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Summary Bulletin

Slip Resistant Floor Surfaces

PEER REVIEWED

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Abstract

Slipping on a floor and falling is a major cause of injury in the home. Older people are among the most susceptible to slip and fall injuries and risk a greater degree of injury when falls occur.

Recent building regulations have specified requirements for the slip resistance of stairs and ramps in all dwellings, as well as floor surfaces in some common areas of higher-density residential dwelling buildings and some specialised dwellings for people with disability. However, these regulations are applicable to new construction only. There is building regulation for slip resistance of existing floors in residential dwellings. Having slip resistant floor surfaces in homes is reliant on home designers, purchasers, owners and residents, either selecting appropriate floors at the time of construction, or modifying inappropriate floors in the existing home. The floor surfaces then need to be maintained so that slip resistance is retained.

For the residential stairs and ramps that are required to be slip resistant, the Australian Building Code provides an acceptable minimum slip resistance classification for the floor surface. However, there is limited guidance available on achieving slip resistant floor surfaces in other areas of the home. Australian Standards handbooks' recommended slip resistance classification for floor surfaces are focused on public environments; quite different to the residential environment. Slip resistance classifications and their corresponding test methods need to be understood when selecting a floor product, to ensure that the classification of a particular floor product is applicable to residential environments. Many floor products do not come with a slip resistance classification rating at all.

This Summary Bulletin responds to recent Australian regulatory changes for slip resistance of floor surfaces within dwellings and on accessways in common areas of dwelling buildings. The current regulations and Australian Standards for slip resistance classification and testing are detailed, and their applicability to residential dwellings discussed. Methods for selecting appropriate slip resistant floor surfaces in new homes, and methods of modifying existing floor surfaces to make them more slip resistant, are then examined.

Keywords

slip resistant; fall; floor; housing; home modification; design; disability

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Contribution of Authors

Joanne Quinn undertook the research for this document. She developed the content, formatted and wrote the Summary Bulletin.

Catherine Bridge provided guidance on the slip resistance information to be included in this document. She also reviewed the Summary Bulletin.

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Glossary

Accessible	**"**Having features to enable use by people with a disability" (*AS 1428.1-2009*, 4.1)
Accessway	A "continuous *accessible* path of travel (as defined in *AS 1428.1*) to, into or within a building" (*NCC 2016*, Vol 1, A1.1)
BCA	**Building Code of Australia**, which comprises Volume 1 & 2 of the **NCC**
BPN	**British Pendulum Number** Value of slip resistance using the British Pendulum Friction Tester
Class 1a Building*	A free-standing (detached) or attached single dwelling that does not have another dwelling above or below. Dwelling types can include houses, semi-detached houses, townhouses, terrace houses and villas.
Class 1b Building*	A free-standing (detached) or attached dwelling, not exceeding 300m^2 floor area or having more than 12 residents, that does not have another dwelling above or below. Dwelling types can include small boarding houses and hostels.
Class 2 Building*	A residential building of two or more storeys, containing two or more dwellings. Dwelling types can include apartments, units, flats, and duplexes.
Class 3 Building*	A residential building (not Class 1 or 2) for numerous unrelated people to live in the short-term or long term. Dwelling types can include boarding houses and hostels, residential dwellings in hotels, motels, healthcare buildings and schools, and specialised accommodation the aged, children, and people with disability.
Co-efficient of Friction (COF)	"The ratio of the tangential force required to move a body across a horizontal surface to the vertical load imposed on the surface by the body." (*AS 4586-2013*, 4.3)
Contamination	"The presence of any substance (wet or dry) on the walking surface that may significantly reduce the slip resistance." (*AS 4663-2013*, 4.5)

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Continuous accessible path of travel	"An uninterrupted path of travel to, into or within a building providing access to all accessible facilities." (*AS 1428.1-2009*, 4.6)
Deemed-to-Satisfy Solution	A method of satisfying the slip resistant floor surface performance requirements in the **BCA**, based on meeting the specified minimum slip resistance classifications for the floor surface in the relevant environment and Building Class*.
Dwelling	A Sole-Occupancy Unit (SOU).
Fall	An "event which results in a person coming to rest inadvertently on the ground or floor or on another lower level" (World Health Organization (2005) cited in Ozanne-Smith, Guy, Kelly, & Clapperton, 2008)
Friction	"An intrinsic property of the two interfacing, interacting surfaces resulting from their micro and macro-roughness, inter- and intra-molecular forces of attraction and repulsion, and their visco-elastic properties" (*AS 4586-2013*, 4.6)
Hospital Separation	Hospital care provided in a single hospital stay
NATA	**National Association of Testing Authorities**, Australia
NCC	**National Construction Code**
Slip Resistant	The amount of friction that limits slipping by a person walking across a floor surface
Sole-Occupancy Unit (SOU)	In a residential building, this is the part for the exclusive use of the occupant or owner. The occupant can be a single person or a household. Most SOUs are self-contained, including one or more bedrooms, bathroom(s), kitchen facilities and living area(s). However, smaller SOUs such as those in boarding houses and specialised housing, can be just a bedroom with or without a bathroom.
SCV	**Slope Correction Value** The increase in **BPN** required to be added to a level surface **SRV**, to compensate for a slope
SDV	**Slope Design Value** The required **BPN** for a sloped surface, based on the application of a **SCV** to the **SRV** of the level surface.

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SRV	**Slip Resistance Value** The mean **BPN** of several pendulum tests of a floor sample

***** Building Class definitions are contained in the Australian Building Code's Classification of Buildings and Structures in the National Construction Code (*NCC 2016*, Vol 1, A3.2)

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Background

Slips and falls are a major cause of serious injury in the home. The causes of slips and falls can involve a range of personal and environmental factors, but are primarily due to insufficient friction between a person's shoe (or bare foot) and the surface of the floor. A home with floor surfaces that provide sufficient friction for everyday use can assist in reducing the risk of slipping.

The higher risk of falls and resulting injury for older people is well known. As well as being more susceptible to falls, older people risk an increased degree of injury when falls occur (Ozanne-Smith et al., 2008, 55-56). The impact of falls on older people's mobility, wellbeing and independence (Home and Community Care [HACC], 2005), is of particular concern, threatening the preference of older people to remain living at home in the future.

However, the risk of slips and falls in the home does not solely apply to the oldest in the population. An Australian study revealed slips, trips and stumbles on the same floor level as the most common cause of falls in buildings leading to hospitalisation. Most of those slips, trips and falls (62%) occurred in the home (Ozanne-Smith et al., 2008, px-xi). In addition to the elderly, children and people who are unwell, were more susceptible to falls (Ozanne-Smith et al., 2008, p iii).

Despite the prevalence of slips and falls in the home, the regulatory requirements for slip resistant flooring are limited. The Building Code of Australia (BCA) requires only that newly-constructed stairways and ramps in residential dwellings and buildings with residential dwellings such as units or apartments, have slip resistant walking surfaces (*NCC 2016*, Vol 1, DP2(c); Vol 2, P2.5.1(b)). Until 2014, there was no measurable definition of 'slip resistant' in the BCA. Following the update to Australian Standards for slip resistance in 2013 (*AS 4586-2013*), and the BCA in 2014 and 2016 (*NCC 2014*; *NCC 2016*), the acceptable ('Deemed-to-Satisfy') minimum slip-resistance classifications are specified for slip resistant floor surfaces on stair treads or nosings to stair treads, landings and ramps, for all dwellings and buildings (Class 2-9) with residential dwellings, such as units or apartments (Australian Building Codes Board, 2014; *NCC 2016*, Vol 1, D2.10(c), D2.13(a), D2.14(a); Vol 2, 3.9.1.4).

Some specialised dwellings for older people and people with a disability, designed according to *AS 4299-1995 Adaptable housing*, have the additional requirement of a slip resistant floor surface on the accessible path of travel into, and throughout the dwelling. Dwellings designed to meet Livable Housing Design guidelines (Livable Housing Australia, 2015) also have a slip resistant floor surface on the accessible path of travel into the dwelling, as well as the parking area and shower. Dwellings achieving Gold Level of Livable Housing Design have additional slip resistant flooring in the kitchen and laundry. However, these specialised Adaptable Housing and Livable Housing dwellings account for a minority of homes.

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Despite the lack of regulatory requirement for slip resistant flooring in homes, Australian Standards provide some recommendations for avoiding slippery floors. *AS 4226-2008 Guidelines for safe housing design* advises that areas that can become wet: bathrooms, laundries, toilets, kitchens, and dwelling entries, need floors that are slip resistant when wet and when dry. Outdoor paths, stairs and ramps also need to be slip resistant.

Unfortunately, choosing such a floor can be difficult, even for a builder, owner or resident who is motivated to have a slip resistant floor. Unlike commercial flooring, many floor products for the home have not had slip testing undertaken on them, and are not provided with a classification of their slip resistance at the point of sale. Floor products that are provided with a slip resistance classification have usually been tested for commercial or industrial requirements. For example, a floor tile with classification 'R13' would be considered highly slip resistant, but this rating is based on testing of the tile surface when coated in oil, and being walked on by a person wearing heavy safety boots. These conditions are applicable, and test results useful, in an industrial setting. This rating is largely irrelevant in a residential environment, where the floor surface could be wet from rain and being walked on with smooth-soled shoes or even barefoot (Bowman, 2012; Safe Environments, n.d.-a, n.d.-b).

For people who don't consider themselves or other residents at risk of slipping and falling on the floor, the slip resistance of a floor surface can receive little consideration when choosing flooring. When building or renovating a home, the floor choices are extensive. Concrete, stone, timber, and ceramic tile, are just some of the materials available. The format of the floor material broadens these choices. For example, a concrete floor could be a poured slab or pavers; tiles range from large format through to mosaic, coated or uncoated; and timber could be provided as floorboards, parquetry, laminated floating floorboards or decking boards. There are then numerous options for the finish. For example, interior timber floorboards can be varnished and polished to a high gloss, oiled, waxed, coated with water-based polyurethane, or pre-finished and laid as a floating floor.

Numerous factors, other than slip resistance, might influence flooring selection for the interior and exterior of a home. There is the style of the home, current fashion and trends, and preferred colours and patterns. Practical issues include the comfort of the floor underfoot, and acoustic effects. Maintenance issues such as the cleaning requirements and the durability of the surface also need to be taken into account. Then there are financial considerations: the cost of the floor and the perceived value of the floor, and consequently, the added value to the home.

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The challenge for the designer, builder or homeowner is selecting a floor surface that meets their requirements for slip resistance, as well as their other priorities, such as style, acoustic effects, maintenance, durability, value and budget. Essential to this process, is having information on the slip resistance of the different floor surfaces, and determining what level of slip resistance is needed in the home environment. This Summary Bulletin examines the role of slip resistant floor surfaces in reducing slips and falls, and identifies methods for selecting appropriate slip resistant floor surfaces and keeping them slip resistant. Methods of modifying existing floor surfaces to make them more slip resistant are also explored.

