propensity on surfaces is also influenced by whether people are bare-foot or in footwear. For footwear, key factors in slips or slip resistance are: a) the material of outersoles (heels and fore-soles) and their degree of stiffness or compressibility; b) whether outersoles have treads or are otherwise textured and, regardless, whether they have been smoothed, including rounded at the rear of heels through prolonged wear; and c) the style of shoe, particularly in terms of the size and shape of the heel (stiletto high-heeled shoes are an extreme example).

There obviously can be a prevalence of certain types of footwear in some settings, such as deeply treaded outersoles in industrial settings, firm smooth outersoles in commercial settings, and highly compressible outersoles in sports and recreational settings. The relevance of footwear is not discussed in this guide, but it is necessary to acknowledge the complicating contribution of footwear to consideration of slip resistance and its measurement, and to the risk assessment of falls.

The Standards Australia handbook *HB 198:2014 – Guide to the specification and testing of pedestrian surfaces* (see further below) provides general guidance on minimum slip resistance for various activities and settings. Importantly, it also illustrates the wide range of slip resistance ratings that may be suitable, depending on the setting. Nevertheless, published indications of products' slip resistance or of slip resistance requirements need to be regarded as approximations because they cannot fully account for the complex interaction of the key factors identified above.

### 3.2.2 Environmental conditions

The significance of environmental conditions is their contribution of moisture or moist matter or, at the other extreme, dry matter such as grit and very small seed pods and twigs[3]. Wet vegetative debris, moss and fungal growth on boardwalks in bushland; moisture from rainfall and mist; and sand on foreshore boardwalks are common instances[4]. The adverse effects of this matter in outdoor settings can be ameliorated if there is exposure to driving rain and drying wind that remove the matter.

Regardless of its origin, it is matter between the wood and the foot or footwear that facilitates slipping, even if the matter is so minute as to be invisible to the naked eye. Moisture or moist matter is the most common slip-inducing type. Regardless of the type, regular monitoring and, if necessary, cleaning and maintenance is necessary to mitigate slip risk[5].

Slippery matter on pedestrian surfaces can be particularly hazardous if it is not evident or anticipated, as discussed in section 3.1.6 Adjacent dissimilarity.

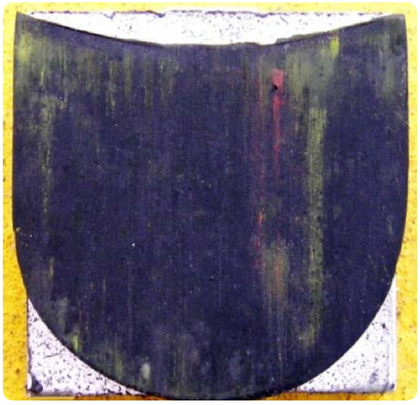


***Figure 3.2: Matter between heel and pedestrian surface. Paint residue has been transferred to the test heel from the pedestrian surface.***

***Figure 3.3: Matter between heel and pedestrian surface. Fungal matter has been transferred to the test heel form from the pedestrian surface.***

**Example: slip resistance of fungal-coated wood**

An example of reduced slip resistance of a wood boardwalk in a swampy area is shown at Figure 3.4. Test results indicated that, along the boardwalk (perpendicular to the boards), the slip resistance of wet fungal-coated boards was 23% less than of the clean boards when wet. Across the boardwalk (parallel with the grain), the slip resistance was reduced by 14%. Differences in slip resistance for movement perpendicular to ('across') and movement parallel with ('along') the grain is discussed below.

*[3] Ice on pedestrian surfaces is not considered in this guide.*

*[4] The risk of dry particles is greater when they are on smooth dense surfaces such as smooth-trowelled concrete or ceramic tiles than it is for textured surfaces and surfaces of wood that are sufficiently easily indented as to restrain the particles or whose surfaces cavities can receive the particles that are rolled into them by the foot; it is also greater for un-textured, non-resilient soles.*

*[5] Matter can also include microscopic abraded debris from the pedestrian surface and the outersoles of footwear, although their contribution is unlikely to be significant in most situations.*

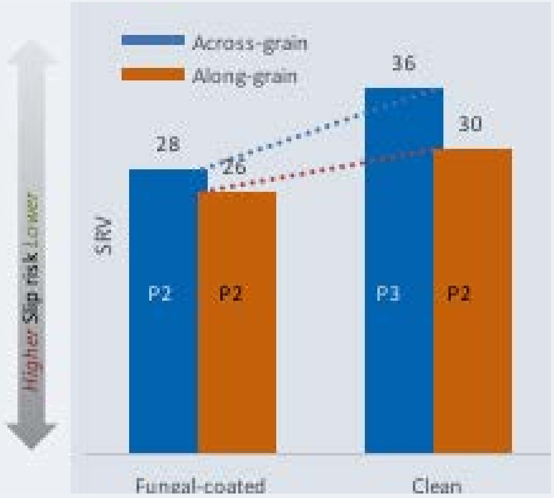



***Figure 3.4: Effect of fungal growth.***

*In this example, the fungal-coated boards were about 23% less slip resistant across the grain and 14% less slip resistant along the grain than the clean boards. There was very little difference in slip resistance across and along the grain for the fungal-coated boards but, for the clean boards, slip resistance across the grain was 20% greater than for along the grain. In other words, fungal growth negated the greater across-grain slip resistance of the board in its clean state.*

***Notes:***

1. *'SRV' = Pendulum slip resistance value.*
2. *'P' ratings as per AS 4586 and AS 4663.*
3. *Surfaces were tested when water-wet.*
4. *'Across-grain' = perpendicularly across the grain. 'Along-grain' = parallel with the grain.*
5. *The percentage variances indicated in the caption are for illustration only and should not be relied-on.*
6. *The sample size was very small, and results should therefore be treated cautiously.*

### 3.2.3 Wear and weathering

Wear by pedestrian traffic and, for outdoor settings, weathering (erosion and rot) can cause the edges and the textured surface of wood to become smoother over time and therefore diminish its slip resistance.

***Figure 3.5: Naturally textured surface from weathering.***

*Weathered boards, when dry, are typically more slip resistant across the weathered grain than along it. However, when they are wet the opposite can apply because the wood fibres can be dislodged by heels at contact with the surface. Suitable wood preservatives will retard the process and help sustain the integrity of the surface.*

The effect of weathering is complex. Apart from possible surface smoothing, checking and cracking of wood and the raising of grain from weather exposure can also occur, imparting surface texture (see Figures 3.5 and 3.6) and therefore possibly increasing slip resistance (for traffic transverse to the wood grain). However, in moist conditions, the surface fissuring can facilitate rotting, surface disintegration and deposition of matter and possibly to reduction of slip resistance.

Wind-borne grit can cause gouging of the wood and possibly contribute to slip resistance (across the gouges) but it can also smoothly scour the ridges and diminish slip resistance. The complexity of wear and weather effects over the service life of boards is indicated by the example at Figure 3.7.

***Figure 3.6: Magnified view of a severely weathered hardwood board.***

*This photo shows surface texture caused by weathering, and the accumulation of stone particles in fissures. The particles have been imported from much further away, by pedestrians and cyclists, and have been dislodged from treaded footwear and tyres.*

More-detailed accounts of weathering can be found in other Wood Solutions Technical Guides[6].

Gaps between external boards can drain water and help surface matter to be removed by wind and foot traffic. However, these benefits can be negated if the boards become concave (cup) with time[5]. The machining of boards so that their upper surface is slightly convex can assist natural drying and compensate for cupping. However, the convexity would need to be sufficiently shallow for the downward slopes on either half of each board not to contribute to slips (nor hinder comfortable wheeled movement).

**Example of wear, weathering and slip resistance**

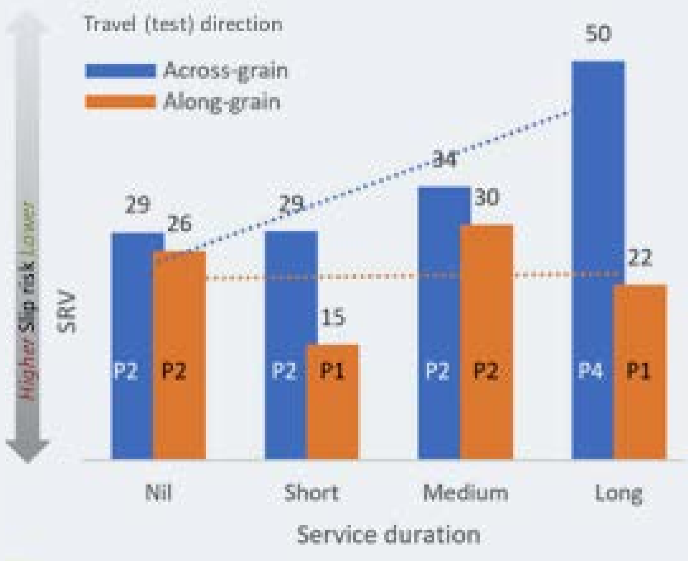



***Figure 3.7: Effect of wear/weathering duration.***

*In this example: Slip resistance across the grain (blue bars) increased with increased service duration, but there was no clear order for along-grain slip resistance (orange bars) over time.*

*The greatest slip resistance was across-grain for long duration (SRV 50, P4). This is attributable to fissures in the wood caused by long-term weathering.*

*The least slip resistance was along the grain for Short duration (SRV 15, P1). This is attributable to the wood having been smoothed by wear and prior to the eventual opposing effect of weathering.*

*The greatest dissimilarity between across-grain and along-grain slip resistance was for short and long duration.*

***Notes:***

*1. 'SRV' = Pendulum slip resistance value.*
*2. 'P' ratings as per AS 4586 and AS 4663.*
*3. Surfaces were tested when water-wet.*
*4. 'Across-grain' = perpendicularly across the grain.*
*5. 'Along-grain' = parallel with the grain.*
*6. The Sample size was very small; results should be treated cautiously.*

*[6] These include Guide No. 5: Timber Service Life Design – Design Guide for Durability, Guide No.13: Finishing Timber Externally, and Guide No. 21: Domestic Timber Deck Design. These and other timber-related guides can be downloaded for free from the WoodSolutions website.*

*[7] Convexity and concavity of boards can prevent easy wheeled movement (by people with prams, wheelchairs and bicycles).*

### 3.2.4 Slopes

As for other materials, wood on slopes is less slip resistant for movement down them than for movement on horizontal surfaces (for identical wood, conditions, footwear and gait[8]) because the angle of the leg at heel strike on downward-sloping surfaces (and therefore the angle of the incident force) is shallower than on a horizontal surface. This is illustrated at Figure 2.2. Additionally, in the event of a slip, there is a greater angle through which the foot must rotate downward to full foot contact, which tends to reflexively happen, and so it takes longer for full foot contact to occur, which diminishes slip-arrest. Generally, as indicated above, the steeper the slope, the less the slip resistance.

The increase in slip risk is not necessarily proportionate to the increase in slope because, if people are aware of the change in plane, they typically adapt their gait. However, there are many reasons why people might be unaware of a change in plane and therefore not adapt their gait.

### 3.2.5 Stairs

Three parts of stairways need to be considered for slip resistance: top landings (near the top tread), treads, and the nosings of treads and top and mid landings.

Slips during stair ascent are unlikely to cause falls down stair flights but slips during descent do predispose to falls. The risk of slips and falls during descent can be considered as low; however, there is a high risk of injury, and even fatality, if a fall does occur.

**Stair descent**

On landings at the top of flights, the foot, as with normal walking, usually lands heel first, although typically at a shallow angle to the landing. On treads and bottom and mid landings, the foot usually lands foresole first and at a very shallow or no angle to the tread, and the leg at little or no inclination to the vertical.

Generally, people place their feet slightly further back from the nosings of treads of larger goings than they do for smaller goings; the same also occurs for slower rather than quicker descent.

As an example, for a size 9 adult male shoe, the potential contact length of the foresole on the tread is 110 mm. Hence, if the front of the foot is placed at the tread nosing, the corresponding contact length on the tread is 110 mm. However, especially on smaller but even on larger treads, the front of the foot typically projects over the nosing, in which case the contact length on the tread is 60 mm. Foresole contact lengths much less than this can occur.

