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# Handbook

## **Guide to the specification and testing of slip resistance of pedestrian surfaces**



This Australian Handbook was prepared by Committee BD-094, Slip Resistance of Flooring Surfaces. It was approved on behalf of the Council of Standards Australia on 28 May 2014. This Handbook was published on 16 June 2014.

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- Association of Consultants in Access Australia
- Australian Building Codes Board
- Australian Ceramic Society
- Australian Institute for Non-Destructive Testing
- Australian Institute of Architects
- Australian Resilient Floorcovering Association
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Standards Australia wishes to acknowledge the participation of the expert individuals that contributed to the development of this Handbook through their representation on the Committee.

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# Handbook

## Guide to the specification and testing of slip resistance of pedestrian surfaces

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## PREFACE

This Handbook has been prepared by the Australian members of joint Standards Australia/Standards New Zealand Committee BD-094, Slip Resistance of Flooring Surfaces, to provide guidance on slip resistance of pedestrian surfaces.

After consultation with stakeholders in both countries, Standards Australia and Standards New Zealand decided to develop this document as an Australian Handbook rather than an Australian/New Zealand Handbook.

This Handbook provides:

- Guidance and commentary on AS 4586—2013, *Slip resistance classification of new pedestrian surface materials* (new pedestrian surfaces) and AS 4663—2013, *Slip resistance measurement of existing pedestrian surfaces* (pedestrian surfaces that have been subject to previous pedestrian traffic).
- Commentary on those parts of the National Construction Code (NCC) that require slip resistance of pedestrian surfaces in particular applications, including guidance on the means of verifying compliance with the Code.
- Guidance on the appropriate slip resistance in some other common applications, the criteria for verifying compliance with slip resistance specifications, and design for slip resistance of sloping surfaces.

At the time of publication of this Handbook, Committee BD-094 was revising the more comprehensive Handbook, HB 197:1999, *An introductory guide to the slip resistance of pedestrian surface materials*, which provided guidance to the application of AS/NZS 4586:1999. When that process is complete, the standing of the Handbooks will be determined.

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# STANDARDS AUSTRALIA

## Handbook

### Guide to the specification and testing of slip resistance of pedestrian surfaces

## 1 BACKGROUND

### 1.1 Purpose

This Handbook provides guidance for designers, specifiers, manufacturers and suppliers in the application of AS 4586—2013 and AS 4663—2013.

NOTE: Titles of documents referred to in this Handbook are listed in Clause 7.

Guidance is provided on ‘deemed-to-satisfy’ provisions introduced in 2014 into the National Construction Code for a limited number of applications (such as stair treads, nosings and some ramps) that are required to be ‘slip resistant’. State and territory governments adopt or vary such provisions in their regulations when appropriate.

Guidance is provided on the appropriate slip resistance of some common applications, the criteria for verifying compliance with slip resistance specifications, and the design for slip resistance of sloping surfaces.

### 1.2 Factors influencing slip hazard

Slip hazard is affected by a large number of factors, including the slip resistance of a pedestrian surface material, its wear characteristics, maintenance and contamination, the presence (or otherwise) of water or other lubricants on the surface, in conjunction with the nature of the pedestrian traffic (including age, gait and crowding), the footwear (or lack thereof), slope and environment factors such as lighting and handrails.

When specifying particular pedestrian surface materials, designers, specifiers and purchasers should also consider (in addition to the slip resistance) potential trip hazards, abrasion resistance, ability to be maintained and cleaned, permeability and the susceptibility to ponding water, and structural integrity of the material. Manufacturers and suppliers can provide information on some of these issues.

### 1.3 Disclaimer

This Handbook establishes a basis for specifying pedestrian surface materials for various locations.

Given the complex interaction of factors affecting pedestrian slip, compliance with recommendations made herein will reduce certain pedestrian risks, but will not necessarily alleviate all hazards.

The information provided in this Handbook is intended for general guidance only and in no way replaces the services of professional consultants to carry out the design and specification of pedestrian surfaces. Standards Australia does not accept any liability arising from its use.

## 2 AS 4586—2013

### 2.1 Purpose

AS 4586—2013 provides four classification methods for surfaces intended for pedestrian traffic, including (but not limited to) tiles, pavers, resilient surfaces, textile floor coverings, timber, concrete, steel, resinous coatings, and the like, used in floors, ramps, stairs and pavements. It may also be used to determine the classification of surfaces treated with sealers, polishes or etchants.

NOTE: AS 4585 and AS 4663 refer to ‘carpet’ and ‘carpet-like’ surfaces. The term ‘textile floor coverings’ is used by the industry to refer collectively to carpet in roll form, modular carpet (i.e. carpet tiles and sheet goods), rugs, runners, mats and textile sports surfaces, and has been used throughout this Handbook.

The inclining ramp test methods are suitable for measuring the slip resistance of gratings, heavily profiled surfaces, tactile indicators, rock, bush-hammered surfaces and resilient surfaces. The displacement volume of heavily profiled surface may be determined by Appendix E of AS 4586—2013.

The classifications provide a means of communicating slip resistance properties from the manufacturer or supplier, via a testing organization, to the designer, specifier, builder and user.

### 2.2 Limitation

AS 4586—2013 applies to new pedestrian surfaces that have not yet been subjected to wear and/or contamination in service.

If a pedestrian surface has been in service, and therefore subjected to possible wear and/or contamination, testing and reporting of results should be carried out in accordance with AS 4663—2013. In such a case, a pre-use wet pendulum classification in accordance AS 4586—2013 cannot be automatically inferred. See also Clause 3.1 for use of AS 4663—2013.