Factors Affecting Slip Resistance

The risk of slipping on an indoor or outdoor floor in the home is based on more than just the texture of the floor surface. Research has shown that multiple factors, in combination, can contribute to slipping: the floor surface material, contamination on the floor, cleaning of the floor, the environment, footwear, and human (pedestrian) factors (Carpenter, Lazarus, & Perkins, 2006).

The Health and Safety Executive [HSE] Slip Potential Model (Carpenter et al., 2006, Figure 2.1) categorised these factors as either controllable, or uncontrollable but predictable. Figure 1 shows the relationship between these factors, adapted from the original HSE model. An additional factor, cleaning, from a more recent HSE Slip Potential Model is highlighted.

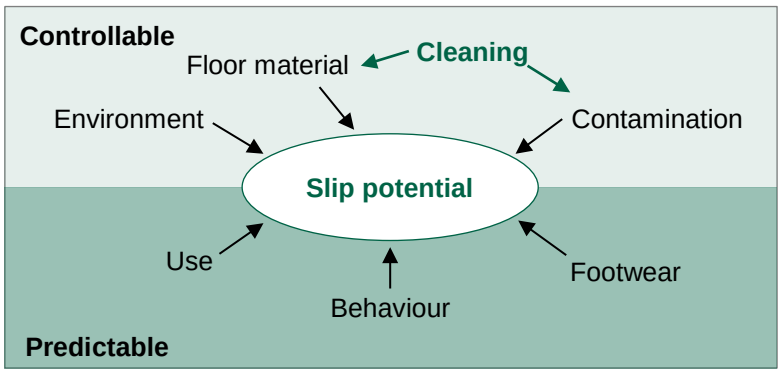

Figure 1. Slip Potential Model

Source: Adapted from Slip potential model (HSE, 2012, Table 1) and Slip Influences (Carpenter et al., 2006, Figure 2.1)

Slipping occurs at the interface between a person's footwear (shoe or bare foot) with the surface of the floor material and any contamination on it, such as water, oil or dirt. This shoe/foot – floor interface can be affected by the surrounding environment, how the floor is used, and the person's behaviour.

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The Shoe/foot–Floor Interface

The interface between the shoe/foot and the floor surface, with any contaminants between, are known as the *tribology* factors in slip resistance (Lockhart, 2008). A three-layer model used to describe the slip resistance foot/shoe-floor interface is shown in Figure 2. The three layers are:

- **Human Layer**: shoe heel (or bare heel), walking speed, gait, weigh
- **Contamination Layer**: dirt, water etc, between shoe (or bare foot) and floor
- **Floor Layer**: material, hardness porosity, surface finish (Slip Alert, n.d.-b)

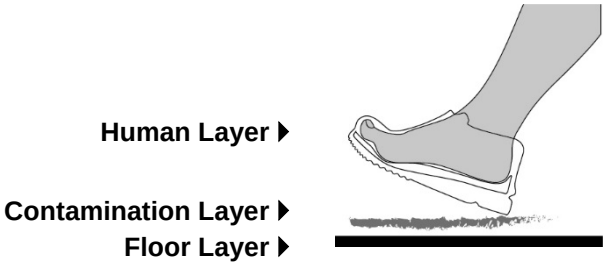

Figure 2. Factors affecting slip resistance – Three layer model

Source: Adapted from Three Layer Model + Floor Safety (Slip Alert, n.d.-b)

Human Layer

When walking, two main forces are applied by the foot, the shear (horizontal) force in the direction of travel (Fh) and the normal (downward vertical) force (Fv). As the heel of each shoe/foot contacts the ground there is a:

- **horizontal force (Fh)** due to the forward thrust in the swing of the foot. The amount of this horizontal force (Fh) "is affected by walking speed which is the product of cadence (number of steps per minute) and step length" (Lockhart, 2008, p207). As the cadence and step length increase, the horizontal force will increase.
- **vertical force (Fv)** due to downward momentum of the leg as the body's centre of mass transfers over the foot.

Slipping occurs if the horizontal (Fh) and vertical (Fv) forces are not opposed by sufficient friction force where the heel of the shoe/foot contacts the floor surface. (Lockhart, 2008)

To lower the risk of slipping, horizontal and vertical forces can be reduced by adjusting gait to decrease cadence and/or step length. Research shows that people adjust their gait when they have experienced a slip on a particular floor, and also when they are anticipating they could slip on the floor. This adjusted gait, either a more cautious leg movement, foot placement, or both, can reduce the chance of slipping (Heiden, Sanderson, Inglis, & Siegmund, 2006; Lockhart, Spauldinga, & Sung, 2007).

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Slip risk can also be lowered by increasing the friction force of the shoe/foot. This friction force is dependent on the hardness and surface roughness of the footwear being worn, or whether a person is barefoot.

In the home environment, footwear (or lack of footwear) is more difficult to predict than in a commercial or industrial environment. Residents and their visitors are more likely to be barefoot, indoors and outdoors, compared to a public environment. The footwear worn in the home environment could also have smoother soles, such as slippers or even socks. The level of friction provided by different types of sock could be unpredictable for the person wearing them. The lower friction provided by many types of sock is a slip risk on dry floors. On wet floors, research has shown that nylon and tight weave socks have an even higher slip risk, whereas cotton and open weave socks are more slip resistant on wet floors (Curry & Matthias, 2009; Matthias, Curry, Donelly, & Drendel, 2010).

Similarly, the hardness of rubber-soles on some footwear can prevent the soles deforming adequately to grip a textured floor. Instead they skid over the surface (Stone Initiatives, n.d.).

Floor Layer

The physical properties of the floor that affect the risk of slipping are concerned with the floor material and its surface finish. Surface textures are usually indicated to provide slip resistance. However, their effectiveness is dependent on the physical characteristics of the texture.

For the size and space of texturing, Australian Standards' guidance is that "[g]enerally, a granulated effect comprised of raised areas 1 mm–2 mm in diameter and a similar distance apart is the most effective. The larger the diameter and the spacing, the less effective the texture becomes" (*AS 4226-2008*, 5.2).

The geometry of the texturing will also have a bearing on slip resistance. Smoother, curved textures can provide less friction than rougher, sharper textures. Any sealers or coatings, and the degree of polish on the textured surface, will also vary the friction provided.

The physical properties of the floor material and the surface finish that provide a slip resistant surface at the time of installation need to be consistent over the lifespan of the floor. Wearing or other deterioration of the floor material or the surface finish can result in a reduction in slip resistance over time. The durability of slip resistant properties and any maintenance required to retain this durability should be considered at the time the floor material and its surface finish are selected.

It is not just the surface of an individual floor material that can affect slipping; differences in slip-resistance of adjacent floor surfaces can be a potential slip hazard. *AS 4226-2008* recommends that where floor materials with differing slip resistance are joined, the transition should be clearly indicated with colour (*AS 4226-2008*, 5.5).

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Contamination Layer

Contamination is the presence of any wet or dry substance on the surface of the floor, which can potentially reduce slip resistance (Carpenter et al., 2006). Contamination on the floor surface changes the slip resistant characteristics of both the floor surface and the shoe/foot surface. The contaminant acts as a lubricant between these two surfaces, lowering their COF and increasing the tendency for slipping. For example, a textured floor surface might be coated in water due to rain (which in some climates, might freeze to ice), sand, a build-up of grime, or a spill of food or grease.

Cleaning contamination from highly textured floor surfaces can be more difficult, compared to cleaning smoother floor surfaces. It is essential that the type and frequency of cleaning needed to keep textured floors free from contamination, is considered before installation. (Bowman, 1999, 5)

The reduction of COF due to contamination is made worse by:

- a larger area of contact between the sole of the shoe/foot and the floor surface, as it becomes more difficult to squeeze out the lubricant (contaminant) between them;
- the less roughness on the sole of the shoe/foot and the floor surface, as it is more difficult for the lubricant to drain;
- the greater the velocity (speed) of the shoe/foot moving along the floor surface, as the lubricant can become trapped;
- the less vertical load from the person moving, as less lubricant can be squeezed out by their shoe-foot contacting the floor surface; and
- the greater the viscosity of the lubricant, the longer the time it takes to drain from the surface. (Lockhart, 2008, p207-208).

To address the risk of contamination on floor surfaces, floor materials and slip resistance treatments are generally categorised as being suited for wet environments or dry environments. In the home, wet environments are mainly outdoor areas and bathrooms, though kitchens and laundries are sometimes included. Despite being considered a dry environment, floors in living areas, hallways and bedrooms can become wet through accidental spills, cleaning or water tracked in from outside. If these floors are likely to become wet, and/or there is a high risk of injury to any residents or visitors if a slip and fall occurs, a floor surface suited to wet areas should be considered.

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Personal Factors

A person's physical, sensory and cognitive abilities will influence their risk of slipping on a floor. A lower level of physical (mobility), sensory (vision) and mental (cognition) ability will have an effect on all layers of the shoe/foot-floor interface: human layer, floor layer and contamination layer.

Mobility

An impairment in mobility can be indicated in difficulty with balance, a shuffling gait, and fatigue; all affecting the potential for slipping on a floor. Medical conditions including Parkinson's Disease, Alzheimer's Disease, and Multiple Sclerosis are common causes of mobility impairments, as is frailty due to ageing. Mobility impairment can also be temporary, the result of illness, injuries, recovery from medical procedures, or effect of alcohol, medication and other drugs, or even overtiredness.

Use of mobility devices such as a walking frame, walking stick or crutches can affect slipping. The friction of the base surface of the device needs to be considered in addition to the sole of the shoe/foot. Also, use of these devices affect posture, centre of gravity, gait, and balance.

Vision

The effects of vision impairment on the human layer of the shoe/foot-floor interface can lead to increased risk of slipping. Impairments include reduced visual acuity (clarity of vision), reduced visual field (area of vision), colour blindness, and light and glare sensitivity.

People with vision impairment could have difficulty perceiving potential slipperiness on a floor. For example, they might not see contamination on the floor from rain, a leak or a spill. It might be difficult to see the edges of steps on a staircase, or the change in slope at the start of a ramp. Similarly, a high gloss surface indicating a potentially slippery floor might not be evident.

The chance of slipping can usually be reduced when people adjust their gait in response to perceiving a slip risk (Heiden et al., 2006; Lockhart et al., 2007). However, when a person's impaired vision leads to a difficulty perceiving the potential slipperiness of the floor and they don't adjust their gait in response, they are at a higher risk of falling (Lockhart, Woldstad, Smith, & Ramsey, 2002).

Vision impairment is a common with increased age, and medical conditions such as diabetes. Vision can also be temporarily impaired as an effect of medications and other drugs or alcohol, illness.

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Cognition

Impaired cognition can lead to increased chance of slipping, due to difficulty interpreting the visual signs that a floor surface could be slippery, not remembering previous experience of a floor being slippery, or incorrect perception of the floor material or floor gradient. Without perception of the slip risk, a person is unlikely to make the required gait adjustment that can prevent slipping (Lockhart et al., 2002).