The slip resistance of treads near their nosings becomes critical if a person's foot lands too far forward (the person over-steps the nosing), in which event the centre of pressure is too close to or in front of the nosing and, if there is insufficient slip resistance, the foot can slip off the tread. However, it is possible that slip-resistant nosings merely retard slips and that loss of balance and falls down stairs occur regardless of slip resistance.

***Figure 3.8: Foot and leg at touchdown.***

*The person's leading foot has just contacted the tread (at its nosing). The foresole is at a very shallow angle to the tread (shown in yellow), and the angles of the leg (shown white) and the force vector (shown red) with respect to the vertical is small. The ball of the foot (and centre of pressure) is very close to but not in front of the nosing.*

[8] *Gait will be slightly different on inclined compared with level surfaces.*

***Figure 3.9: Foot and leg just after contact.***

*As weight becomes borne on the leading foot, the leg angle becomes vertical, the force vector angle becomes closer to vertical, and the centre of pressure on the tread moves further back from the nosing.*

***Figure 3.10: Risk of overstep slip.***

*This person's foot has just contacted the tread (at its nosing), with the ball of the foot perilously close to over-stepping the tread. However, the compressibility of the outersole and the presence of the metal insert helped avoid an overstep slip.*

### 3.2.6 Adjacent dissimilarity

Dissimilarity of adjacent surfaces or surface conditions (even if the conditions are momentary) is an easily overlooked slip hazard. People stepping unknowingly from a slip-resistant to a slippery surface, and so not adjusting their gait, risk slipping and possibly falling.

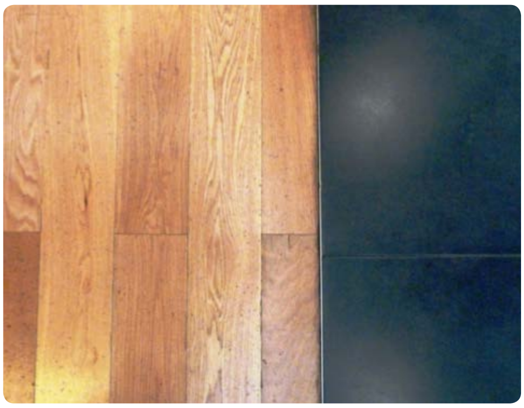


***Figure 3.11: Adjacent dissimilar materials.***
*Highly polished ceramic tiles adjacent to sealed hardwood floorboards.*

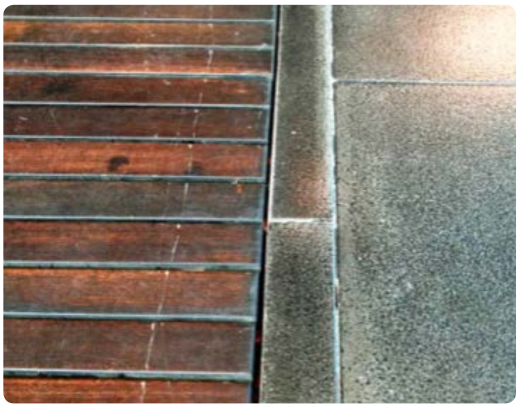


***Figure 3.12: Adjacent dissimilar materials.***
*Stone tiles adjacent to sealed hardwood boards in an area prone to walked-in moisture.*

Transitions between indoor and weather-exposed outdoor areas, and between food stalls and adjacent walkways, or dining areas and retail spaces, are where matter can be transferred. For the area onto which matter is transferred, it is good practice to provide a surface whose slip resistance is the same as that of the surface of the area from which the matter is transferred (and for each of the adjacent surfaces to be sufficiently slip resistant). Isolated momentary dissimilarity of conditions can also occur within any setting because of spillage and, while this is a facilities maintenance issue, consideration should be given to transient matter in the choice of surface products.

***Figure 3.13: Walked-in moisture.***
*The walked-in rainwater is evident from this vantage point but not necessarily from other vantage points or to a person too busy striding or running across the wet patches or towards the doorway to notice.*

Another example of adjacency effect is outdoors where part of an area is exposed to breeze and sunlight and therefore kept clean and dry, but another part is shaded and wind-protected and therefore remains moist, harbours fungal growth and accumulates small debris.

Alleviation of these problems entails a combination of good design of adjacent spaces, good selection of pedestrian surfaces and good maintenance.

***Figure 3.14: Dissimilar surface conditions.***
*This boardwalk over a swampy area is shaded from the sun and sheltered from the wind on one side; hence, that side is moist and has fungal growth whereas the other side is comparatively clean and dry. A sudden divergence by a pedestrian from the dry side to the moist side could lead to a slip.*

*See also Figure 3.4.*

## 3.3 Enhancing the slip resistance of wood

There are several options for increasing wood's slip resistance, including by: - choice of orientation with respect to traffic; surface texturing; incorporating inserts and attachments; and applying coatings. Coverings, such as mats, is another option, but are not discussed in this guide.

### 3.3.1 Orientation

Wood surfaces with directional characteristics because of grain, texture (from rough-sawing, roughening, profiling or weathering) or board juxtaposing are generally more slip resistant across than along those characteristics. Wood should be installed so that its predominant directionality is perpendicular to predominant directions of traffic (or to direction of most rapid traffic[9]).

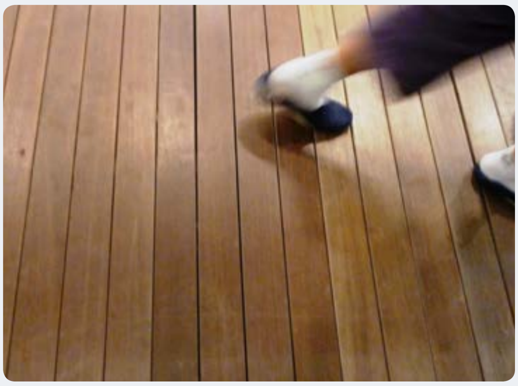


***Figure 3.15: Board orientation and traffic direction.***

*Wood installed transversely to predominant traffic tends to be more slip resistant than when installed parallel to it. However, this depends on the saliency of the grain. Coatings will diminish the slip resistance difference, increasingly so with thicker coatings, which then become the paramount slip-resisting surface.*

**Examples of grain direction and slip resistance**

The effect on slip resistance of the orientation of wood grain and other directional surface features is illustrated in Figures 3.4 and 3.7. A comparison of slip resistance ratings across and along wood boards is shown in Figures 3.15 to 3.18.

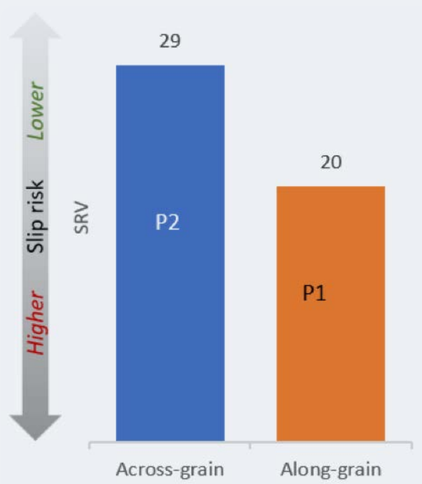



***Figure 3.16: Effect of grain direction: grouped results.***

*For this group of dissimilar boards, slip resistance across the grain (SRV 29, P2) was 47% greater than along it (SRV 20, P1). However, the difference does not accurately indicate individual results. For example, the greatest difference between two boards was 57% and, in one instance, there was no difference. Results for the individual boards are shown in Figure 3.17.*

*For a different or larger group of boards, the average slip resistance values and the difference between them could be very different. This highlights the difficulty of providing generalised slip resistance guidelines for timber surfaces.*

***Notes:***

*1. 'SRV' = Pendulum slip resistance value.*
*2. 'P' ratings as per AS 4586 and AS 4663.*
*3. Surfaces were tested when water-wet.*
*4. 'Across-grain' = perpendicularly across the grain. 'Along-grain' = parallel with the grain.*
*5. The Sample size was very small; results should be treated cautiously.*

*[9] Rapid traffic (such as fast walking and running) and erratic traffic (that entails sudden acceleration and deceleration) increases slip risk.*

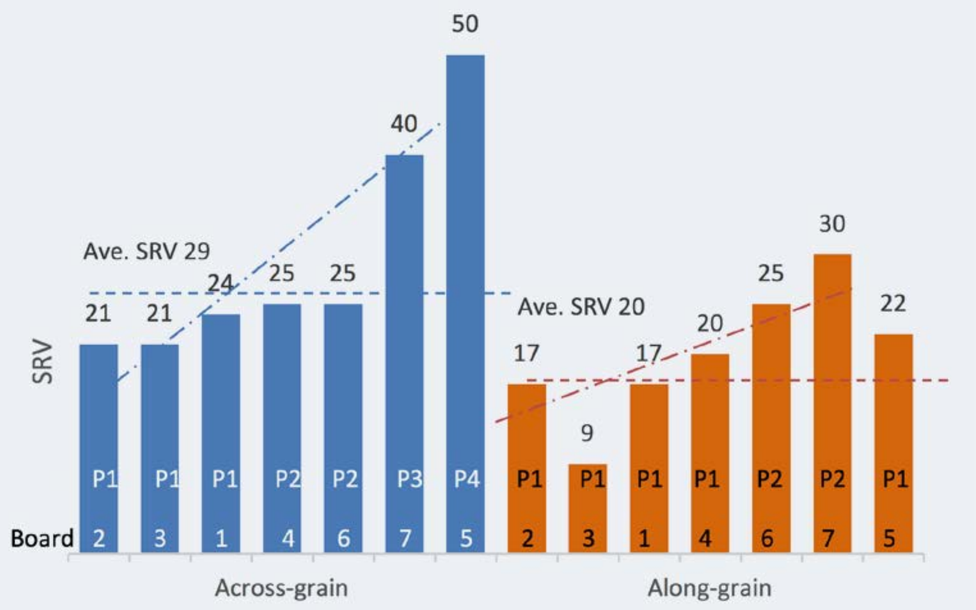



***Figure 3.17: Effect of grain direction: individual results.***

*When arranged in order of increasing across-grain slip resistance (blue bars), the same boards also show a generally increasing order of along-grain slip resistance (orange bars), although not as consistently.*

***Notes:***

*1. 'SRV' = Pendulum slip resistance value.*
*2. 'P' ratings as per AS 4586 and AS 4663.*
*3. Surfaces were tested when water-wet.*
*4. 'Across-grain' = perpendicularly across the grain. 'Along-grain' = parallel with the grain.*
*5. The Sample size was very small; results should be treated cautiously.*

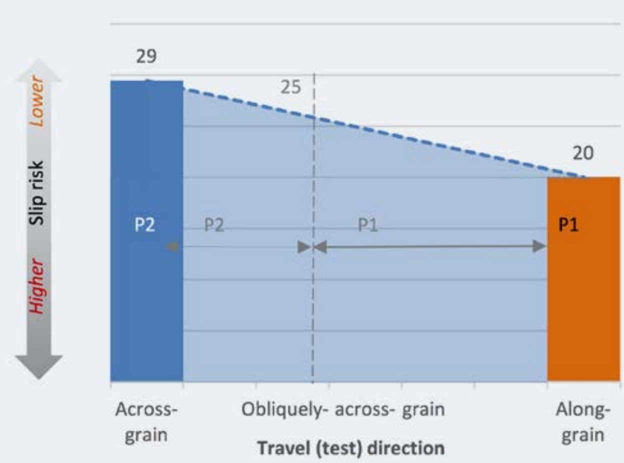



***Figure 3.18: Intermediate slip resistance for travel directions obliquely across the grain.***

*In this example the slip resistance was found to be 29 SRV across the grain and 20 SRV along it. Test results for intermediate angles would be approximately proportionate to the difference between these two values.*

*The risk of slipping decreases with higher SRVs; however, categorisation of slip risk, recognised internationally for Pendulum test results and reflected in Australian standards and building regulations, is at a larger scale – as expressed by the P classifications. In the above case-study, test results at intermediate angles would be either P1 (for SRVs less than 25) or P2 (for SRVs less than 29 and equal to or greater than 25). The P classification scale is further illustrated in Figure 3.17.*

Figure 3.19: Incorrect orientation of boards at landings.

Figure 3.20: Incorrect orientation of boards at landing.