Impaired cognition can lead to increase of spills on the floor, delay or difficulty cleaning the floor following a spill, and difficulty addressing ongoing floor maintenance requirements. This resulting contamination layer on the floor increases likelihood of slipping for themselves and other residents.

Impaired cognition is commonly associated with medical conditions such as dementia or intellectual disability. Cognition might be temporarily affected in many other people by a range of life experiences, such as illness, tiredness, stress and rushing to complete home activities.

Environment Factors

Gradient of the floor

Sloped floors, ramps and stairs generally require a higher level of slip resistance than level floors. Walking on a sloped surface increases the risk of slipping due to higher shear forces; increasing the gradient of slope produces a corresponding increase in shear force (Lockhart, 2008). Therefore, the greater the gradient of slope, the greater the slip resistance needed.

The risk of slipping when walking down a slope is greater than the risk when walking up. The likelihood of the slip resulting in a fall is also increased, as it is more difficult to recover when a slip occurs (Redfern et al., 2001).

To determine the increase in slip resistance required for a sloped floor, the slip resistance of a level floor in the same location first needs to be established. The additional slip resistance due to the slope of the floor can then be calculated. The calculation methods, different for wet and dry surfaces, are addressed in Australian Standards. (*AS HB 198:2014*, 6).

Increased potential for slipping on ramps is recognised in the Australian Building Code, with regulated slip resistance requirements for ramps in new residential dwellings and buildings (*NCC 2016*, Vol 1, DP2(c) & Vol 2, P2.5.1(b)). The acceptable minimum slip resistance classifications are also included (*NCC 2016*, Vol 1, D2.10(c); Vol 2, 3.9.1.4(b)).

Stairs have a higher slip risk due to the small surface area of the stair, and the greater height of a potential fall. The most serious falls are when descending the stairs, if the heel of the front foot is placed near the front edge (nosing) of the tread and there is not enough friction to prevent it sliding off (Templer, 1992, 3.6.1).

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The slip resistance of stair treads should be uniform across the surface. Slip resistant strips are sometimes applied to stair treads to improve slip resistance of the stair nosings, when the stair surface is inadequate. This can reduce the chance of the foot slipping off the tread, but has its own risks. Highly abrasive strips can cause tripping, especially if raised above the tread surface, and can increase injury to the skin in a fall. Also, if the strip is not on the very edge of the nosing, it leaves this most critical area with a hazardous slippery surface, and can cause visual confusion about where the edge of the stair is. (Templer, 1992, 3.6)

The high risk of slips on stairs is reflected in the Australian Building Code's requirement for slip resistance of stair treads, with Deemed-to-Satisfy minimum slip resistance classifications, in residential dwellings and communal areas of residential buildings (*NCC 2016*, Vol 1, D2.13(a); Vol 2, 3.9.1.4(a)).

Lighting

Having adequate lighting so that potential floor hazards can be seen, is essential for people to be able to either avoid the hazard or adopt a more cautious gait, helping to prevent a slip and fall. Potential slip hazards could be indicated by contamination, such as water, on the floor; a high-gloss finish on the floor; or a change in gradient with ramp or stairs.

Having ambient lighting at a too high level creates glare, limiting mobility. An adequate lighting level for people with vision impairment to move safely through the home (e.g. in the hallway), is in the range 20-40 lux (Pitch & Bridge, 2006). Australian Standards guidelines for safe housing design recommend a higher level of lighting for stairs: 100 lux, evenly distributed on stair treads (*AS 4226-2008*, 11.8.1).

However, at night, daytime lighting levels may be too bright for the eye to quickly adjust to. Studies have shown that low level task lighting is suitable for wayfinding at night and along escape routes. This wayfinding lighting low on the path of travel can be 0.5-1.0 lux. (Pitch & Bridge, 2006).

Weather & Landscape

Exposure of exterior flooring to the weather can result in reduced visibility of the floor surface. It can also lead to contamination with rain, ice or snow. A floor surface that is coated in a layer of water, ice or snow is a slip risk.

When these elements of weather are combined with dropped foliage and dirt from the landscape, flooring can become very hazardous. Even highly textured 'slip resistant' floor surfaces can become coated, and the recesses in the texture filled with debris and grime.

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If visibility will be an issue, or debris and grime cannot be adequately managed through cleaning and maintenance, there are options. The landscape can be changed to prevent contamination from dirt and foliage. Alternatively, overhead cover can be provided.

Handrails

The use of handrails on steps, staircases and ramps, as well as other areas where slips are more likely, can help prevent a fall. Handrails can provide a visual cue, indicating a change in gradient or other potential slip risk.

On stairs, handrails can prevent falls by assisting with balance as a person ascends or descends a staircase. Holding a handrail can also aid in the recovery from a slip, potentially preventing it turning into a fall. (Templer, 1992, 3.6.1)

In residential dwellings, the BCA requires “suitable handrails where necessary to assist and provide stability to people using the stairway or ramp” (*NCC 2016*, Vol 1, DP2(c); Vol 2, P2.5.1(b)). Where elevated more than 1m, a barrier is also required (*NCC 2016*, Vol 1, DP3; Vol 2, P2.5.2).

An acceptable (Deemed-to-Satisfy) solution to meet the BCA handrail requirements in a residential dwelling, is a handrail along the length of at least one side of the stairway or ramp, where the elevation is higher than 1m (*NCC 2016*, Vol 1, D2.17(a); Vol 2, 3.9.2.4). However, an alternative solution to meet the BCA handrail requirements might be better suited for residents, especially if they are at higher risk of slip and fall injury.

In the non-mandatory Australian Standard *Guidelines for safe housing design*, a handrail is recommended along the full length of stairs in the home, on both sides. It also advises having a handrail on exterior steps and ramps, for people with reduced mobility. A suitable design and height of the handrail are also specified (*AS 4226-2008*, 2.5.4, 11.5).

Similarly the Australian Standard specifying requirements for handrails in housing for people with disability, *AS 1428.1-2009*, is non-mandatory for dwellings (unless a new residential building required to be ‘*accessible*’ (*NCC 2016*, Vol 1, D3.3), but could provide a more suitable handrail solution for residents needing assistance. It specifies having the handrails on both sides of all stairs and ramps. These handrails should continue 300mm beyond the top and bottom of the stairway or ramp to provide additional stability, and there are detailed specifications for handrail height and design. (*AS 1428.1-2009*, 10.3, 11.2, 12).

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Regulatory Requirements and Guidelines for Slip Resistant Floor Surfaces in Homes

The slip resistance of floor surfaces in the home is regulated by the Building Code of Australia (BCA), part of the National Construction Code (NCC). These regulatory requirements are based on Australian Standards for slip resistance and accessibility.

Building Code of Australia (BCA)

The BCA requires slip resistant surfaces for ramps and stairways, within dwellings and the public areas of apartment blocks and other buildings that contain dwellings (*NCC 2016*, Vol 1, DP2(c); Vol 2, P2.5.1(b)). The BCA specifies the minimum 'Deemed-to-Satisfy' slip resistance classifications under dry and wet conditions, when the new floor surface is tested according to *AS 4586* (Table 1).

For stairs, the same classifications are specified for single-dwelling (Class 1) buildings such as houses, town houses and villas, and throughout multi-dwelling (Class 2-9) buildings, such as apartments and units (*NCC 2016*, Vol 1, D2.13-2.14; Vol 2, 3.9.1.4). However, the minimum specified classifications provided for ramps differ. Single-dwelling (Class 1) buildings have a higher level of slip resistance specified for accessible (gradient 1:20 < 1:14) ramps (*NCC 2016*, Vol 1, D2.10(c); Vol 2, 3.9.1.4).

Table 1. Slip resistance classifications 'Deemed-to-Satisfy' slip resistance requirements in the NCC, when tested to *AS 4586*

Minimum slip resistance classification for stairs and ramps in dwellings and dwelling buildings		
Stairs	**Dry surface**	**Wet Surface**
Stair tread surface	P3 or R10	P4 or R11
Stair nosing strip	P3	P4
Ramps	**Dry surface**	**Wet Surface**
Multi-dwelling building (Class 2-9) Ramp steeper than 1:14 but not steeper than 1:8 Ramp steeper than 1:20 but not steeper than 1:14	 P4 or R11 P3 or R10	 P5 or R12 P4 or R11
Single dwelling building (Class 1): Ramp with gradient not steeper than 1:8	P4 or R10	P5 or R12

Source: Adapted from the National Construction Code 2016. Australian Building Codes Board (ABCB) www.abcb.gov.au (*NCC 2016*, Vol 1, Table D2.14; Vol 2, Table 3.9.1.3)

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There is also a BCA requirement for slip resistant accessways for people with disabilities, in certain common areas and throughout accessible dwellings, in parts of some multi-dwelling residential buildings. An accessway is “a continuous accessible path of travel (as defined in *AS 1428.1*) to, into or within a building” (*NCC 2016*, V1, A1.1). The details of these slip resistant requirements are provided in Table 2.

The BCA requirement for slip resistant accessways applies only to residential dwelling buildings that are being newly constructed or being extensively renovated. However, the slip resistant stair and ramp requirements apply to all newly constructed stairways and ramps, both in new and existing buildings. This is an important consideration when a new accessible ramp is being constructed or installed as part of a home modification.

Australian Standards and Guides for Access and Safety in Housing

The primary Australian Standard addressing building access requirements for people with disabilities, and the basis for the slip resistant accessway requirements multi-dwelling residential buildings, is:

AS 1428.1-2009 *Design for access and mobility*
Part 1: General requirements for access—New building work

Residential dwellings, whether new built or existing, are not required to comply with this Standard, unless a home is required by regulations to be ‘Accessible’. However, *AS 1428.1-2009* specifications for slip resistant floor surfaces for people with disability, could be used to guide the design of housing for residents who have a higher risk of slip and fall injuries.

AS 1428.1 specifies that floors on a “continuous accessible path of travel and any circulation spaces shall have a slip-resistant surface” (*AS 1428.1-2009*, cl 7.1). In housing, this “continuous accessible path of travel” would be the route throughout the dwelling, including from the footpath and parking area to the entry door, then to all the areas inside and outside the dwelling, where a resident would go. The definition of “slip resistance” is not provided in the Standard.

Another Australian Standard, concerned with the design of specialised housing for people with a disability, addresses slip resistance in the dwelling interior:

AS 4299-1995 *Adaptable Housing*

This Standard adopts the slip resistant ‘continuous accessible path of travel’ requirements of *AS 1428.1*. *AS 4299* is regulated for specialised housing in some states, such as State Environmental Planning Policy (Housing for Seniors or People with a Disability) 2004 in NSW, and in some states’ public housing. Some local councils also specify a percentage of new housing comply with *AS 4299* to address the needs of people with disabilities and the increasing ageing population.

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Current non-regulatory guidelines that address access in all housing, are the

Livable Housing Design Guidelines.

Livable Housing Design is based on sixteen livable design elements that can be incorporated into *all* housing to make it "easier and safer to use for all occupants including: people with disability, ageing Australians, people with temporary injuries, and families with young children." (Livable Housing Australia, 2015, p8). Livable Housing Design has three performance levels, Silver, Gold and Platinum, ranging from basic requirements through to best practice in livable home design. Some local and state governments require a percentage of housing be built to Livable Housing Design levels, and it is also a requirement for some Specialist Disability Accommodation. (Livable Housing Australia, 2016)

Livable Housing Design includes slip resistant flooring in its most essential and basic requirements. This Silver Level of Livable Housing has slip resistant floor surfaces on the pathway from the car parking space or front boundary; car parking space; and shower recess. The higher, Gold Level, includes slip resistant surfaces on stair treads, and the kitchen and laundry floor. A definition of "slip resistant" is not provided for Livable Housing Design.

A non-regulatory Australian Standard that is also concerned with all housing, and focusing on safety, is:

AS 4226-2008 *Guidelines for safe housing design*

This Standard has general guidance for safer housing design. For designing a home to avoid slips, this Standard is focused on wet areas: bathrooms, laundries, toilets, kitchens, and dwelling entries where people may enter with wet shoes. *AS 4226-2008* advises that these floors should be slip resistant when dry and when wet. (*AS 4226-2008*, 5.2)

The Standard warns that textured floor surfaces are only effective if regularly cleaned with appropriate products (not soapy detergents), and that cleaning should be done according to the manufacturers recommendations. It also advises checking the durability and maintenance requirements of the flooring, as slip resistant surfaces will wear over time. (*AS 4226-2008*, 5.6)

Exterior stairs, ramps and paths should be slip resistant. Also, *AS 4226-2008* recommends having handrails even for level and gently sloping surfaces that could be affected by snow, ice or frost, as they cause slip resistance to be "significantly impaired". (*AS 4226-2008*, 2.5)

Additional measures to reduce the risk of slipping include adequate lighting on paths of travel, especially stairs. This should be minimum 50 lux at floor level, and be set low and even to minimise glare (*AS 4226-2008*, 2008 2.6). Rugs and mats should have a "slip resistant interface" beneath them, to prevent them slipping when used on a hard floor surface (*AS 4226-2008*, 5.7).

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Table 2. Areas of multi-dwelling residential buildings requiring slip resistant accessways in the NCC

Multi-dwelling residential buildings requiring slip resistant accessways	
Small Boarding Houses, Hostels and Group Housing	
Class 1b Building	*A free-standing (detached) or attached single dwelling that does not have another dwelling above or below, with a floor area less than 300m^2 and a maximum of 12 residents.*
	To and throughout: - one bedroom and its bathroom facilities; - at least one of each of these common areas if provided for residents: cooking area, eating area, laundry, sauna, gymnasium, pool, games room; and - rooms or spaces for residents' common use that can be accessed by a (*AS 1428.1* complying) ramp or passenger lift.
Apartments, Units, Flats	
Class 2 Building	*Dwelling in a residential building, of two or more storeys, containing two or more dwellings.*
	From a required accessible pedestrian entrance to: - at least one floor containing dwellings; and - to the entrance door of each dwelling on that floor. On floors reached by a (*AS 1428.1* complying) ramp or passenger lift - to the entrance door of each dwelling. - to and throughout common rooms and spaces. To and throughout: - at least one of each of these common areas if provided for residents: cooking area, eating area, laundry, sauna, gymnasium, pool, games room, and shop.
Class 3 Building	*Dwelling in a residential building (not Class 1 or 2) for numerous unrelated people to live in the short-term or long term.*
	From a required pedestrian entrance to: - at least one floor containing dwellings; and - to the entrance door of each dwelling on that floor. On floors reached by a (*AS 1428.1* complying) ramp or passenger lift - to the entrance door of each dwelling - to and throughout common rooms and spaces. To and throughout: - at least one of each of these common areas if provided for residents: cooking area, dining room, lunch room, lounge room, laundry, sauna, gymnasium, pool, games room, TV room, shop, public viewing area, ticket purchasing service; and - all dwellings required to be accessible.

Source: Adapted from 'Table D3.1 Requirements for access for people with a disability' in the *National Construction Code 2016*. Australian Building Codes Board (ABCB) www.abcb.gov.au (NCC 2016, Vol2, D3.1)

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Australian Standards for Slip Resistance

Five Australian Standards publications are directly relevant to slip resistance of floor surfaces in the home:

AS 4586-2013 Slip resistance classification of new pedestrian surface materials

AS 4663-2013 Slip resistance measurement of existing pedestrian surfaces

AS/NZS 3661.2:1994 Slip resistance of pedestrian surfaces
Part 2: Guide to the reduction of slip hazards

SA HB 198:2014 Guide to the specification and testing of slip resistance of pedestrian surfaces

AS 4586-2013 and *AS 4663-2013* provide the classifications for slip resistance of floor surfaces and the test methods to determine those classifications. *SA HB 198:2014* is the handbook developed as a guide to *AS 4586-2013* and *AS 4663-2013*.

AS 4586-2013 – for slip resistance classification of new floor surfaces

Several different measures of slip resistance are used for floor surfaces, due to the variety of different slip resistance test methods. Accordingly, there are a range of classifications that could be used for interior and exterior floor materials, available in the Australian market.

Four slip resistance test methods and corresponding slip resistance classifications for new floor surface materials, are specified in Australian Standards (*AS 4586-2013*):

- Wet Pendulum Test - Pendulum Classification
- Dry Floor Friction Test - Co-efficient of Friction Classification
- Wet Barefoot Inclining Ramp Test - Ramp Barefoot Classification
- Oil-wet Inclining Platform Test - Ramp Classification

A description of each slip resistance classification and test method is contained in Appendix 2.

There is also a classification and test not addressed in Australian Standards, which is based on a proprietary onsite testing device: the Slip-Alert. The Slip Alert test results are designed to directly correlate to test results for the Wet Pendulum Test and Dry Floor Friction Test (Slip Alert, n.d.-a). The Slip Alert system and test is supported by independent evaluation (Hallas & Shaw, 2006).

For new floor products, the suitability of a slip resistance classification depends on whether the floor surface would be wet, oily, or dry, and the likelihood of people wearing shoes or being barefoot. Table 3 shows the different slip resistance classifications and test methods, and their potential application for housing environments.

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AS 4663-2013 – for slip resistance measurement of existing floor surfaces

Only two of the slip resistance classifications in Australian Standards are applicable to existing floor surfaces: Pendulum and Co-efficient of Friction, as these tests can be conducted in-situ. The Wet Pendulum Test is usually carried out on floors subject to wet conditions, and the Dry Floor Friction Test is only used for dry conditions. *AS 4663-2013* specifies these test methods and corresponding classifications, in essentially the same manner as *AS 4586-2013*. (*AS HB 198:2014*, 3.2)

Table 3. Slip resistance classifications and their test methods

Slip resistance classifications and test methods				**Applications for housing**
Classification	**Test Method**	**Slip Resistance Class** lowest slip risk ↑ highest slip risk		
Pendulum	Wet Pendulum Test	P5 P4 P3 P2 P1 P0	Very low Low Moderate High Very high	Wet floors where shoes would be worn e.g. outdoor concrete, tiling, paving and decking; interior floors; wet or dry carpet and heavily profiled floor surfaces
Co-efficient of Friction	Dry Floor Friction Test	D1 (≥0.40) D0 (<0.40)		Smooth floors that would not become wet. Limited application in housing. Note: not applicable to carpet or heavily profiled floors
Ramp Barefoot	Wet-Barefoot Inclining Platform	C B A		Wet floors where people would be barefoot e.g. mainly bathrooms; also outdoor concrete, tiling, paving and decking; and other interior floors
Ramp	Oil-wet Inclining Platform Test	R13 R12 R11 R10 R9		Wet or oily floors where shoes would be worn e.g. outdoor concrete, tiling, paving and decking; interior floors
SlipAlert	Slip Alert	STV <130 STV 130≤173 STV >173	Low Medium High	For on-site testing for corresponding values to the Wet Pendulum Test and Dry Floor Friction Test

Source: Slip Resistance Classifications and Tests adapted from *Slip Alert (n.d.-a)* and *AS 4586-2013.*

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SA HB 198:2014 – for guide to specifying and testing slip resistance of floor surfaces

The *SA HB 198:2014* handbook largely replaces the *HB 197:1999* handbook, following the update of Australian Standards *AS 4586-2013* and *AS 4663-2013*.
HB 197:1999 was for many years, the flooring industry's reference guide when "slip resistant" was specified for a particular location.

The new handbook, *SA HB 198:2014*, explains the slip resistance classifications and corresponding tests in *AS 4586-2013* and *AS 4663-2013.* For compliance with the BCA's slip resistance requirements for stairs and ramps, it sets out the 'Deemed-to-Satisfy' slip resistance classifications (in effect since 2014), as well as outlining some alternative solutions to comply.

For floor applications that do not have regulated slip resistance requirements, *SA HB 198:2014* provides recommended slip resistance classifications (*AS HB 198:2014*, Table 3B). These recommendations are focused on public and industrial environments; there are no recommendations specifically for housing.

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The Need for Slip Resistant Floor Surfaces in Homes

Having suitably slip resistant floor surfaces in the home is particularly important for people at higher risk of falls: older people, children, and those with reduced ability. Combined with the increased risk of falls, is their greater likelihood of serious injury when a slip leads to a fall.

The BCA addresses the risk of falls on stairways and ramps with its requirement for a slip resistant floor surface on all new stairs and ramps in homes. It provides a clear measure of this slip resistance through the Deemed-to-Satisfy slip resistance classifications.

However, there are other areas of the home where slips and falls can occur. The risk is higher in 'wet' areas such as the bathroom. There is also a risk in other areas where accidental spills and leaks can occur, and a wet floor surface is unexpected. Slip resistant floor surfaces in these other areas of the home is only required by the BCA, in specialised *accessible* housing. Floor surfaces on "accessways" in the common areas of residential multi-dwelling buildings must have a "slip resistant surface" (*AS 1428.1-2009*, 7.1; *NCC 2016*, D3.2), and this slip resistance extends to interior floors in some specialised accessible, Livable and Adaptable housing. Unlike stairs and ramps in the BCA, there is no definition of what is meant by "slip resistant surface" and no acceptable minimum slip resistance classification specified.

Residents, designers and builders, who need to comply with the slip resistance requirements in the BCA, or who need a safer, slip resistant surface in other areas of the home, face a number of issues:

- how to ensure new ramps and stairs have the slip resistant floor surface required by the BCA;
- how to provide a suitable slip resistant surface on new or existing floors, in other areas of the home; and
- how to maintain the slip resistance of the floor surface over time.

Providing the slip resistant floor surfaces required by the BCA

The BCA requires slip resistant floor surfaces on all newly constructed stairways and ramps in homes. To comply with this slip resistance Performance Requirement, the floor material should either achieve the specified minimum 'Deemed-to-Satisfy' slip resistance classification when tested in accordance with *AS 4586* (a Deemed-to-Satisfy Solution), or comply with the requirement through an alternative Performance Solution. (ABCB, 2014, p4-5).