*The boards on the landings in Figures 3.19 and 3.20 are parallel to the travel direction and are therefore more likely to facilitate slips than if they were transverse. The wood grain is also less likely to restrain underfoot movement of sand particles and other small vegetative matter, which also facilitates slips. Installation of wide, slip resistant fixtures at the landing edge would help alleviate the slip risk, preferably rebated to avoid accumulation of surface matter at their rear edge.*

In some settings, such as around swimming pools, it might be feasible to lay boards in different orientations in different areas to correspond with the different types of traffic, although assessing or predicting predominant traffic characteristics could be difficult. Moreover, there might be slip risk at the junction of the different orientations precisely because of the difference: someone moving across the directional characteristic of wood in one part might unknowingly step onto adjacent wood in a direction parallel with the adjacent wood's directional characteristics.

One method sometimes adopted is a chequerboard configuration of short boards in groups perpendicular to each other. However, unless each board is extremely short, there will be adjacent dissimilarity of board direction and possibly therefore slip risk for the reasons previously indicated. The risk might be the greater because people might perceive the chequerboard configuration as being slip resistant and so move on it with false confidence.

***Figure 3.21: Chequerboard configurations can give the illusion of slip resistance.***

## 3.3.2 Board width

Surfaces such as boardwalks and decks that have boards with gaps between them may be more slip resistant if the boards are narrow than if they are wide. This is suggested by a preliminary study that found that 30 mm wide boards were 40% more slip resistant than 20 mm wide boards 67% more slip resistant than 90 mm wide boards, as shown in Figure 3.22.

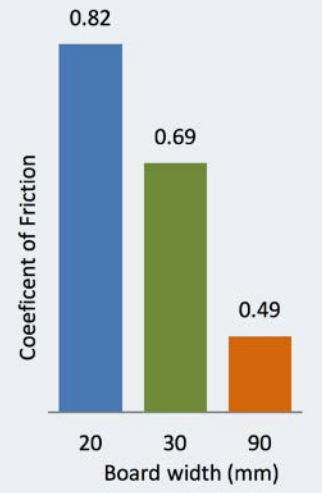



***Figure 3.22: Contribution of board width to slip resistance.***

*In this study, 20 mm wide boards, with gaps between them, were found to be 20% more slip-resistant than 30 mm wide boards, and 67% more than 90 mm boards*

***Notes:***

1. *Slip resistance is expressed in terms of Coefficient of Friction, not Slip Resistance Value (SRV).*
2. *Surfaces were tested when water-wet.*
3. *The sample size was very small; results should be treated cautiously.*
4. *These results were obtained with a slip resistance tester that measures slip distances up to 450 mm, compared with the 124 mm of the pendulum.*

## 3.3.3 Texture

**Machine-roughened wood**

Multi-directional roughness imparts slip resistance in any direction but has the disadvantage of retaining moisture and very small debris and being resistant to cleaning, including by wind and rain. Uni-directional roughness will impart slip resistance across the texture but diminished slip resistance along it, depending upon the sharpness and configuration of the texture (and upon the compressibility, 'treadedness' and rigidity of footwear outersoles).

Depending on pedestrian traffic loads and characteristics, the slip resistance of roughened wood will diminish with time as it is abraded and smoothed by wear. Sustained slip resistance for the setting will require board replacement or re-roughening.

***Figure 3.23: Saw-roughened boards.***

*Because of the semi-circular configurations, boards such as these can provide slip resistance in all directions and, in this example, opportunity for water run-off. However, the texture might not be sustained over time if installed in high traffic areas or continuously moist settings.*

### Example of machined roughness and slip resistance

For boards with gaps, such as outdoor decking and boardwalks, narrow boards may be more slip resistant than wide boards. This is suggested by a preliminary study that found that 30 mm wide boards were 40% more slip resistant and 20 mm wide boards 67% more slip resistant than 90 mm wide boards, as shown in Figure 3.22.

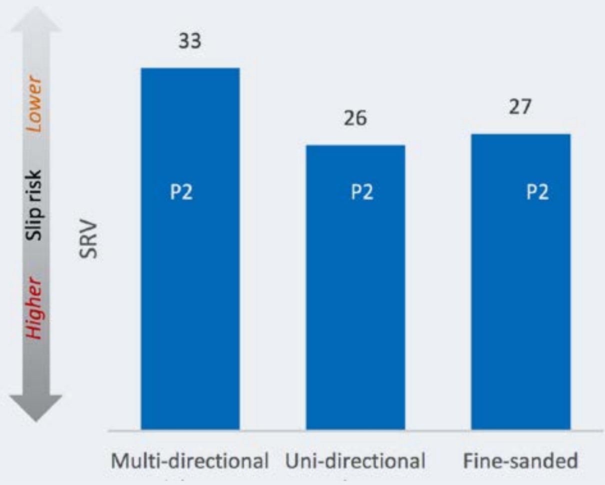



***Figure 3.24: Effect of machined roughness on slip resistance.***

*The multi-directional rough-sawn texture was 22% more slip resistant than the fine-sanded board, and the uni-directional rough-sawn texture was 4% less slip resistant.*

*The multi-directional texture was 27% more slip resistant than the uni-directional texture.*

*The boards were each tested twice, once from each end of the sample.*

*The machined roughness did not increase the P classification compared with the fine-sanded board.*

***Notes:***

1. *'SRV' = Pendulum slip resistance value.*
2. *'P' ratings as per AS 4586 and AS 4663.*
3. *Surfaces were tested when water-wet.*
4. *'Along-grain' = parallel with the grain.*
5. *Tests were conducted along the grain only*
6. *The sample size was very small; results should be treated cautiously.*

### Reeding

Reeded boards can provide slip resistance across the reeding but much-less-so along them (see Figure 3.27). They are best-suited for uni-directional traffic such as on narrow boardwalks and footbridges.

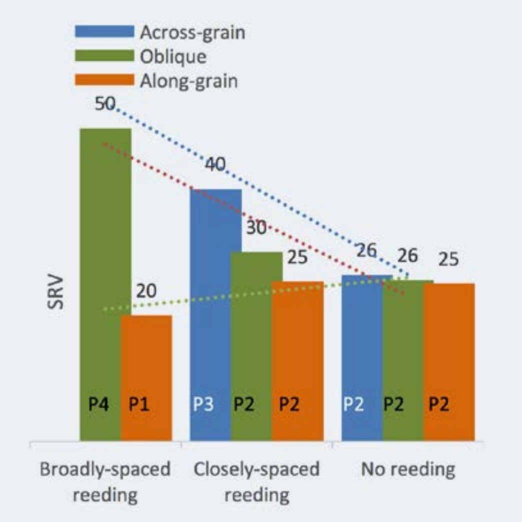
Increasing the gap size between reeds (see Figures 3.25 and 3.26) can substantially increase slip resistance across the reeding but decrease it along it, as shown in Figure 3.27.

A significant disadvantage of reeded boards is that they are not self-draining unless they are in short lengths.

***Figure 3.25: Reeded board 4 mm diameter, closely spaced (1 mm gaps).***

***Figure 3.26: Reeded board 4 mm diameter, broadly spaced (6 mm gaps).***

**Example of reeded wood and slip resistance**




***Notes:***

*1. 'SRV' = Pendulum slip resistance value.*
*2. 'P' ratings as per AS 4586 and AS 4663.*
*3. Surfaces were tested when water-wet.*
*4. 'Across-grain' = perpendicularly across the grain.*
*'Along-grain' = parallel with the grain.*
*5. 'Oblique' = offset by 12° from perpendicular to grain (the pendulum is unsuitable for perpendicularly across-grain testing of broadly spaced reeding).*
*6. The sample size is very small; results should be treated cautiously.*

***Figure 3.27: Effect of reeded wood on slip resistance***

*Across-reeding slip resistance of closely-spaced reeding was found to be 52% greater than for plain boards*

*Obliquely-across-grain slip resistance of closely-spaced reeding was 18% greater than for plain boards, and broadly-spaced-reeding was 94% greater. Broadly-spaced-reeding had 65% greater slip resistance than closely-spaced reeding.*

*Along-grain slip resistance of closely-spaced reeding was almost the same as for plain boards; however, broadly-spaced reeding was 25% less slip resistant than plain boards. Broadly-spaced reeding was 21% less slip resistant than closely-spaced reeding.*

*For closely-spaced reeding, the slip resistance across the grain/reeding was 58% greater than for along the grain/reeding, and 18% greater than for obliquely across the grain/reeding.*

*For broadly-spaced reeding, the slip resistance obliquely across the grain/reeding was 148% greater than for along the grain/reeding.*

*For plain boards, there was very little difference in slip resistance of different grain/reeding directions.*

*Of the different surfaces, broadly-spaced reeding offers the greatest slip resistance obliquely across the grain/reeding (SRV 50, P4) but the least for along the grain/reeding (SRV 20, P1).*

**Example of reeded wood with grit-augmented coating**

Slip resistance of reeded boards can be further improved by applying grit-augmented coating. In a test of broadly-reeded boards, slip resistance was increased by a P classification for along-grain and obliquely across-grain (see Figure 3.28).

The susceptibility of the tops of reeds to traffic wear, and therefore to gradual removal of the grit coating, would diminish the slip resistance with time. Regular re-coating would be required.

**Example of reeded wood and slip resistance**

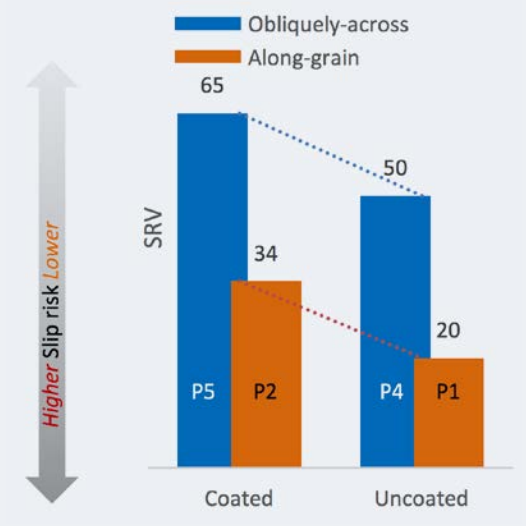



***Figure 3.28: Broadly reeded board with grit-augmented coating***

*The coating provided 30% more slip resistance across the reeding and 70% more along it.*

*The coated board was 95% more slip resistant and the uncoated board 148% more slip resistant obliquely across the reeding than along it.*

*P classifications increased from P4 to P5 obliquely across the reeding and from P1 to P2 along it.*

***Notes:***

*1. 'SRV' = Pendulum slip resistance value.*
*2. 'P' ratings as per AS 4586 and AS 4663.*
*3. Surfaces were tested when water-wet.*
*4. 'Along-grain' = parallel with the grain.*
*5. 'Obliquely across' = offset by 12° from perpendicular to grain (the pendulum is unsuited for perpendicularly across-grain testing of broadly spaced reeding).*
*6. The sample size is very small; results should be treated cautiously*

### 3.3.4 Fixtures

Slip resistant 'fixtures' are the wide variety of single and multiple inserts and attachments that can be used for enhanced localised and broad-area slip resistance. 'Inserts' are thin metal strips inserted on edge into rebated wood but protruding slightly above it—commonly applied in parallel configurations on stair treads and top landings. 'Attachments' are thin flexible or rigid slip-resistant straps, or rigid metal sections incorporating one or more thin flexible or rigid slip resistant straps, each type being attached to or rebated into the wood. Single attachments are commonly used on stair treads, and multiple attachments on walkways and ramps.

***Figure 3.29: Boards with inlaid grit straps.***

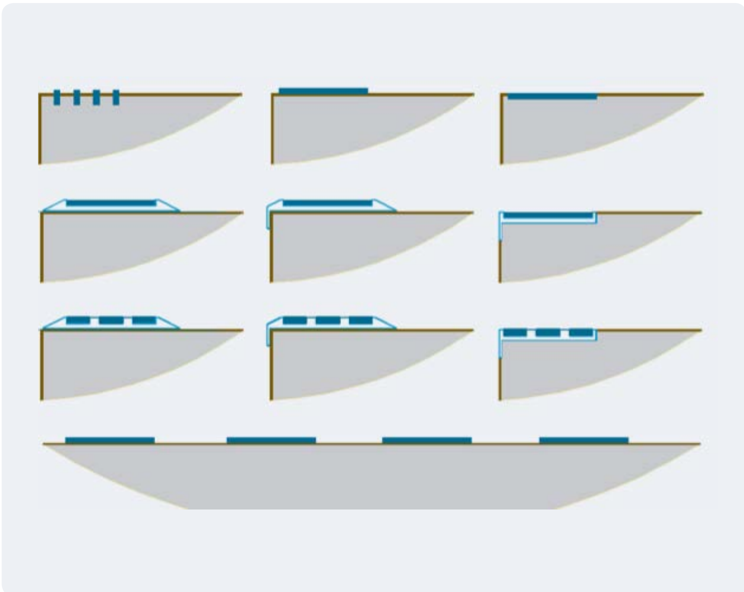


***Figure 3.30: Examples of fixtures on treads and walkways.***

On stair treads, the primary function of fixtures is to resist slipping of foresoles during ascent and descent. On ramps and walkways, their primary function is to resist heel slips and, secondarily, fore-sole slips.

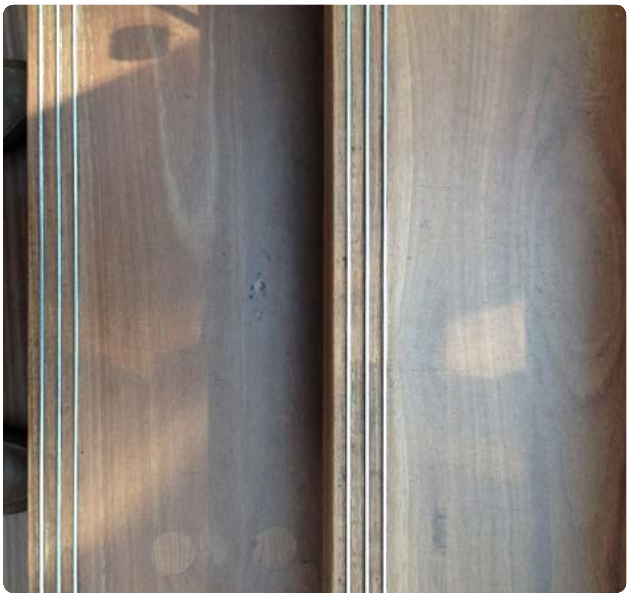


***Figure 3.32: Metal ribs at stair tread nosings.***

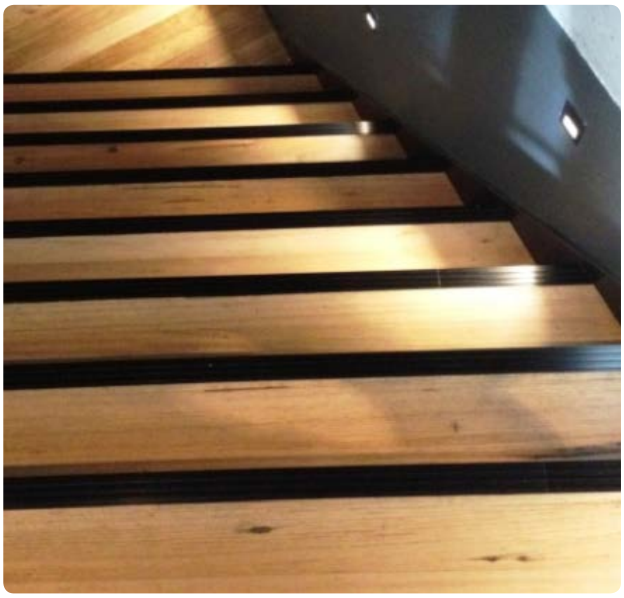


***Figure 3.31: Polymer straps at stair tread nosings.***

**Parallel fixtures and heel slip arrest**

Key factors in heel slip arrest are heel slip distance and the area of contact of the heel's rear edge at touchdown.

**Parallel fixtures perpendicular to pedestrian traffic**

With respect to heel slip distance, a key dimension in the placement of parallel fixtures orientated perpendicular to traffic is the distance between them.

On level surfaces, distances between fixtures of no greater than about 100 mm or, for greater safety, no greater than about 75 mm may be required. On sloped surfaces, depending on the slope, or on level surfaces on which rapid traffic is common, distances of much less than about 75 mm may be necessary.

Parallel fixtures can function in two ways: a) a heel slip on the substrate just after one of the fixtures is arrested or retarded by the next fixture; and b) if reflexive downward rotation of the foot occurs with slip initiation, the foresole will engage the next fixture (if it is close enough).

For traffic oblique to the fixtures, the fixtures need to be increasingly closely spaced with increasing angular divergence from the perpendicular.

Another key dimension is the width of each fixture. A reflexive downward rotation of the foot when a slip occurs contributes to slip arrest and fall avoidance because it brings increasingly greater foot area (heel then foresole) into contact with the pedestrian surface. Fixtures whose width wholly or substantially accommodates the heel will contribute the most to slip arrest.

**Parallel fixtures parallel with pedestrian traffic**

Heel rear edge contact area has the greatest relevance to parallel fixtures that are also parallel to pedestrian traffic and when foot contact occurs between the fixtures.

The contact area of the heel at touchdown (when heel slips occur) is at its rear edge and is very small. Unless fixtures are very closely spaced, they will allow a heel slip to continue and possibly cause a fall (unless the substrate and the person's reactions enable balance recovery). Even if reflexive downward rotation of the foot occurs on heel slip initiation, and notwithstanding the progressively greater heel and foresole contact area, unless the fixtures are close enough, insufficient of the increasing area of the heel and foresole will engage the adjacent fixtures to aid slip arrest.

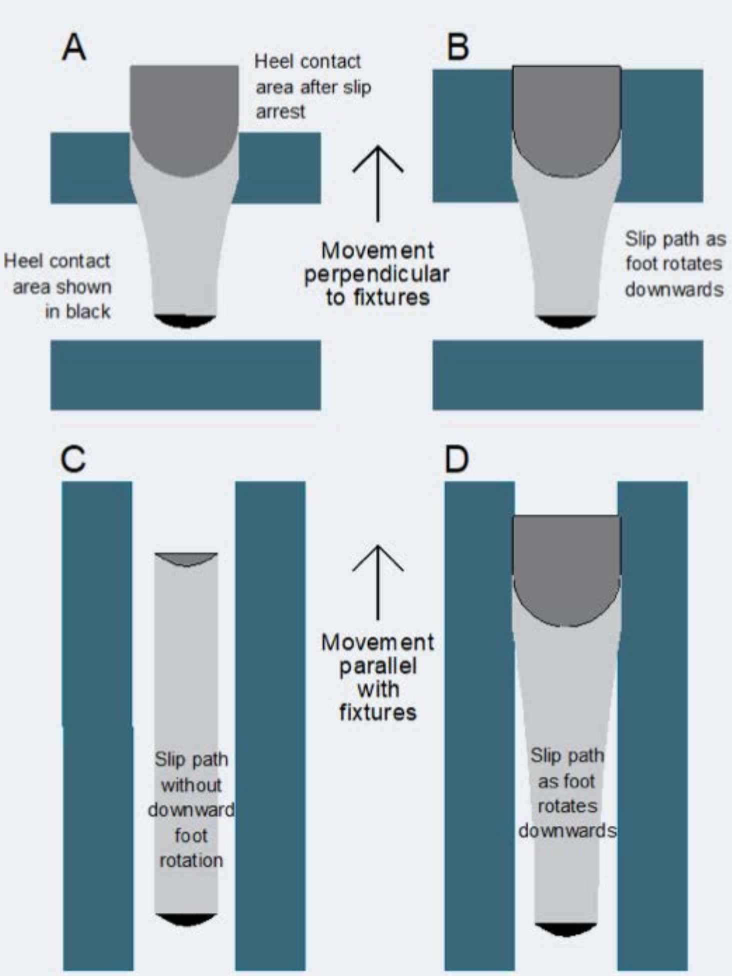



***Figure 3.33: Diagrammatic representation of heel slips and slip resistant fixtures.***

*The heel/ground contact area at touchdown is shown in black. The shoe is that of an adult male and has been rounded from wear. New shoes or shoes with smaller heels would have a much smaller contact area. The foresole area has been omitted from the diagrams.*

*Diagrams A and B show the heel having been arrested by the second fixture.*

*Diagram B indicates the contribution to slip arrest provided by wider fixtures.*

*Diagram C shows heel contact between fixtures. In this example, there has been no reflexive downward rotation of the foot and it can be assumed that a fall occurs at the end of the slip. It is evident that the surface fixtures have no slip arrest role.*

*Diagram D shows the typical reflexive downward rotation of the heel (and foot) as a means of regaining balance and fall avoidance. In this example, the slip arrest depends on the wood substrate, not the slip-resistant fixtures at each side of the foot.*

**Example of grit-tape and slip resistance**

Grit fillings or grit-tape products are amongst the most effective way of achieving slip resistance for wood surfaces. Their effectiveness depends on their extent of coverage. In the test in Figure 3.34, for partial coverage, 13 mm wide strips with 40 mm gaps between them were the most slip resistant, slightly more slip resistant than the 13 mm strips with 15 mm gaps and the half-width strips.

Different results would be derived for different grit type and size, different width strips, different-sized gaps and, to a much lesser extent, different starting positions for the Pendulum test foot.

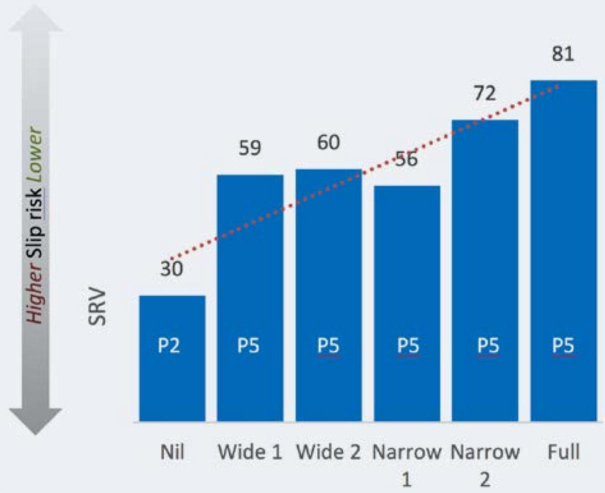



***Figure 3.34: Contribution of grit-tape to slip resistance.***

*Compared with the Nil (uncovered) condition, grit tape increased slip resistance substantially, the most for full coverage (170% increase to SRV 81, P5) and, in descending order, Narrow 2 (by 139% increase to SRV 72, P5), Wide 2 (by 100% to SRV 60, P5), Wide 1 (by 96% to SRV 59, P5) and Narrow 1 (by 87% to SRV 56, P5). with very little difference between Wide 1 and Wide 2.*

*Grit-tape with 40 mm gaps was 28% more slip resistant than for 15 mm gaps.*

*The grit tape increased the slip resistance classification from P2 to P5, regardless of the extent of tape coverage.*

***See Figure 3.35 for the Narrow 2 sample.***

***Notes:***

*1. 'SRV' = Pendulum slip resistance value.*
*2. 'P' ratings as per AS 4586 and AS 4663.*
*3. Surfaces were tested when water-wet.*
*4. Slip resistance was assessed along the grain only (as the worst case). The grit tape was perpendicular to the grain.*
*5. The sample size is very small; results should be treated cautiously.*
*6. 'Full' = whole surface covered with grit-tape*
*7. 'Narrow 1' =13 mm wide grit-tape with 15 mm gaps*
*8. 'Narrow 2' = 13 mm wide grit-tape with 40 mm gaps*
*9. 'Wide 1' = half-coverage (63 mm wide strip); test foot commenced on tape.*
*10. 'Wide 2' = half-coverage (61 mm wide strip); test foot commenced on wood.*
*11. 'Half coverage' = half of the 124 mm travel length of the Pendulum test foot.*

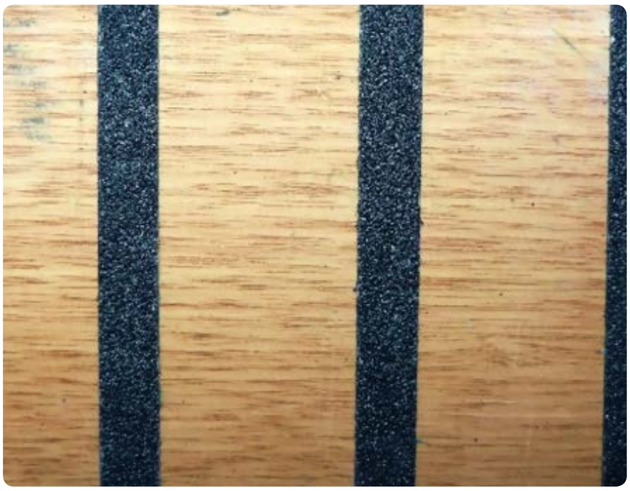


***Figure 3.35: Victorian Ash hardwood with grit-tape strips.***

*This is the sample 'Narrow 2' referenced in Figure 3.34. It has 13 mm wide grit-tape straps with 40 mm gaps.*

### Example of metal rib inserts and slip resistance

As indicated above, fixtures such as metal rib inserts can be effective for uni-directional traffic. The test described in Figure 3.37 found that thin metal rib inserts at 36 mm and 18 mm centres (see Figure 3.36) substantially increased the slip resistance of wood, increasing the P classification across the ribs from P1 to P3 for ribs at 36 mm centres, and from P1 to P4 for 18 mm centres. In other words, of the two spacings, the closer-spaced ribs were more slip resistant (when measured with the Pendulum).