Deemed-to-Satisfy Solution to comply with BCA requirements

Compliance with the Deemed-to-Satisfy Provisions is the more straightforward approach of ensuring the BCA requirement for slip resistant floor surfaces on new ramps and stairways is met. The new floor material needs to be tested in accordance

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with Australian Standard *AS 4586,* and achieve the minimum slip resistance classification for the location, environment and Building Class (see Table 1). The testing organisation must be accredited by the National Association of Testing Authorities (NATA).

Floor materials that have been tested for slip resistance will usually have information on the slip resistance classification included in the supplier's advertising and/or technical documentation. The floor material supplier should also have the NATA slip resistance test report showing the exact floor product and surface finish that has been tested (Bowman, 2001), the slip resistance test method, and the resulting classification. When selecting a floor material for a new ramp or stairway, the slip resistance test report should always be obtained from the supplier, to ensure the slip resistance classification is valid for a Deemed-to-Satisfy Solution.

Some suppliers advertise floor materials with a slip resistance classification that has resulted from testing to Standards other than *AS 4586*, or from testing by an organisation that is not accredited by NATA. Many tiles and pavers imported from Europe have slip resistance classifications from testing overseas, to international standards such as *DIN 51130* (for 'R' classifications) and *BS 7976* (for BPN and 'P' classifications). Though these international test methods are similar to test methods in *AS 4586*, test results could vary (Bowman, 2001; Bowman, 2007). European slip resistance test classifications might be able to form part of an alternative, Performance Solution to complying with the BCA requirements, but are not applicable for a Deemed-to-Satisfy Solution.

Performance Solution to comply with BCA requirements

The alternative method of complying with the BCA Slip Resistance Performance Requirement, the Performance Solution, requires other sources of evidence that the ramp or stairway floor surface is suitably slip resistant. For example, "a scientific study of the combination of pedestrian surface, expected pedestrian traffic, footwear, cleaning, lighting, handrails etc. for a particular application. The outcome of such a study could be an assessment and quantification of the risk of slipping on a surface in a particular application." (ABCB, 2014, p5)

To verify that a Performance Solution complies with the slip resistance Performance Requirement, requires one or more of these assessment methods be used:

- documentary evidence to support that the material, form of construction or design meets the Performance Requirement;
- verification methods such as a test, inspection or calculation;
- comparison with the (Deemed-to-Satisfy) Provisions; or
- judgement of an expert with the required qualifications and experience. (ABCB, 2014, p5; *NCC 2016*, Vol 1, A1.1)

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Performance Solutions can be a more difficult approach for individual dwellings and home modifications, as the time and cost constraints can make these types of assessment unfeasible.

Providing slip resistant floor surfaces in other areas of the home

Beyond regulated requirements for new stairs and ramps, there is limited guidance available on the suitable level of slip resistance for floor surfaces in the home. Adaptable Housing and Livable Housing require slip resistant floor surfaces, but do not specify a suitable level of slip resistance for areas of the home (*AS 4299-1995*; Livable Housing Australia, 2015). Similarly, residents needing or wanting slip resistant floor surfaces, do not have a suitable level of slip resistance defined in *Guidelines for Safe Housing Design* (*AS 4226-2008*).

Unlike for home environments, Australian Standards provide some guidance to selecting floor surfaces that will be sufficiently slip resistant for certain activities in public buildings and environments. Recommended minimum slip resistance classifications for floor surfaces in public built environments are featured in Australian Standards Handbook *SA HB 198:2014*. These recommendations cannot simply be directly applied to similar areas of the home. There are important differences between public and home environments that need to be considered; for example:

- there is a greater likelihood that residents would be barefoot both in indoor and outdoor areas of the home, than they would be in public environments;
- residents are likely to wear more slippery-soled footwear, or even socks, in their home environment; and
- the classification of what would be ‘wet’ and ‘dry’ areas in the home environment is less easily distinguished.

Yet, these recommendations for public built environments might help to inform the selection of slip resistant floor surfaces in homes, where similar types of activities are undertaken and the differences between public and residential environments are taken into account. Table 4 shows suggestions for the slip resistance of floor surface in some areas of the home environment, based on *SA HB 198:2014* guidance for floor surfaces in public buildings and environments.

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Table 4. Suggested slip resistance for floor surfaces in housing, based on guidance in *SA HB 198:2014*

SA HB 198 – Guidance on slip resistance classifications for applications where slip resistance is not required by NCC			**Suggested applications for housing - areas where slip resistance is not required by NCC 2016**
SA HB 198 3B: Location*	Wet pendulum test	Oil-wet inclining platform test	
			EXTERIOR
External Pavements and Ramps 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	Paths, paving, balconies, courtyards, decks, driveways, and existing ramps, with a slope under 1:14 - where shoes would be worn
External ramps including sloping driveways, footpaths etc. steeper than 1 in 14	P5	R12	Driveways and existing ramps, with a slope steeper than 1:14 - where shoes would be worn
Swimming Pools and Sporting Facilities Swimming pool surrounds and communal shower rooms	P4	B	Paths, paving, balconies, courtyards, decks, driveways, and existing ramps, with a slope under 1:14 - which would be used barefoot
Swimming pool ramps and stairs leading into water	P5	C	Driveways and existing ramps, with a slope steeper than 1:14 - which would be used barefoot
			INTERIOR
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	P3	R10	Floors adjacent to entrances
Hospitals and Aged Care Facilities Wards and corridors in hospital and aged care facilities	P2	R9	Floors unlikely to become wet
Hospitals and Aged Care Facilities Bathrooms and en suites in hospitals and aged care facilities	P3	B	Floors likely to become wet: kitchens, laundries, bathrooms
Swimming Pools and Sporting Facilities Swimming pool surrounds and communal shower rooms	P4	B	'Wet area' floors: showers and adjacent bathroom areas

Source: *Location Classifications extracted from Table 3B, *SA HB198:2014.*

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Although there are some classifications included for floor surfaces in dry environments in Table 4, these should be used with caution. It is a safer approach to consider that the majority of floor surfaces in the home could become wet and select floors accordingly. Classifications for outdoor pavements in Handbook *SA HB 198:2014* are intended for public environments where footwear would be worn. As it is likely that residents could be barefoot in outdoor environments, which might become wet, the classifications related to swimming pools are more appropriate.

When selecting the classifications for internal floors, it is important to consider that the majority of floors in the home are likely to become wet, even those not in a 'wet area' such as the bathroom or laundry. For example, many homes do not have a foyer as a transition area from the outdoors, so residents may enter the dwelling in wet shoes and rainwear. Also, food and drinks (which can be spilt) are often consumed in recreational areas and bedrooms, not just the kitchen.

Whilst precautions can be specified to prevent floors becoming wet and slippery, such as "spills should be cleaned up immediately" (*AS/NZS 3661.2:1994*), this is not always achievable. Spills and leaking appliances might not be noticed, particularly when there are children or numerous residents in the household. Also, it might not always be practical to stop and clean a spill immediately, in a busy household.

Approaches to Slip Resistant Floor Surfaces in Homes

Three approaches to providing suitable slip resistant floor surfaces are:

- installing a floor with a slip resistant surface;
- application of a slip resistant treatment, such as abrasion or a coating, to an existing floor surface; and
- maintaining the floor surface to ensure continued slip resistance.

A combination of these approaches is generally required.

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Installing Slip Resistant Floors

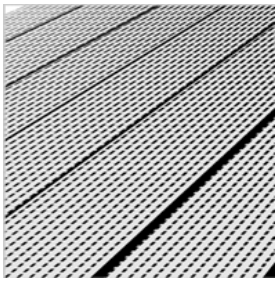
Slip resistant floor surfaces are best considered at the time of installation of the floors in and around the home. It allows for slip resistance to be considered alongside other flooring preferences, including appearance, durability, underfoot comfort, and cost.

For outdoor flooring, the options include timber or composite timber decking; tiles in porcelain, ceramic, or stone; pavers in clay, concrete or stone; and poured slab floors such as concrete and terrazzo. Similarly, indoor floor surfaces include timber, tile, and poured slab floors, as well as carpet, synthetic sheet product like vinyl, and natural sheet product such as linoleum.

The slip resistance of the floor surface can be achieved through a variety of methods. These methods can have an effect on appearance, durability, maintenance and cost.

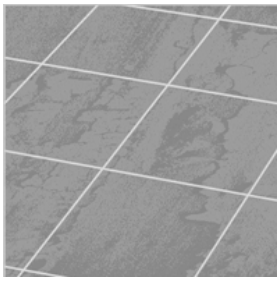
Floor Materials with Form Texture

A slip resistant surface can be provided through a texture that is incorporated into flooring during the manufacturing process, as the material is formed. Textures formed into the floor surface during manufacture can give greater control and consistency for slip resistance. The textured material needs to be sufficiently durable for the environment of use, as surface damage to the texture can be difficult to repair after installation. The floor material might need to be replaced to restore slip resistance.



Reeded (ribbed) decking boards are an example of a form texture on timber. The ribs are machined into the timber decking boards during manufacture. On synthetic and composite timber decking, the ribs are formed into the surface as the boards are extruded. Similarly, aluminium decking may have ribbed surface, formed as the length is extruded.

Other examples of machined textures include moulded, pressed, and extruded textures, on the surface of tiles, steel and vinyl sheet, or pavers; and a broom finished surface on concrete. Form texture can also be provided by the natural physical properties of the floor material.



Naturally rough finishes on natural and synthetic stone tiles and pavers, and uncoated porcelain tiles, are an example of form textures that can be inherent in the floor material. No further surface treatment is required. Durability of the material is important, as wearing of the surface due to heavy use, or inappropriate cleaning methods, can reduce the slip resistance of the surface over time.

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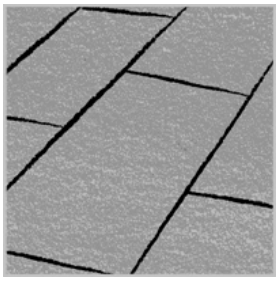
Floor Materials with Surface Treatment Texture

Surface treatment textures are also incorporated during manufacture of the floor product, but are applied to the surface after it has been formed. Materials such as concrete, terrazzo and natural stone can be surface treated in a variety of ways, depending on the visual effect and slip resistance required.

Honing and polishing are treatments that can produce a very smooth finish. These finishes might be selected for their higher gloss level, or colour enhancement. They usually have limited slip resistance, and can become quite slippery when wet.

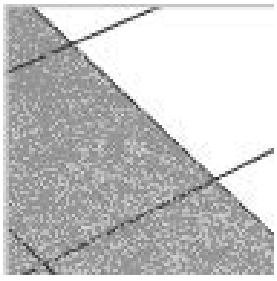


Acid washing, bush hammering, **burnishing**, and **shot blasting** are finishing treatments that give a more textured finish to solid surfaces, like stone, concrete, and terrazzo. Each of these textures can have a different effect for each material type, affecting colour, gloss level, cleaning and maintenance, smoothness underfoot, and slip resistance. Their increased slip resistance makes them more suited to outdoor applications.