***Figure 3.36: Victorian hardwood with thin metal rib inserts at 18 mm centres***

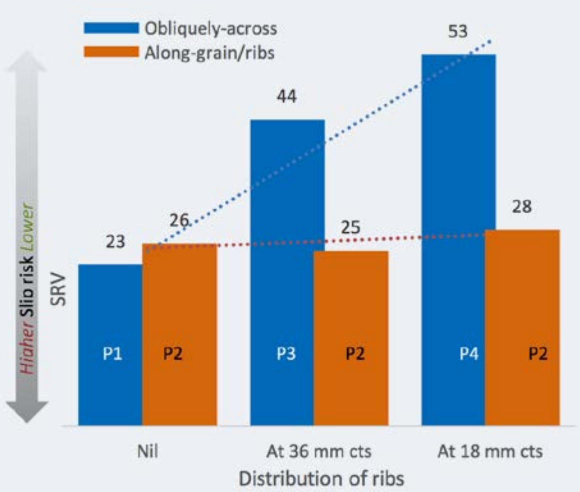



***Figure 3.37: Enhancing slip resistance with thin metal rib inserts.***

*For travel obliquely across the grain/ribs, increased slip resistance of the plain board was increased by 90% for ribs 36 mm apart, and by 130% for ribs at 18 mm (the closer-spaced ribs were 21% more slip-resistant than the broader-spaced ribs).*

*The P classification increased from the P2 of the plain board to P3 for the 36 mm spaced ribs and P4 for the 18 mm spaced ribs.*

*For travel along the grain/ribs, there was very little difference in slip resistance between the three conditions.*

*Slip resistance obliquely across the ribs was 75% and 89% greater than for along them for the 36 mm and 18 mm spaced ribs respectively.*

***Notes:***

1. *'SRV' = Pendulum slip resistance value.*
2. *'P' ratings as per AS 4586 and AS 4663.*
3. *Surfaces were tested when water-wet.*
4. *'Along-grain' = parallel with the grain.*
5. *'Obliquely across' = offset by 12° from perpendicular to grain (the pendulum is unsuited for perpendicularly across-grain testing of surfaces with protuberances such as these ribs).*
6. *The sample size is very small; results should be treated cautiously.*

### Fixtures for multi-directional pedestrian traffic

For slip resistance, fixtures for multi-directional traffic need to be closely spaced and in a matrix configuration.

### Fixtures for fore-sole slip resistance during stair descent

Optimum widths of slip resistant fixtures during descent on stair treads depend on tread, footwear size, and descent speed.

Consistent with the foresole contact area indicated above, a slip-resistant fixture measuring about 110 mm from the nosing can be considered generally effective. Other factors influence this but are not discussed here.

### Example of nosing fixtures to slip resistance

In this example, two nosing straps were tested with the Pendulum: a 60 mm wide grit-coated metal strap, and a 25 mm wide fluted metal strap (see Figures 3.38 and 3.39). As shown in Figure 3.40, both straps increased the slip resistance substantially, with the wider grit-coated strap being slightly more slip resistant than the narrower fluted metal strap. The slip resistance can be partly attributed to the fact the fixtures were surface mounted and not rebated into the wood. Results would vary considerably with less slip resistant wood, different fixture widths and fixture surfaces. As indicated above ('Parallel fixtures perpendicular to pedestrian traffic'), fixtures wider than the 25 mm and 60 mm of these two samples is recommended.

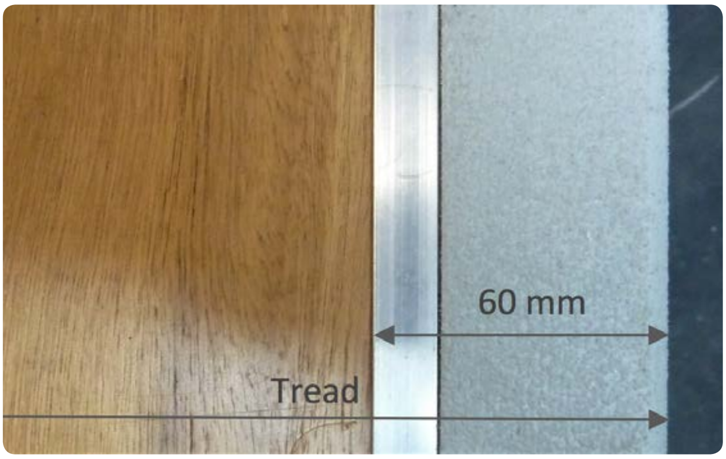



***Figure 3.38. Grit-coated metal strap, 60 mm wide, at nosing of wood tread.***

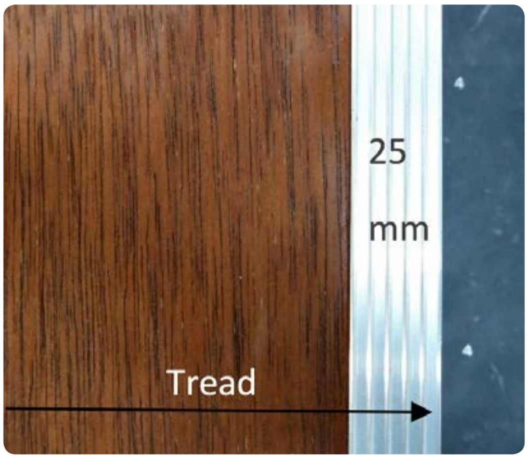



***Figure 3.39: Fluted metal strap, 25 mm wide, at nosing of wood tread.***

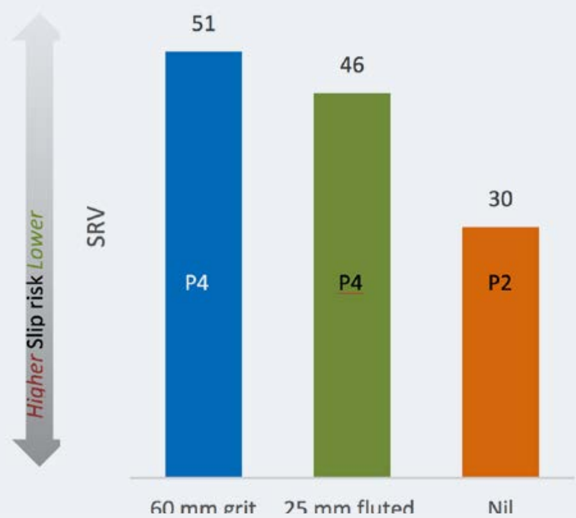



***Figure 3.40: Contribution of nosing features to slip resistance.***

*For this small sample of treads:*

*The 60 mm wide grit-covered metal strap increased the slip resistance of the plain board (finely sanded, coated with non-micro-grit polyurethane) by 70%; the 25 mm wide fluted metal strap increased it by 53%.*

*The tread underlying the 60 mm wide grit-covered metal strap was finely sanded and coated Australian hardwood with non-micro-grit polyurethane; the tread underlying the fluted metal strap was fine-sanded uncoated merbau (both with SRV of 30).*

*The grit-coated strap was 11% more slip resistant than the fluted metal strap (due to the extra width, or possibly the greater effectiveness of the grit coating, or both).*

***Notes:***

*1. 'SRV' = Pendulum slip resistance value.*
*2. 'P' ratings as per AS 4586 and AS 4663.*
*3. Surfaces were tested when water-wet.*
*4. 'Across-grain' = perpendicularly across the grain.*
*5. The samples were positioned so that the end of the Pendulum's test foot run ended at the front edge of each fixture.*
*6. Very few samples were tested; results should therefore be treated cautiously.*

### Failure of fixtures over time

Slip-resistant fixtures need to be fixed to resist dislodgement or delamination by foot traffic or items dragged across them so that they do not deteriorate to protrude and become even more susceptible to mechanical damage (and contributing to trip risk). The rebating of fixtures minimises their susceptibility to dislodgment including, for fixtures lipped over and rebated into tread nosings, by people ascending stairs[10].

For wood outdoors, particularly if unseasoned, weather can cause differential thermal and moisture movement between the wood and strips, bands and fixings, thus admitting moisture and promoting failure of fixings, rotting of the wood and increased vulnerability of dislodgement of the strips and bands. Figures 3.41 and 3.42 illustrate the failure of inset straps.

[10] *Lipped fixtures that are rebated into stair risers also avoids the risk of people's feet or the tips of their walking aids being snared during ascent.*

*Figure 3.41: Delamination of inset grit-tape straps.*

*Figure 3.42: Dislodgement of inset straps.*

***Figure 3.43: Wire netting attachments.***

*Wire-netting is commonly used for increasing slip resistance. However, it is susceptible to damage and consequent contribution to trip risk.*

**Tactile ground surface indicators**

Tactile ground surface indicators (TGSIs) should not be used as slip-resistant attachments. TGSIs must be slip resistant, but this is not their primary purpose: it is to act as navigation aids for people with low vision.

### 3.3.5 Coatings

Coatings (applied in liquid or viscous form) tend to supplant the wood substrate's role in slip resistance, increasingly with coating thickness and extent of coverage. Coatings might not increase wood's slip resistance, and could even decrease it, unless they contain suitable particles.

Slip-resistant coatings are available as alkyd, 'latex'[11], polyurethane, epoxy and wax types, and in transparent, semi-transparent and opaque forms.

Particles in slip-resistant coatings are of various sizes, shapes and materials. The materials include silicon dioxide (sand, ground quartz), aluminium oxide, silicon carbide (carborundum), ceramic microspheres, polymer microspheres, ground polypropylene, ground polycarbonate, demineralised potash, and crushed glass[12].

The particles are supplied already within the coatings; separately, for mixing prior to application; or broadcast over freshly-applied coating. The suppliers' stated advantages of their particles over others include lighter weight and therefore greater retention at the finished surface, less reduction of transparency, sharper asperities, and greater resistance to wear.

A review of slip resistance ratings published by suppliers of the various coatings indicate slip resistance ratings of between P3 and P5 when tested new and water-wet with the Pendulum, and between R9 and R11[13] when tested new and oil-wet with the Inclining Platform. The P ratings are similar to those found in the study in Figure 3.43.

[11] *'Latex' is an inaccurately used term to denote coatings that contain synthetic polymers such as acrylic, vinyl acrylic (PVA) and styrene acrylic.*

[12] *In North America and possibly other countries, ground rubber and ground walnut shells are also used as admixtures.*

[13] *'R' ratings are explained in 'Statutory codes'.*

### Example of micro-grit-augmented coatings

In the study shown in Figure 3.43, wood with a micro-grit augmented coating was compared with uncoated wood. The coated wood had substantially greater slip resistance than the uncoated wood, achieving a P classification of P3. Different results would be obtained with a combination of coatings of different git type and size and different characteristics of the uncoated wood.

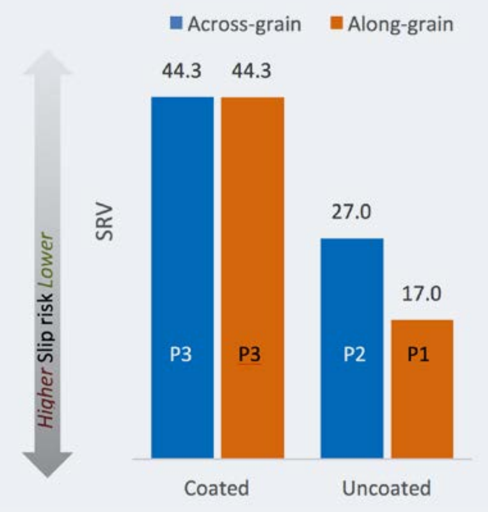



***Figure 3.44: Increasing slip resistance with micro-grit augmented coatings***

*The micro-textured coating increased the slip resistance of the uncoated wood by 64% across the grain and 160% along it, increasing the Class to P3 (almost Class 4) in each case.*

*The micro-textured coating nullified any difference between across-grain and along-grain slip resistance. For the uncoated condition, across-grain slip resistance was 59% greater than the along-grain slip resistance.*

***Notes:***

*1. 'SRV' = Pendulum slip resistance value.*
*2. 'P' ratings as per AS 4586 and AS 4663.*
*3. Surfaces were tested when water-wet.*
*4. 'Across-grain' = perpendicularly across the grain. 'Along-grain' = parallel with the grain.*
*4. The Sample size was very small; results should be treated cautiously.*

### Example of micro-roughness of coated and uncoated wood

The micro-roughness of coated and uncoated wood was measured; results are shown in Figure 3.45. Consistent with previous indications of differences between across-grain and along-grain slip resistance, the study demonstrates a similar difference in three travel directions on the wood, with the greatest micro-roughness being for across the grain, the least for along the grain, and intermediate values for the intermediate angle.

Regardless of the travel direction, the thickly coated sample shows the substantially least micro-roughness, consistent with comments above about the paramount slip resisting role of thick coatings.

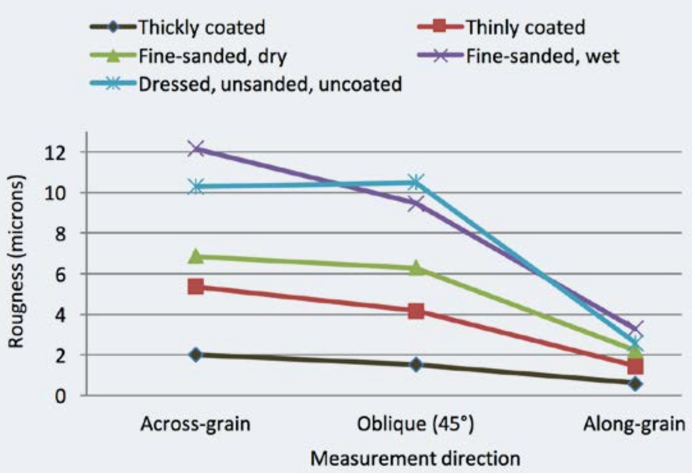



***Figure 3.45: Micro-roughness of coated and uncoated wood.***

*Greatest micro-roughness was for water-saturated, uncoated and fine-sanded wood measured across the grain and, as can be expected, the smoothest was for the thickly coated wood measured along the grain.*

*Generally, micro-roughness increased with increasing measurement angle from the grain direction.*

*The contribution of differential surface swelling of the saturated wood is evident.*

*The small variance in micro-roughness for the thickly coated wood in the three directions affirms the nil difference between across-grain and along-grain slip resistance for the coated wood reported in Figure 39.*

***Notes:***

*1. The one sample, Vic. Ash HW, was used for all conditions.*
*2. 'Fine-sanded, wet' = measured after 10 minutes water saturation*
*2. 'Across-grain' = perpendicularly across the grain. 'Along-grain' = parallel with the grain.*

**Degradation of coatings with time**

Delamination and erosion of coatings from their wood substrates because of wear, mechanical damage or failure of adhesion, including from moisture ingress outdoors, obviously compromises the efficacy of the slip resistant coatings. The coating and its intended location should therefore be carefully considered, and the coating properly applied for sustained suitability of the coating.

***Figure 3.46: Coating degradation outdoors.***

*The textured coating is delaminating due to weathering, and abrasive wear from traffic. Regular monitoring and maintenenace is necessay to avoid the degradation.*

***Figure 3.47: Coating degradation due to abrasive wear.***

*Abrasive wear of smooth-coated timber in an indoor high traffic area has exposed the wood grain. Because traffic through the doorway is across the wood grain, it is possible that the resulting surface is more slip resistant in the entry and exit direction than the original smooth coating.*

## 3.4 Decrease of slip resistance over time

A new surface that only just satisfies the NCC and HB 198 is unlikely to satisfy them after being subject to wear from traffic and, for outdoor settings, weathering. Even short-term use can reduce slip resistance ratings.

Testing the slip resistance of newly completed coatings in situ is recommended to ensure they have been applied effectively in terms of consistency of texture across the coated area and, for sequenced coating systems, that the top coating has not submerged the broadcast particles and diminished the intended slip resistance. Regular periodic testing of coatings should also be conducted to ensure retention of slip resistance.

One coatings supplier, to its credit, indicates the results of slip resistance tests of samples of its products after they have undergone accelerated wear tests so effects of traffic wear on slip resistance can be anticipated (see later for accelerated wear tests).

## 3.5 Wood slip resistance factors: effectiveness ranking

From the 14 slip resistance tests presented above, factors contributing to slip resistance can be aggregated and ranked for effectiveness, as shown in Table 3.1.

The ranking is expressed in terms of the ‘P’ classifications of AS 4586 and AS 4336, from the lowest (P1) to the highest (P5).

The table seeks to enhance a general understanding of wood slip resistance factors. However, it is based on a very small number of tests and is not based on a rigorously objective compilation. Consistent with previous discussions, it cannot be relied upon for consideration of individual wood products: each one must be considered in the context of its unique environmental conditions and occupational setting.

*Table 3.1: P Classifications and Wood Conditions.*

| Class | Factors | Basis of assessment |
|---|---|---|
| P1 | **Lowest rating is likely for:**<br>• travel along reeding, grain, weather-textured grain<br>• fungal-coating<br>• finely sanded finish<br>• smooth-sawn finish. | 57% of results were for tests along reeding or grain, including weather-textured grain, and fungal-coated boards.<br>43% were for tests across the grain (obliquely or perpendicularly) of finely sanded or smooth-sawn boards, including some with fungal-coating. |
| P2 | **Low rating is likely for:**<br>• travel along reeding, grain<br>• finely sanded finish<br>• smooth-sawn finish<br>• fungal-coating. | 47% of results were for tests along reeding, grain, or metal ribs, including some with fungal coating.<br>43% were for tests obliquely or perpendicularly across reeding or of the grain of finely sanded or smooth-sawn boards including some with fungal-coating.<br>Note: Fungal-coated boards had grit-augmented coating. Along-grain and across-grain test results were the same, notwithstanding minor surface degradation due to weathering (likely to yield dissimilar results between across-grain and along-grain tests with increased weathering and degradation). |
| P3 | **Mid-rating is likely for:**<br>• travel across grain<br>• grit-augmented coating<br>• metal ribs<br>• reeding (for travel across)<br>• long-term weather-texturing<br>• multi-directional rough-sawn texture. | 25% of results were for along-grain tests .<br>75% were for across-grain tests (obliquely or perpendicularly).<br>Along-grain samples had grit-augmented coating or multi-directional rough-sawn texture. Across-grain test samples had grit-augmented coating, metal ribs, reeding, or long-term weathered texture.<br>The multi-directional rough-sawn textured sample was not tested across the grain because the multi-directionality would probably have masked the underlying grain. |
| P4 | **High rating is likely for:**<br>• travel across-grain<br>• grit-augmented coating<br>• fluted metal nosing band<br>• grit-coated nosing band<br>• metal ribs<br>• broadly spaced reeding (for travel across)<br>• weather-texturing. | 18% of results were for along-grain tests of boards with grit-augmented coating.<br>82% were for across-grain tests (obliquely and perpendicularly) of boards with grit-augmented coating; fluted metal or grit-coated nosing band; broadly spaced (10 mm) reeding; metal ribs; or weather-texturing. |
| P5 | **Highest rating is likely for:**<br>• grit tape covering<br>• grit-augmented coating including broadly spaced reeded board tested obliquely across reeding. | Grit-tape covering or grit-augmented coating; broadly spaced reeded board tested obliquely across the grain/reeding.<br>Except for the full grit tape coverage, other instances of grit tape were of intermittent strips laid perpendicularly across and tested along the grain (slightly higher results would probably occur if the intermittent strips were laid along and tested across the grain). |

# 4 Statutory codes

## 4.1 National Construction Code

The National Construction Code (NCC)[14] mandates slip resistance for ramps, and stairway treads or near their nosing – at performance requirement DP2 in NCC Volume 1, and P2.5.1 in NCC Volume 2.

NCC Volume 1 is for 'public' buildings and structures (Classes 2 to 9, 10a and 10b). NCC Volume 2 is for 'private' buildings and structures (Classes 1 and 10).

The NCC quantifies the required degree of slip resistance in its Deemed-to-Satisfy provisions (DTSPs)[15]. The DTSPs are expressed identically in NCC Volume One (for Classes 2 to 9 buildings) and Volume Two (for Classes 1 and 10 buildings). In NCC Volume 1, the slip resistance is specified at Part D2.10(c) for ramps, D2.13(A)(v) for stair treads, and D2.14(A)(ii) for landings and summarised in Table D2.14.

In NCC Volume 2, it is specified at Part 3.9.1.4 and in its Table 3.9.1.3.

Fixed platforms, walkways, stairways and ladders are also required to satisfy NCC Parts D2.10, D2.13 and D2.14, except for the concessions given below. The slip resistance ratings are those determined in accordance with Australian Standard *AS 4586-2013: Slip resistance classification of new pedestrian surface materials.*

***Table 4.1: NCC slip resistance performance requirements***

| **Classes of building and pedestrian surfaces within them that require slip resistance** | | | | **Pedestrian surface** | | |
|---|---|---|---|---|---|---|
| | | | | **Treads[1]** | **Ramps[2]** | **Intermediate & top landings[3]** |
| Vol. | Class | | Building type | Y | Y | Y |
| Two | 1 | 1a | Detached dwellings | Y | Y | Y |
| | | 1b | Attached dwellings, e.g. row house, terrace house, town house | Y | Y | Y |
| | 10 | 10a | Non-habitable structure, e.g. garage, carport, shed | Y | Y | Y |
| | | 10b | Structure such as fence, retaining or free-standing wall[4]. | Y | Y | Y |
| | | 10c | Private bushfire shelter | - | Y | - |
| One | 10b | | Accessible swimming pool[5] | Y | Y | Y |
| | 2-9 | | All others | Y | Y | Y |

***Notes***

*[1] Or nosing of treads; [2] But not ramp landings; [3] Or edge strip of landings;*

*[4] Relevant here if a ramp or stair is integrated with the structure; [5] Ref NCC Spec D3.10.2.*

***Table 4.2: NCC DTS slip resistance provisions***

<table>
<tr><th rowspan="2">Application</th><th rowspan="2">Building class</th><th colspan="2">Surface condition</th></tr>
<tr><th>Dry</th><th>Wet</th></tr>
<tr><td>Ramp <= 1:8</td><td>1, 10</td><td>P4 or R10</td><td>P5 or R12</td></tr>
<tr><td>Ramp > 1:14</td><td>2 – 9</td><td>P4 or R11</td><td>P5 or R12</td></tr>
<tr><td>Ramp > 1:20 <= 1:14</td><td>2 – 9, 10B</td><td rowspan="2">P3 or R10</td><td rowspan="2">P4 or R11</td></tr>
<tr><td>Stair tread</td><td>1, 2 - 9, 10</td></tr>
<tr><td>Stairway landing</td><td>2 - 9</td><td>P3 or R10</td><td>P4 or R11</td></tr>
<tr><td>Tread nosing strip</td><td rowspan="2">1, 2 - 9, 10</td><td rowspan="2">P3</td><td rowspan="2">P4</td></tr>
<tr><td>Stair landing edge strip</td></tr>
</table>

> 'steeper than'; < 'not steeper than'

*[14] The NCC is enforced at a State and Territory level by means of States' and territories' building acts and subsidiary regulations. Volumes 1 and 2 of the NCC constitute the Building Code of Australia Volumes 1 and 2.*

*[15] DTS is titled 'Acceptable Construction' in Volume Two of the NCC.*

Slip resistance for NCC DTSP compliance must be determined with a Pendulum or an Inclining Platform (see further below). The 'P' values nominated in the NCC DTSPs are Pendulum test results and the 'R' values are Inclining Platform test results. The P values are for water-wet surfaces and dry textile surfaces (carpets, mats etc.). The R values are for dry and oil-wet surfaces. The values are derived from the Standards Australia handbook *HB198-2014 Guide to the specification and testing of slip resistance of pedestrian surfaces* (see further below). Testing with both tribometers is not required by the NCC: testing with only one is permissible.