Floor Materials Installed with Sealers or Surface Coatings

Floor materials have sealers and coatings applied during the installation process, for a variety of reasons. The purpose of most sealers and coatings is usually to protect the surface, especially of stone. They can reduce water-absorption in porous materials and increase stain or graffiti resistance. Some topical protective sealers can be used to increase slip resistance (though others can make the floor more slippery). (Australian Stone Advisory Association [AASA],2015)

Some sealers and coatings have a permanent effect, but generally, recoating is required during the lifespan of the floor. The frequency and complexity (eg. whether stripping of old surface is needed) needs to be considered when selecting the product.



Specialised slip resistant coatings, aimed at increasing floor friction and reducing slip risk, are available. These coatings generally have abrasive particles added to a clear or coloured liquid. Being focused on slip resistance, these coatings can have unintended effects on stain-resistance, gloss level, and colour of the floor material. These effects need to be considered in the choice of slip resistant coating.

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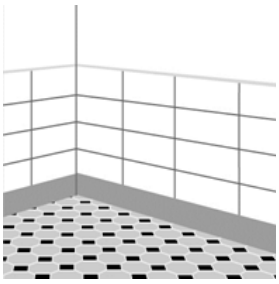
Small Sized Floor Materials Installed in a Pattern

Small-sized floor material products can be installed in a pattern that increases slip resistance, due to the location, direction, and number of joins in the floor material.



Mosaic and tessellated floor tiles result in numerous grout lines. When there is a slight recess of the grout lines, an overall texture is achieved on the floor. Small-sized pavers can have the same effect outdoors. This resulting texture can increase grip for the shoe sole and bare foot, and prevent a build-up of water on the floor surface. Use of smaller-sized tiles can also make sloped floors for drainage in bathrooms and showers easier to achieve. Slip resistance is only maintained if recessed grout is kept clean to prevent grime build up.

Decking boards laid across the direction of travel, particularly on a ramp, can achieve an overall slip resistant texture. The direction of travel should be considered when decking is designed, especially when decking boards are reeded (ribbed) on the surface. In New Zealand, access routes are required to having ribbed decking laid across the direction of travel, to meet the slip resistance requirements of the Building Code. (Branz, 2007; Elkink, 2013).

Floor Materials with Slip Resistant Inserts

Slip resistant materials can be inserted into a floor surface to increase its slip resistance. Slip resistant materials are usually metal, such as brass, aluminium or stainless steel; or composites, such as silicon carbide. Slip-resistant inserts provided at the time of manufacture have the advantage of generally being more secure and set flush to the adjacent surfaces, avoiding trip hazards. The surface roughness of inserts will affect cleanability and underfoot comfort when barefoot.

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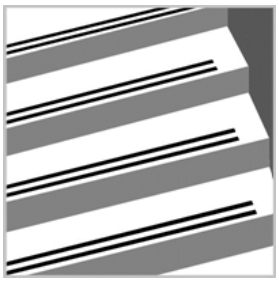
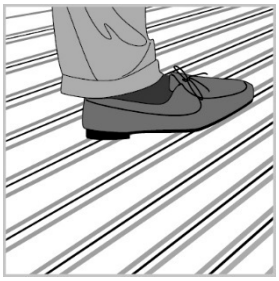


Slip resistant nosing inserts on stair treads are common, sometimes using high-visibility materials. These slip–resistant inserts can be used when the surface material of residential stairs does not meet the BCA's (*NCC 2016*) slip resistance requirements. However, having an even and smooth slip resistant surface across the full stair, is recommended (Bowman, 1999, p7; Templer, 1992, 7.2.11).



Slip resistant inserts in decking boards are popular in climates affected by severe weather, though have limited availability in Australia. Inserts on the nosing of timber stair treads, are more prevalent. As for all decking, these strips should be laid across the path of travel.

Modifying Existing Floors with a Slip Resistant Treatment

Floors can be modified after installation to increase their slip resistance, with the application of surface treatments. Some of these treatments are similar to those used in flooring manufacture and are easily integrated into the floor surface. They include the application of slip resistant coatings on uncoated or previously coated floors; slip resistant surface strips that are either attached with adhesive or mechanical fasteners; and abrasive surface treatments. AS/NZS 3661.2 presents a range of methods for improving the slip resistance of existing floors (see Appendix 2).

Applying Slip Resistant Coatings

Slip resistant coatings can be applied to flooring materials after they are installed. Floor surfaces could require application of a coating to improve slip resistance, if uncoated, or if a previously coated surface has become worn. Most slip resistant coatings will require re-coating when they become worn.

Slip resistant coatings could provide slip resistance through sand or other gritty particles in a clear or coloured liquid coating, which is painted on. Alternatively, slip resistance can be achieved with a thick liquid coating that achieves a texture when applied with a coarse roller or other applicator. Slip resistant coatings can potentially change the appearance of the floor, such as the colour, or gloss level.

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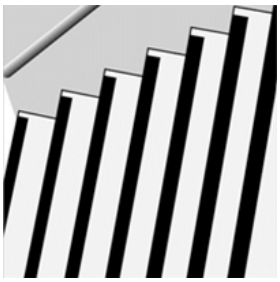
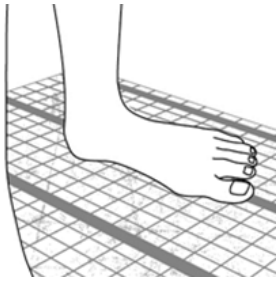
Attaching Slip Resistant Surface Materials

Slip resistant surface materials can be attached to slippery floor surfaces to reduce the risk of slipping. These surface materials usually affect the appearance of the floor; they can be selected to coordinate or contrast with floors, and some even glow in the dark. Attachment can be by adhesive or mechanical fasteners.

Generally, slip resistant surface materials are attached in strips, so do not provide an even slip resistant surface. This inconsistence can create a further trip risk.



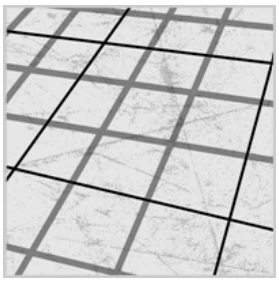
Slip resistant tapes and nosing capping are often applied to stairs, both to reduce the chance of slipping and to highlight the edge of steps for safety. These additions to the stair can make a slippery staircase safer, potentially providing the same level of slip resistance as newly constructed stairs that meet current BCA requirements (*NCC 2016*). However, they could be a trip hazard if they result in a raised surface on the stair nosing.



Slip resistant tape applied to the bathroom floor, shower or bathtub is a common home modification. As these tapes are generally applied with adhesive, they are not a permanent slip resistance solution in a wet environment, but might be used as a temporary fix for a slippery floor surface. The tapes are available in a variety of colours, but will usually have a distinctive appearance, which might not be desirable to residents.

Applying Abrasive Surface Treatments

Abrasive surface treatments are generally applied to slippery pavers, tiles and poured-slab floors. Treatments include shotblasting, grinding and acid etching. Abrasive surface treatments roughen the floor surface by cutting into it. This has an effect on the appearance (especially colour), porosity, and cleaning requirements. (Slip Check, n.d.)



Shotblasting is suited to large areas of commercial or public flooring, such as carparks, pavements and footpaths. Sometimes referred to as ‘sandblasting’, shot blasting does not use sand due to health risks; instead, abrasive used include metal shot and minerals like garnet (Slip Check, n.d.).

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Maintaining the Slip Resistance of Floor Surfaces

Floor surfaces require maintenance to retain their level of slip resistance. Retained water, ice, dirt, moss and leaves, can make floors slippery. Even highly-textured surfaces can lose their slip resistance when recesses in the texture become filled with grime. Coated surfaces can become worn and less slip resistant over time.

The maintenance requirement for floors will depend on durability of the flooring material, the amount of texture on the surface, and the floor environment. The type and schedule of maintenance that is required to retain the slip resistance of a floor surface in the floor environment need to be understood at the time of flooring selection, to ensure this is feasible for owners' and residents' circumstances. This information should be sought from the flooring supplier.

Cleaning

AS/NZS 3661.2:1994 advises that outdoor floor surfaces be kept free from leaves, mud, clippings and paper, and moss and slime be removed with chlorine-based solution, to reduce slip hazards.

The appropriate method of cleaning needs to be determined at the time of floor surface specification. Incorrect cleaning methods could potentially damage a slip resistant floor surface.

Factors affecting cleaning include:

- the tools and cleaning solutions that are required,
- residents' physical or financial ability to undertake necessary cleaning,
- the effect of the cleaning process on surrounding outdoor environment, and
- the safe and convenient storage requirements of cleaning tools and solutions.

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Reapplying slip resistant coatings

Most slip resistant coatings will require recoating during the lifespan of the floor. The frequency of recoating will depend on frequency of use, exposure to the environment and durability of the coating. For some coatings, it is necessary to strip off the previous coating prior to application of a new coating.

Slip resistant coating reapplication requirements should be considered when the coating is initially selected. Considerations include whether the recoating is a DIY or commercial process, the compatibility of a new coating with any current surface treatments, the frequency and cost, and the time the floor will be unusable during the recoating period.

Approaches for Slip Resistant Floors – Comparison

The methods for providing a slip resistant floor surface are dependent on a range of factors, including:

- whether the floor is new (or being replaced), or an existing floor is being modified;
- the funding available for the new or modified floor surface;
- the slope of the floor surface;
- the likelihood that the floor surface will be wet;
- the cleaning requirements for the environment and particular floor's surface, and the feasibility of meeting the cleaning requirements; and
- the current and future needs of all residents and users of the dwelling.

A comparative summary of methods for providing a slip resistant floor surface is contained in Tables 5-7.