Slip resistance features and testing with devices other than those stipulated in the NCC DTS are allowed by the NCC under its Alternative Solutions provisions, if they can be demonstrated to have at least equivalent effectiveness as the DTSPs.

**AS 4586**

The slip resistance ratings required by the NCC DTSPs must be determined in accordance with Australian standard AS 4586. See Section 5.2. In some circumstances under the NCC DTSPs, the earlier version of AS4586 may be used.

**Limitation of the NCC**

Under the NCC, stairways are those having more than one riser; hence, neither a single step (one riser) nor two steps (one tread and two risers) needs to satisfy the NCC for slip resistance[16].

The NCC DTSPs do not address slip resistance for stepped aisles in theatres, auditoria, spectator stands and the like.

The NCC has statutory force only for buildings (and associated structures and facilities) that require a building permit. It is therefore not applicable to existing buildings, or structures and facilities that do not require a permit under the NCC, although there is no reason why the NCC requirements cannot be used as criteria in circumstances where the NCC is inapplicable.

**Concessions and limitations of the NCC DTSPs**

If a fixed platform, walkway, stairway or ladder 'only serves (a) machinery rooms, boiler houses, lift-machine rooms, plant-rooms, and the like; or (b) non-habitable rooms, such as attics, storerooms and the like that are not used on a frequent or daily basis in the internal parts of a sole-occupancy unit in a Class 2 building or Class 4 part of a building', the NCC DTPSs may be disregarded in favour of the non-prescriptive AS 1657[17] (see further below). This also applies to farm buildings or sheds[18]. Similarly, a stairway 'that provides access to a service platform, rigging loft, or the like' in Class 9b buildings need only comply with AS 1657[19].

Because the NCC DTSPs reference AS 4586, they are limited to new, yet-to-be-used surfaces; the NCC DTSPs do not address existing surfaces (these are addressed by AS 4663). In other words, NCC DTSPs compliance relates only to new surfaces although, outside the matter of DTSPs compliance, the DTSPs they can be validly applied to existing surfaces under the NCC performance provisions AS 4663 (and HB:198-2014).

Slip-resistance ratings for ramps into and the sloped entries of swimming pools[20] are not included in the NCC DTSPs.

**Configuration of slip resistance on ramps, stair treads and landings**

The NCC does not stipulate the configuration of slip resistant characteristics, nor therefore the width and spacing of intermittent slip resistant elements. It simply states that they be provided on (NCC-required) ramps and, on stairways, on their treads and landings or on their leading edges. For characteristics at leading edges, the NCC does not provide any dimensions, nor therefore the width and spacing of intermittent slip resistant elements. It simply states that they be in the form of a 'nosing strip'.

*[16] There is no definition of stairway in the NCC. However, it is inferred in D2.13 (a)(i) Goings and risers.*

*[17] Ref. NCC Part 2.18.*

*[18] Ref. NCC Part H3.5.*

*[19] Ref NCC Part H1.6.*

*[20] Ref. NCC Part D3.10*

**Slip-resistant luminance-contrasting nosing strips**

Volume 1 of The NCC at Part D3.3(a)(ii) requires compliance with 11.1(f) of *AS1428.1-2009: Design for access and mobility, Part 1: General requirements for access – New building work*. AS 1428.1 requires the provision of a 50 mm to 75 mm wide luminance contrasting strip at tread nosings. However. neither the NCC nor AS1428.1 directly associates slip resistance requirements with luminance contrast strips, although it is clearly subsumed under NCC's requirement for slip resistance under Parts D2.13(A)(v) and D2.14(A)(ii).

It is common practice that luminance contrasting strips have slip-resistant coatings or inserts, but which are not commonly provided for the whole width of the strip and that they are provided in a width of 50 mm. Consequently, the slip resistance might have a width of only 40 mm. Such widths represent industry practice, not specifically NCC requirements.

NCC Volume 1 does not require luminance contrasting strips at nosings.

## 4.2 Disability Discrimination Act Standards

The Disability Discrimination Act (DDA) requires compliance with its buildings[21] and public transport standards[22].

The slip-resistance requirements of the DDA buildings standards are in the DDA Access Code for Buildings (ACB) and are the same as those of the NCC. Compliance with the NCC constitutes compliance with the ACB and vice versa, including with respect to slip-resistance ratings.

The DDA public transport standards apply to public transport conveyances, premises and infrastructure. The only stipulation in the standards for slip resistance is for 'boarding devices' (such as manually or mechanically operated ramps and lifts); there is no stipulation for other types of pedestrian surface. However, the standards require compliance of ground and floor surfaces (including 'access paths' and ramps[23]) with Australian standard *AS 1428.2-1992 Design for access and mobility Part 2: Enhanced and additional requirements – Buildings and facilities* which, in turn, requires compliance with the then current version of *AS1428.1 Design for access and mobility Part 1 – New building works.* AS1428.1 requires that ground or floor surfaces of 'continuous accessible paths of travel[24] and circulation spaces[25] be slip resistant; however, it is silent about the need for slip resistance of steps and stairways[26,27,28] and does not stipulate minimum slip-resistance ratings.

**Public pedestrian areas under the DDA**

Public pedestrian areas come under the meaning of 'premises' in the DDA. There is no DDA slip-resistance requirement for public pedestrian areas, except to the extent that they are referenced within the DDA buildings and public transport standards.

## 4.3 Other statutory obligations

Other obligations reside in municipal bylaws and policies for public areas; in States' and Territories' health and safety acts and codes of practice; and in States' and Territories' regulations that mandate essential safety measures and building maintenance. However, the obligations are expressed in performance terms without quantification of minimum slip resistance ratings.

[21] *Disability (Access to premises – Buildings) Standards, 2010*

[22] *Disability Standards for Accessible Public Transport 2002, as amended 2010*

[23] *AS1428.2 also requires kerb and step ramps to be slip resistant.*

[24] *A continuous accessible path of travel is 'an uninterrupted path of travel to, into or within a building providing access to all accessible features'. Accessible features are, at the least, those nominated by the NCC.*

[25] *A circulation space is a 'clear unobstructed area, to enable persons using mobility aids to manoeuvre'.*

[26] *Providing that the accessible paths of travel and circulation spaces are 'traversable by people who use a wheelchair and those with an ambulant or sensor disability'*

[27] *Though not stated in AS 1428.1, continuous accessible paths of travel are those that are usable by wheelchairs and therefore excludes steps and stairs.*

[28] *However, it requires stairway and ramp landings to have tactile ground surface indicators (TGSIs) that comply with AS1428.4.1 and that therefore must be slip resistant*

# 5 Non-statutory codes

## 5.1 AS/NZS 3661.2

Australian and New Zealand standard *AS/NZS 3661.2-1994, Part 2: Guide to the reduction of slip hazards* provides useful information relevant to wood surfaces.

Key sections are: Selection of pedestrian surfaces for slip resistant characteristics; Slipping problems during installation of finishing; Care and maintenance of floors; and Reduction of slip hazards on existing floors.

Part 2 refers to Part 1 of AS/NZS 3661; however, Part 1 has been superseded by AS 4586 and AS 4663.

## 5.2 AS 4586

Australian standard AS 4586-2013*: Slip resistance classification of new pedestrian surface materials* describes tribometers and testing procedures but does not indicate required or recommended slip resistance ratings. The tribometers are the British Pendulum, the Inclining Platform and the Dry Floor Friction Tester (see Section 7).

AS 4586 stipulates directions in which wood surfaces must tested (as indicated in Sections 7.1.1 and 7.1.2), and describes a method for measuring the roughness of very coarse textures ('Displacement Volume Test'). It also provides a formula and table for relating slip resistance values obtained with the Pendulum and Dry Floor Friction Tester with sloped surfaces.

AS 4586 is a non-statutory code, but it has statutory authority because it is referenced by the NCC.

## 5.3 AS 4663

A surface when new that satisfies the NCC and HB 198:2014 is unlikely to satisfy them after it has been subject to wear from traffic and, for outdoor settings, weathering.

Australian standard AS 4463-2013: *Slip resistance classification of existing pedestrian surfaces* was developed for surfaces after they had been applied and used. AS 4663 is very similar to AS 4586 insofar as it describes tribometers and testing procedures and does not indicate required or recommended slip resistance ratings. A principal difference is that it does not include the Inclining Platform or Displacement Volume test methods.

An important difference between AS 4586 and AS 4663 is that AS4586 is addresses individual samples, whereas AS 4663 also addresses larger surface areas and includes a procedure for obtaining a representative sample of the area.

Like AS 4586, AS 4663 stipulates directions in which wood surfaces must tested, as indicated in Sections 7.1.1 and 7.1.2.

## 5.4 AS 1657

Australian standard AS 1657-2013: *Fixed platforms, walkways, stairways and ladders – Design, construction and installation* stipulates the need for underfoot surfaces of walkways, platforms, landings, stair treads and ladder rungs to be slip resistant, although it does not specify required slip resistance ratings.

The standard creates a quandary because it references AS 3661 and HB 197, neither of which are current standards (see further below). Given the non-prescriptive nature of the standard, it would be reasonable to apply AS 4586 or AS 4663, as appropriate, and HB 198.

## 5.5 Standards Australia Handbook HB:198-2014

Standards Australia Handbook HB:198-2014 (HB 198) is an important guideline because it is the source of the NCC DTSPs for slip resistance (Table 3A of HB 198), and for slip resistance ratings in circumstances not covered by the NCC (Table 3B).

The handbook addresses the methods of measuring and clarifying slip resistance using the slip testing devices and procedures referenced by AS 4586 and AS 4663. The standards relate to water-wet, oil-wet and dry surfaces as tested by the Pendulum, the Dry Floor Friction Tester and the Inclining Ramp.

The classifications in the schedule should be interpreted in the context of risk management. Slip resistance results less than the classifications will increase the probability of slips (and falls) and results greater than the classifications will decrease the probability.

A schedule of slip resistance classifications indicated by Tables 3A and 3B of HB 198 is reproduced below at Table 6.1.

HB 198 is an interim, partial, successor to Standards Australia Handbook HB:197-1999 (HB 197). HB 197 references an earlier version of AS 4586-2013. HB 197 has no statutory relevance to new building works.

# 6 Common Law

**Apart from statutory obligations, duty of-care obligations exist under Common Law. These are not prescribed but are established by legal precedent or as new findings on a case-by-case basis.**

Compliance with the NCC DTSPs can provide substantial and even sufficient protection against legal action under Common Law, although not necessarily if the compliance was with a superseded version of the DTSPs and legal action was taken for an incident occurring after the introduction of the new version. Conversely, non-compliance with the NCC DTSPs can provide the basis of action at Common Law.

The performance provisions of the NCC, and other non-prescriptive statutory obligations do not provide the same defence against or basis of action at Common Law because of their non-prescriptiveness. In these instances, it would need to be proven by a defendant that duty-of-care obligations had been discharged or, by a plaintiff, that they had not been discharged.

Satisfying Australian standards, regardless of statutory requirements can also provide defence against or the basis of legal action.