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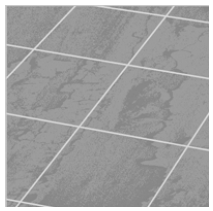
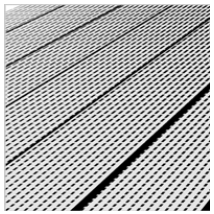
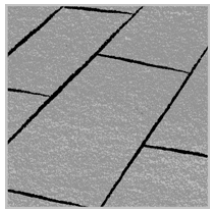
Table 5. Comparison of methods for providing a new slip resistant floor surface

Installing new slip resistant floors		
METHOD	**ADVANTAGES AND DISADVANTAGES**	**EXAMPLES***
Floor Materials with Form Texture	- incorporated into floor surface during manufacture, as surface is being formed. - can be inherent in material - e.g. ribbed (reeded) decking boards; rough sawn timber decking boards, sawn stone pavers; vitrified tile ✓ provides greater control and consistency of texture in manufacture, and better ensure slip resistance tests are representative across different batches of the floor material × rough textures can accumulate grime × if texture is damaged it can be irreparable	 
Floor Materials with Surface Treatment Texture	- incorporated into floor surface during manufacture, after surface is formed - treatment affects colour, gloss level, cleanability, smoothness underfoot, as well as slip resistance - e.g. smooth textures are produced by honing and polishing and more slip resistant rough textures produced by acid washing, burnishing, shotblasting and bush-hammering. ✓ consistency in manufacture can better ensure that slip resistance tests are representative across different batches of the floor material ✓ different types of texture can be applied to the same material for different applications in the home, producing a more unified appearance – rougher textures can provide increased slip resistance for wet floor applications, while smoother textures can be used for dry floors and bench tops. ✓ some surfaces can be re-treated after installation, if they become worn × uncontrolled or inconsistent surface treatment method can result in slip resistance tests of sample products not being representative across different batches of the floor material × rough textures can have undesired effect on stain resistance, grime accumulation, gloss level and colour	

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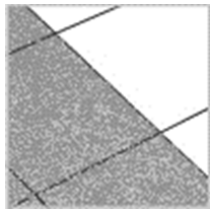
Installing new slip resistant floors		
METHOD	**ADVANTAGES AND DISADVANTAGES**	**EXAMPLES***
Floor Materials Installed with Sealers or Surface Coatings	- applied to floor surface during the installation process, generally for protection. - e.g. pre-finished timber floor boards, sealers and coatings applied to floorboards after fitting and sanding; sealers and coatings applied to natural and synthetic stone or concrete pavers and tiles, during installation. ✓ can be used to reduce water-absorption in porous materials, increase stain-resistance or graffiti resistance, change the gloss level or colour, as well as increase slip resistance. ✓ can be used to increase slip resistance of a desired floor product that might not otherwise be suitable × uncontrolled or inconsistent onsite application method can result in slip resistance tests of sample products not being representative of the installed floor surface × recoating is usually required during the life of floor. × specialised slip resistant coatings can have undesired effect on stain resistance, gloss level and colour.	
Small-sized Floor Materials Installed in a Pattern	- pattern of small-sized floor products can increase slip resistance, due to number, location and direction of joins - e.g. mosaic tiles, tessellated tiles, small-sized pavers, floorboards laid across the direction of travel ✓ the installed floor surface can have a higher level of slip resistance than the floor material, due to increased grip and improved drainage of recessed grout or gaps at joins ✓ consistent slip resistance across floor surface ✓ sloped floor surfaces can be easier to achieve during construction × ongoing slip resistance requires prevention of grime build up in recessed areas and gaps	 

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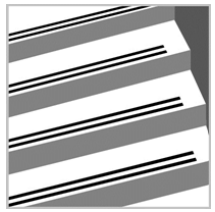
Installing new slip resistant floors		
METHOD	**ADVANTAGES AND DISADVANTAGES**	**EXAMPLES***
Floor Materials with Slip Resistant Inserts	- insert materials include metal, such as brass, aluminium or stainless steel; and composites, such as silicon carbide. - e.g. slip resistant strips on stair nosings, slip resistant inserts in decking for harsh climates ✓ integrating insert during initial manufacture or installation can provide a flush surface, reducing trip hazards ✓ contrasting colour inserts can be used to increased visibility of stair edges × inconsistent slip resistance on a continuous surface can also be a 'stick' or trip hazard × inserts can have an undesirable appearance × the roughness of the insert can affect ease of cleaning and be uncomfortable under bare feet.	 

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Table 6. Comparison of methods of modifying existing floor surfaces to increase slip resistance

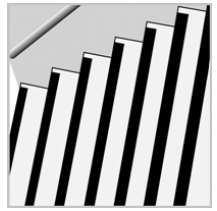
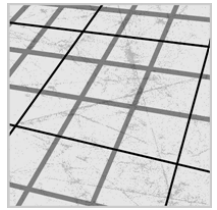
Modifying Existing Floor Surfaces		
METHOD	**ADVANTAGES & DISADVANTAGES**	EXAMPLE
Applying Slip Resistant Coatings	- slip resistant coatings can be applied to a variety of floor surfaces, after installation - can be applied to uncoated surfaces or previously coated surfaces - e.g. coatings with sand or other gritty particles ✓ can be used to change slip resistance as required × recoating is usually required during the life of the floor. × can have undesired effect on stain resistance, gloss level and colour.	
Attaching Slip Resistant Surface Materials	- applied to slippery floors to provide effective slip resistance - available in a range of colours, and even glow-in-the-dark. - attachment by adhesive or mechanical fasteners, commercially or DIY ✓ nosing strips can also provide a visual contrast for safety on stairs × can have undesired aesthetic effect × raised edges and inconsistent slip resistance on a continuous surface can also be a 'stick' or trip hazard	 
Applying Abrasive Surface Treatments	- can increase slip resistance of solid floors such as stone, terrazzo and concrete - can be suitable for large public areas like carparks, pavements and footpaths - e.g. shotblasting, grinding, acid washing ✓ can be used to 'fix' too slippery floors × more costly than formed textures or textures applied during manufacture or installation process × cuts into surface, so can have undesired effect on stain resistance, gloss level and colour.	

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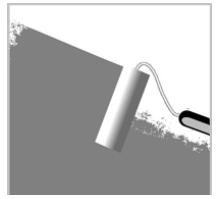
Table 7. Comparison of maintenance methods for keeping a floor surface slip resistant

Maintenance of Floor Surfaces		
METHOD	**ADVANTAGES & DISADVANTAGES**	**EXAMPLE**
Cleaning	- frequency and feasibility of cleaning needs to be considered when floor surfaces are specified - e.g. sweeping, vacuuming/blowing, washing, and high-pressure washing ✓ can be low-cost and easy for residents × might not be physically feasible for residents to undertake themselves × incorrect cleaning methods can damage floor surface and reduce slip resistance	 
Reapplying Slip Resistant Coating	- frequency and feasibility of recoating needs to be considered when slip resistant floor coatings are specified ✓ can be used to change slip resistance of floor surface as required × might not be physically or financially feasible for residents to undertake themselves	

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Checklist for a Slip Resistant Floor Surface

SLIP RESISTANCE REGULATORY REQUIREMENTS

- ☐ Will the floor surface be used on any newly constructed ramps or stairs, which the BCA requires to be slip resistant?

  If so:

  - ☐ the applicable slip resistance classifications that are deemed-to-satisfy the BCA requirements for ramps and stairs need to be checked in the current National Construction Code [NCC], available at http://www.abcb.gov.au/.
  - ☐ for a 'Deemed to Satisfy' Solution to meeting the BCA requirements - the slip resistance test report for the selected floor material should be obtained, to confirm the slip resistance classification and check that testing has been undertaken by a NATA accredited testing organisation.
  - ☐ for an alternative, Performance Solution to meeting the BCA requirements - suitable evidence and documentation should be obtained to confirm the floor surface will be slip resistant.

- ☐ Will the floor surface need to comply with any other regulatory requirements for slip resistant accessways or slip resistant flooring in any other areas of the home?

USERS

Prior to selecting a slip resistant floor surface, the following information is needed:

- ☐ who the users (residents, visitors and carers) of the floor surface are, and how their abilities could affect their risk of slipping on the floor
- ☐ the frequency of use of the floor surface
- ☐ the types of footwear likely be worn on the floor surface, and whether it would be used barefoot
- ☐ the assistive equipment, furniture, floor rugs and mats, and any other items that users would have on the floor surface

FLOOR SURFACE SPECIFICATION

Does the floor material supplier provide information on:

- ☐ the slip resistance classification for the floor surface, with a test report available?
- ☐ the durability of the floor surface for the location where it will be used?
- ☐ the method and frequency of cleaning, required for the floor surface?
- ☐ the ongoing longer term maintenance (such as recoating), to keep the floor surface

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slip-resistant?

HOME ENVIRONMENT

- ☐ Does the slip resistant floor surface fit aesthetically with the other floors and furnishings in the home?
- ☐ Is the slip resistance of the floor surface compatible with the slip resistance of adjacent floor surfaces?

Will the slip resistance of the floor surface be affected by:

- ☐ environmental conditions, such as rain, ice, snow?
- ☐ surface contaminants, such as water, spilled food and drink, dirt or mud from shoes, grime build up?
- ☐ possible water builds up on the floor surface, which requires drainage?
- ☐ floor coverings such as rugs and mats on the floor?

Do other environmental factors need to be considered to reduce the risk of slipping:

- ☐ handrails on stairs?
- ☐ covering for weather protection?
- ☐ adjustment of ambient lighting to improve visibility?

MAINTENANCE

- ☐ Are residents aware of the method and frequency of cleaning, required for the floor surface?
- ☐ Are residents aware of the ongoing longer term maintenance required for the floor surface?
- ☐ Can residents undertake the required cleaning and maintenance of the floor surface, currently and in the future?

  If not,

  - ☐ is the required cleaning and maintenance feasible and likely to be done either by friends and family or a maintenance service?
  - ☐ can a lower-maintenance alternative floor be used?

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Appendix 1: Slip Resistance Classifications and Test Methods

Pendulum Classification

The Pendulum Classification is derived from the British **Wet Pendulum Test.** It is used to test the surface of floor materials under wet conditions. It is also used (without water) to test carpets under dry conditions (*AS 4586-2013*; *AS 4663-2013*).

The Wet Pendulum Test varies depending on whether the floor surface is new or has been subject to wear.

- On new floor surfaces (in a laboratory or installed) testing is conducted according to Appendix A of *AS 4586*.
- After a floor surface has been installed and subjected to wear and/or contamination, testing is conducted according to Appendix A of *AS 4663*.

For the Wet Pendulum Test, the wet floor surface is tested using a Pendulum Friction Tester (Figure 3). If carpet is being tested for dry conditions, the carpet sample is tested dry.

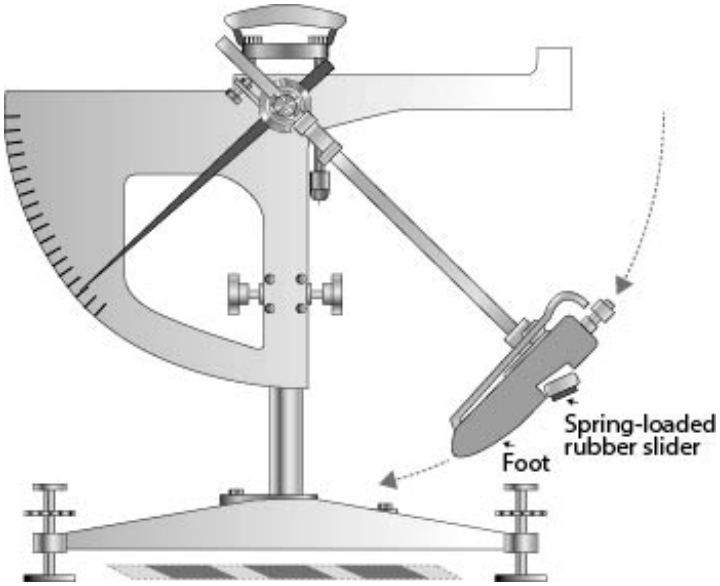

Figure 3. Wet Pendulum Tester

Source: Adapted from Figure A1, *AS 4586-2013.* **© Standards Australia Limited. Copied by** HMinfo **with the permission of Standards Australia under Licence 1801-c061.**

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The pendulum friction tester consists of a spring-loaded rubber slider mounted on the end of a swinging pendulum arm. In the test, the rubber slider is swung across the horizontal floor material surface, for the Pendulum Friction Tester to calculate the British Pendulum Number [BPN]. The mean BPN of several pendulum tests of the floor sample is called the Slip Resistance Value [SRV].

Two different rubber sliders can be used for the test.

- Slider 96 (4S) is usually used to test polished and less textured surfaces. It is a harder rubber, simulating the sole of a standard or dress shoe.
- Slider 55 (TRL) is usually used to simulate the sole of softer shoes or bare feet. (Stone Initiatives, n.d.)

Test results will state whether slider 96 (4S) or slider 55 (TRL) was used for the test. The test result with the applicable slider for the likely used of the floor should be selected; either floor surfaces that would be walked on with particular footwear, or floor surfaces that would be walked on barefoot.

The slip resistance classes for the two rubber sliders are shown in Table 8.

Table 8. Wet Pendulum Test classifications

Classification of pedestrian surface materials according to the *AS 4586* wet pendulum test		
Class	**Pendulum SRV**	
	Slider 96	**Slider 55**
P5	>54	>44
P4	45-54	40-44
P3	35-44	35-39
P2	25-34	20-34
P1	12-24	<20
P0	<12	

Prior to the 2013 editions of Standards *AS 4586* and *AS 4663*, the wet pendulum test classification was Z to V (least to most slip resistant). In these Standards, the method of preparing the rubber pendulum test slider was modified to better differentiate slip resistant levels of smoother floor surfaces. As the slip test results could change with the modified test method, the classification was changed, to the current P0 - P5. (*AS HB 198:2014*, 2.4.4 - 2.4.6)

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Ramp Classification

The Ramp Classification is derived from the Oil-wet Inclining Platform Test. The test classification, from R9 to R13, is commonly applied to commercial floor tiles. It is most applicable to industrial and commercial environments with oil contamination to the floor, such as commercial kitchens.

The test is conducted on new floor surface materials in a laboratory environment, according to Appendix D of *AS 4586-2013.* This test cannot be undertaken on installed floor surfaces.

The Oil-wet Inclining Platform Test is undertaken using adults wearing prescribed rubber-soled shoes, walking on the floor surface being tested (Figure 4). The floor material being tested is placed on a platform that is coated with engine lubricating oil and then inclined at increasing angles. The test person walks upright, forwards and backwards on the platform. The angle of the platform is increased from 0° to a maximum of 45°, until it is no longer safe to walk (*AS 4586-2013*, Appendix D) .

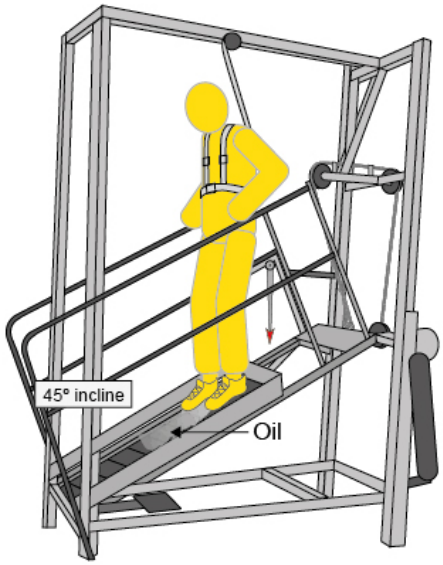

Figure 4. Ramp test

The platform angle achieved in the test is classified as shown in Table 9. Despite the name of the classification and the ramp-based test procedure, the test results refer to horizontal installation and the mean acceptance angle is not a reference to the performance of the surface material when installed on a ramp of the same angle.

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Table 9. Ramp Test classifications

Classification of pedestrian surface materials according to the Oil-wet Inclining Platform Test	
Classification	Corrected mean overall acceptance angle (α_{ave}), degrees
No classification	<6
R9	≥6<10
R10	≥10<19
R11	≥19<27
R12	≥27<35
R13	≥35

Source: Adapted from Table D3, *AS 4586-2013.*

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Ramp Barefoot Classification

The Ramp (Barefoot) Classification is derived from the **Wet-Barefoot Inclining Platform Test**. It is used to test the slip resistance of floor surfaces in wet conditions, when people are barefoot.

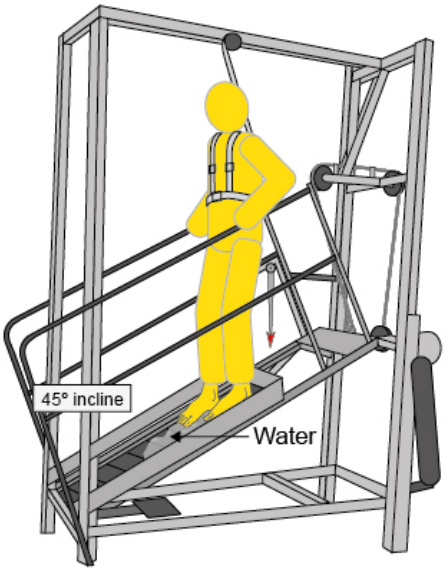

Figure 5. Wet-Barefoot Inclining Platform Test

Adapted from Figure D1, *AS 4586-2013.* **© Standards Australia Limited. Copied by** HMinfo **with the permission of Standards Australia under Licence 1801-c061.**

The Wet-Barefoot Inclining Platform Test is conducted according to Appendix C of *AS 4586-2013*, for new floor materials. Testing is undertaken in a laboratory environment, so installed floors cannot be tested.

The test is undertaken using barefoot adults walking on the floor surface being tested (Figure 5). The floor material being tested is placed on a platform that is subjected to a continuous stream of water containing a wetting agent. The test person walks forwards and backwards on the platform as the angle of the platform is incrementally increased, until an angle where slipping occurs (*AS 4586-2013*, Appendix C).

The platform angle achieved in the test is classified as shown in Table 10. Despite the name and test process, the results are applicable to horizontal surfaces only. The angles of inclination are not meant to imply slip resistance of floor surfaces on an inclined surface or ramp to the tested mean angle.

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Table 10. Barefoot Ramp Test classifications

Allocation of mean angle of inclination to quality groups for friction characteristics	
Mean angle of inclination, degrees	Quality group
≤12	No classification
≥12	A
≥18	B
≥24	C

Source: Adapted from Table C1, *AS 4586-2013.*

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Co-efficient of Friction

The **Co-efficient of Friction Test** is applicable to dry floor surfaces only, and is conducted using a Floor Friction Tester [FFT]. The FFT is a portable, self-powered device, which contains a rubber slider that moves at a constant speed of 1 m/min. across the floor surface. The device measures ratio of the tangential force to the vertical load. (*AS 4586-2013*)

The Dry Coefficient of Friction Test varies depending on whether the floor surface is new or has been subject to wear and/or contamination.

- On new floor surfaces (in a laboratory or installed) testing is conducted according to Appendix B of *AS 4586-2013*.
- After a floor surface has been installed and subjected to pedestrian traffic, testing is conducted according to Appendix B of *AS 4663-2013*.

The FFT device is sometimes referred to by the name of a proprietary FFT device, the 'Tortus™'. A FFT device is shown in Figure 6.

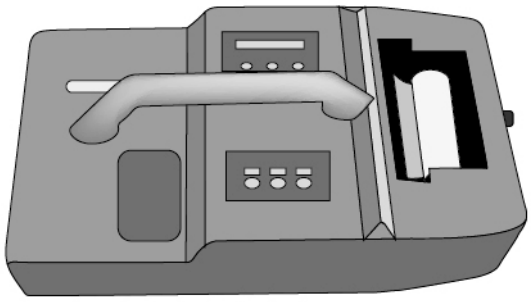

Figure 6. Floor Friction Tester

The results of the Dry Coefficient of Friction Test cannot be used to indicate the slip resistance of a floor surface when it is wet. It therefore has limited application in housing.

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SlipAlert™ Test Value

The **SlipAlert** is a ramp and trolley device intended for onsite testing of pedestrian floor surfaces. The SlipAlert device provides slip resistance test results [SRV] that correlate with wet and dry Pendulum results. (Hallas & Shaw, 2006; SlipAlert, 2008)

The advantage of the SlipAlert™ is that it can be used by inexperienced users, unlike a pendulum friction tester. Installed floors can be monitored over time to measure changes in slip resistance due to floor surface wear, or contamination such as cleaning liquids, dust, water or oil. The SlipAlert™ can also be used to assess the effect on slip resistance of polishing or coating the floor material. (Slip Alert, n.d.-a)

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Appendix 2: Methods of Improving Slip Resistance

Table 11. Improving slip resistance

Surface	Acid-Etch	Blasting (sand /captive)	Grind	Paint and Sand	Groove (diamond saw)	Floor sander	Proprietary Treatment	Adhesive Strip
Concrete	✓	✓	✓	✓	✓			✓
Ceramic Tiles		✓	✓	✓	✓		✓	✓
Granite		✓	✓		✓		✓	✓
Marble		✓	✓		✓		✓	✓
Pavers - concrete	✓	✓	✓	✓	✓			✓
Pavers - clay		✓	✓	✓	✓		✓	✓
Porcelain enamel							✓	✓
Steel plate		✓		✓				✓
Wood				✓		✓		✓
PVC sheet and tiles							✓	✓

NOTES

1. The methods of improving slip-resistance listed in Table 11 do not account for aesthetic or cleanability characteristics of resultant flooring after treatment. Consideration should be given to these aspects.
2. Hydrochloric acid used in acid etching must be handled with care. It will attack body tissues and clothing as well as paints and metal.
3. Sand blasting should be used with caution. Try it on a small area to make sure the surface is removed evenly.
4. Grinding will usually be slow, noisy and dusty
5. Sand is supplied either premixed into the paint, or separately. If separate, oven-dried clean sand should be sprinkled over the wet first coat of paint, the excess removed when dry, and a second seal coat of paint applied.
6. Grooving should result in shallow grooves (2-3mm) closely spaced (7-10mm) in strips.
7. Proprietary treatments may require regular retreatment to remain effective. Follow manufacturer's instructions. Some proprietary surface treatments contain hydrochloric acid. These should only be used by specialist personnel. Hydrofluoric acid is a toxic and extremely corrosive chemical. It will also cause severe skin burns. However, some treatments are formulated with very low acid concentrations to reduce the hazard. Instructions shall indicate the necessary precautions to be taken in application.
8. Textured adhesive strips are useful, but often serve only as a temporary measure. They should be replaced immediately when they show signs of wear or loss of adhesive.

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