***Table 6.1: Recommended minimum slip resistance classifications indicated of HB 198. (continued on next page).***

| Location | Slip testing device | |
|---|---|---|
| | Pendulum | Inclining platform |
| **External Pavements and Ramps** | | |
| External ramps including sloping driveways, footpaths etc. steeper than 1 in 14 | P5 | R12 |
| External ramps including sloping driveways, footpaths, etc. under 1:14, external sales areas (e.g. markets), external carpark areas, external colonnades, walkways, pedestrian crossings, balconies, verandas, carports, driveways, courtyards and roof decks | P4 | R11 |
| Undercover car parks | P3 | R10 |
| **Hotels, Offices, Public Buildings, Schools and Kindergartens** *Entries and access areas including hotels, offices, public buildings, schools, kindergartens, common areas of public buildings, internal lift lobbies.* | | |
| Wet area | P3 | R10 |
| Transitional area | P2 | R9 |
| Dry area | P1 | R9 |
| Toilet facilities in offices, hotels and shopping centres | P3 | R10 |
| Hotel apartment bathrooms, en-suites and toilets | P2 | A |
| Hotel apartment kitchens and laundries | P2 | R9 |

**Entries and access areas including hotels, offices, public buildings, schools, kindergartens, common areas of public buildings, internal lift lobbies.*

***Table 6.1: Recommended minimum slip resistance classifications indicated of HB 198. (continued).***

| **Location** | **Slip testing device** | |
|---|---|---|
| | **Pendulum** | **Inclining platform** |
| **Supermarkets and Shopping Centres** | | |
| Fast food outlets, buffet food servery areas, food courts and fast food dining areas in shopping centres | P3 | R10 |
| Shop and supermarket fresh fruit and vegetable areas | P3 | R10 |
| Shop entry areas with external entrances | P3 | R10 |
| Supermarket aisles (except fresh food areas) | P1 | R9 |
| Other separate shops inside shopping centres – wet | P3 | R10 |
| Other separate shops inside shopping centres – dry | P1 | R9 |
| **Loading Docks, Commercial Kitchens, Cold Stores, Serving Areas** | | |
| Loading docks under cover and commercial kitchens | P5 | R12 |
| Serving areas behind bars in public on hotels and clubs, cold stores | P4 | R11 |
| **Swimming Pools and Sporting Facilities** | | |
| Swimming pool ramps on stairs leading to water | P5 | C |
| Swimming pool surrounds and communal shower rooms | P4 | B |
| Communal changing rooms | P3 | A |
| Undercover concourse areas of sports stadiums | P3 | R10 |
| **Hospitals and Aged Care Facilities** | | |
| Bathrooms and en-suites in hospitals and aged care facilities | P3 | B |
| Wards and corridors in hospital and aged care facilities | P2 | R9 |

**Equivalence of P values and Coefficient of Friction**

Using the formula given in F1 of AS 4586 and C1 of AS 4663, the Coefficient of Friction values corresponding with the Slip Resistance Values determined with the Pendulum slip resistance tester are shown in the following table.

***Table 6.2: Equivalence of P values and coefficient of friction***

| **Pendulum Slip Resistance Values converted to Coefficient of Friction** | | | | |
|---|---|---|---|---|
| **Class** | **Slider 96 rubber** | | **Slider 55 rubber** | |
| | **SRV** | **CoF** | **SRV** | **CoF** |
| P1 | 12 – 24 | 0.11 – 0.24 | <20 | <0.19 |
| P2 | 25 – 34 | 0.25 – 0.35 | 20 – 34 | 0.19 – 0.35 |
| P3 | 35 – 44 | 0.36 – 0.46 | 35 – 39 | 0.36 – 0.40 |
| P4 | 45 – 54 | 0.47 – 0.59 | 40 – 44 | 0.41 – 0.46 |
| P5 | >54 | >0.59 | >44 | >0.46 |

# 7 Assessing Slip Resistance

## 7.1 Slip Resistance Measuring Devices

There is a multitude of slip resistance measuring device types throughout the world. They include pendulum, skid, trolley, ramp and impact types. Many are portable and suitable for on-site and *in situ* testing, but others, such as the inclining platform, are not. Very few are suitable for *in situ* testing of mid-flight stair treads.

Three types of devices are recognised by Standards Australia: the portable British Pendulum, portable 'Dry Floor Friction Tester', and the non-portable Inclining Platform. AS 4586 and AS 4663 describe the standardised testing procedures, and HB 198-2014 provides supporting information and consumer guidance.

### 7.1.1 British Pendulum

This portable device comprises a suspended radial rod at the end of which is a spring-tensioned rubber pad ('slider'). When the rod is released, it swings down onto the test surface and drags the edge of the pad along it. The extent to which the rod rotates about its fulcrum indicates the resistance of the surface to the sliding of the rubber edge. The pendulum can be used for testing wet and dry surfaces and a wide variety of surface textures, although surfaces with coarse texture or protuberances, cavities or troughs can adversely affect the travel of the test pad over the surface. This can be ameliorated by adjusting the orientation of the surface being tested.

Material other than rubber can be used for the pad, and it can be used at reduced lengths, although this would place tests results outside the scope of the Australian Standards.

The Australian Standards AS 4586 and AS 4663 require that wood is tested parallel with the grain, and that stairway treads be tested in the direction of descent[29]. To avoid the adverse effects of very coarsely textured surfaces, including therefore multi-protuberant surfaces, the Standards require that they be orientated at an angle to the pendulum so that a part of the pad is always on the top of protuberances and so that the pad remains parallel with the plane of the tops of the protuberances.


***Figure 7.1: The British Pendulum.***

[29] *Because the pendulum is too large for treads, the standards allow for top landings, if they have surfaces identical to the treads, to be tested as substitutes for the treads.*

### 7.1.2 The ‘Dry Floor Friction Tester’

The ‘Dry Floor Friction Tester’, as it is identified in AS 4586 and AS 4663, is a portable, autonomously travelling device that drags a very small rubber pad across the test surface, digitally recording the slip resistance of the surface to the pad as it moves. Its name is prefixed here with ‘Dry’ to indicate that it is widely considered to be only suitable for testing dry surfaces[30], and for which it is the only application considered by the Australian standards for it.

The smallness of the test pad restricts its use to surfaces that are finely textured and that do not have protuberances, cavities or troughs.


***Figure 7.2: Tortus Dry Floor Friction Tester.*** *From http://www.mastrad.com/tortus3.pdf*

### 7.1.3 Inclining Platform

Sometimes referred to as a ramp[31], the inclining platform is a non-portable device. Samples of a pedestrian surface are placed on the narrow platform and a person takes several steps (forwards down, then backwards up the platform). The angle of inclination at which the person slips is recorded as the slip resistance of the samples.

***Figure 7.2: Inclining platform*** *From https://oshwiki.eu/wiki/File:ERO-10-06-b-7b.fig1.jpg#file*

*[30] It is widely accepted internationally that results of tests with the Dry Floor Friction Tester on wet surfaces are insufficiently reliable.*

*[31] Such as in earlier versions of the Standards Australia standards; they now refer to it as ‘inclining platform’.*

The inclining platform is customarily used with people in footwear of standardised synthetic outsoles or in bare feet because the SA standards provide for these conditions. However, it can be used with any type of footwear or foot covering.

The platform is customarily used with water-wet or oil-wet surfaces, although surfaces can be tested for any fluid or other matter, or when they are clean and dry. Under AS 4586, wood needs to be tested so that the grain or directional texture is aligned with the slope of the platform.

The inclining platform enables the testing of surfaces that range from very smooth to coarsely textured or multi-protuberant. There are very few inclining platforms in Australia.

### 7.1.4 Other slip resistance measuring devices

Another portable slip testing device commercially available and used by some practitioners in Australia is a very small trolley fitted with a very small rubber test pad like that of the Dry Floor Friction Tester.

It operates by being placed on a small ramp so that, when released, it rolls down the ramp onto the test surface. The travel distance on the test surface is used to determine the slip resistance of the surface. Its use is best suited to surfaces that are not coarsely textured nor that have protrusions, cavities or troughs.

A prototype portable tribometer has been developed by the author. It can test horizontal and inclined surfaces, stair treads and nosings, and a range of textured surfaces including highly textured ones such as Tactile Ground Surface Indicators. It can be fitted with an electronically recordable and multi-articulated foot (including with footwear), and can simulate reflexive responses to slips (see Figure 7.3). An earlier prototype was used in preliminary research of which some results are shown in this guide.

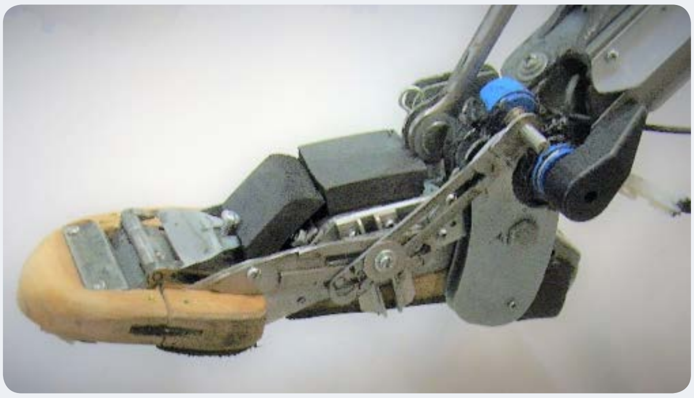


***Figure 7.3 Replica of human foot***

*Test foot used in a prototype tribometer. It is multi-articulated and, with the leg, is electronically recordable. It can be shod with footwear; used for a large range of conditions; and simulate reflexive responses to slips.*

## 7.2 Texture measurement

An ancillary method for assessing slip resistance, although not for directly measuring it, is surface texture measurement.

It is customary to refer to microtexture and macrotexture, with the former regarded as the primary agent in slip resistance. However, there can be several scales of texture that can simultaneously influence slip resistance. Generally, there is a correlation between surface texture and slip resistance such that an increase in texture tends to increase the slip resistance. However, there are many criteria for quantifying texture and there is no broadly accepted quantum of texture that reliably and accurately correlates with slip resistance.

There are two methods of texture measurement methods, one with profilometers for microtexture and another by concavity volume calculation for macrotexture.

## 7.2.1 Profilometers

There are two common types of hand-held profilometers used for testing pedestrian surfaces—stylus and optical. The stylus type has a diamond tipped needle whose vertical displacement is recorded as it is moved across the surface; the optical type relies upon reflected light which records variation of texture as the device is moved.

Although surface texture as an indicator of slip resistance is promoted in the United Kingdom, for example, the reliability of the method is not universally accepted. A difficulty is that there are many ways of defining texture, including with respect to shape, spacing and heights of asperities.

Hand-held profilometers are limited to measurement of very fine textures, such as dressed or coated wood. Moreover, granular textures such as carborundum finishes can exceed the capability of stylus profilometers.


***Figure 7.4: Stylus profilometer***

*This is the profilometer used for the study at Figure 3.44. Stylus profilometers are only suitable for micro-textured surfaces and, typically, only those that are not comprised of individual sharp particles such as comprise grit-tape and grit-coated fixtures.*

## 7.2.2 Concavity volume calculation

This method can be used for textures that cannot be measured by profilometers. The procedure entails filling a particular sized area of a textured surface with very fine sand or paste and identifying the volume that occupies the area. AS 4586 describes this method using paste.

## 7.3 Simulated wear

Because surface modification from traffic and, for exterior surfaces, weather and other environmental conditions can alter slip resistance, it can be valuable to simulate this by subjecting the surfaces to an accelerated wear procedure prior to measuring or re-measuring the surfaces for slip resistance.

As indicated above, two opposite results of modification can occur from wear and weathering. If the wood is initially polished or coated, the surface texture will tend to increase as will the slip resistance (at the cost of appearance). If the wood is initially textured or has protuberances, it will tend to become less textured or more planar, and therefore less slip resistant.

## 7.3.1 Abraders

Two types of abraders are commonly used for accelerated simulation of wear: a powered or manually operated horizontally reciprocating type, and a rotating (Tabor) type. The reciprocating device can test a larger area than the rotating type which can only treat a very small area, and samples are simpler to prepare for it than for the rotating type. However, the rotating device can be better suited than the reciprocating device for surfaces that are coarsely textured or have protuberances.

Neither of the reciprocating and rotating devices replicates foot impact forces and they are therefore unable (nor intended) to replicate mechanical damage to surface protuberances or the edges of surface cavities and troughs. These features can contribute to slip resistance, so their blunting or removal will tend to reduce slip resistance.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