The supplier of new pedestrian surface materials should ensure that, at the time of delivery, the materials are in conformance with the specification. The supplier may be required to produce evidence of such compliance.

The installer, and (where appropriate) the head contractor, should ensure that a new pedestrian surface, at the time when it is handed over, it is in conformance with the specification. If, after installation but before handover to the eventual owner, the surface becomes worn or contaminated, then that is considered to be the condition of a ‘new’ surface. Therefore, it is incumbent on those responsible to take steps to protect the surface until handover, bearing in mind that it could be subject to site test and possible rejection should it fail to meet the specification at the time of hand over.

After hand over to the owner, the surface ceases to be ‘new’ and subsequent testing would be in accordance with AS 4663—2013.

### 2.3 Methods of test

AS 4586—2013 sets out four methods of testing and classifying the slip resistance of new pedestrian surfaces, as follows:

- (a) Wet pendulum test method.
- (b) Dry floor friction test method.
- (c) Wet-barefoot inclining platform test method.
- (d) Oil-wet inclining platform test method.

The provision of alternatives permits Australian designers and specifiers to use both local and imported products that have been tested using either the wet pendulum test or inclined platform test.

## 2.4 Wet pendulum test method

### 2.4.1 General

The wet pendulum test method is a relatively inexpensive test, and may be performed either in a testing laboratory or on site. The test instrument utilizes a pendulum slider making contact with the test surface over a prescribed distance and measures the quantity of resistance to the motion of the pendulum created by the contact. The contact surface of the slider material is prepared to a consistent level of smoothness prior to each group of tests.

Except in the case of internal textile floor coverings, AS 4586—2013 requires that the test be performed under wet conditions, and refers to it as the wet pendulum test method. The terminology ‘wet pendulum test method’ is adopted throughout this Handbook, notwithstanding that internal textile floor coverings are tested dry.

This test provides the greatest flexibility to designers and specifiers, and enables verification of classifications either during manufacture and/or at the completion of construction.

Clause 5 of this Handbook describes the design of pedestrian surfaces using the classifications given in Table 1.

**TABLE 1**  
**CLASSIFICATION OF PEDESTRIAN SURFACE MATERIALS**  
**ACCORDING TO THE AS 4586—2013 WET PENDULUM TEST**

Classification	Wet pendulum SRV	
	Slider 96 rubber	Slider 55 rubber
P5	>54	>44
P4	45–54	40–44
P3	35–44	35–39
P2	25–34	20–34
P1	12–24	<20
P0	<12	

NOTES:

- 1 The test is known as the ‘wet pendulum test method’, reflecting the fact that it is commonly applied to hard or resilient surfaces to which water is applied. One exception is for internal textile floor coverings, which are tested dry.
- 2 While either Slider 96 or Slider 55 rubbers may be used depending on the material and its intended application, the test report requires that the rubber that was used be specified.
- 3 For surfaces that are particularly slippery, it is appropriate to use slider 96 rubber.

### 2.4.2 Ageing and wear

The Foreword, and Scope and Application clauses of AS 4586—2013 caution that wear can affect the long-term slip resistance of some pedestrian surfaces; however, the Standard does not specify a method of accelerated wear conditioning or testing that is uniformly applicable and warranted for all pedestrian surface materials.

Notwithstanding, Paragraph A3 of Appendix A of AS 4586—2013 (applicable only to the wet pendulum test) states:

*‘If a product Standard or specification contains a requirement for the permanence of slip resistance, this requirement shall be determined after the appropriate accelerated ageing or wear testing procedure.’*

The key to understanding Paragraph A3 is in the wording ‘If a product Standard or specification *contains a requirement* for the permanence of slip resistance...’. Specifications provided in Table 3B of this Handbook are for the slip resistance of new pedestrian surfaces, and are a consensus position formed on the understanding that many surfaces exhibit some degree of wear and contamination in service, and this is implicit in the values so specified. What such specifications do not anticipate is abnormally high wear (induced by the nature of some materials or the nature of some pedestrian traffic).

Paragraph A3 anticipates this situation. Consistent with the Foreword, Scope and Application of AS 4586—2013, Paragraph A3 does not dictate a particular method of accelerated wear conditioning or testing; however, if a ‘product Standard or specification’ is dealing with a situation where ageing and wear are known to be potential problems, Paragraph A3 requires that an ‘appropriate accelerated ageing or wear testing procedure’ be performed.

If accelerated wear conditioning or testing is contemplated, the specifier should consider whether the particular procedure accurately reflects the wear expected in-service. Guidance may be available from experienced testing organizations.

#### **2.4.3** *Slider rubber*

The choice of slider rubber in the wet pendulum test will influence the classification of some products. The options reflect both the wide differences in applications covered by the Standard and the historical conventions that have grown around testing various types of material.

For surfaces of relatively high slip resistance, a softer rubber (such as Slider 55) provides relatively good discrimination (small changes in slip resistance corresponding to large changes in wet pendulum test reading). Comparatively rough surfaces, such as exhibited by segmental clay or concrete pavers, have been traditionally tested with such rubbers.

For surfaces of relatively low slip resistance, a harder rubber (such as Slider 96) provides relatively good discrimination.

Table 2 of AS 4586—2013 provides for both slider rubbers.

Sliders 96 and 57 are used in some countries. If Slider 57 has been used, the results will differ from what will be achieved using Slider 55.

#### **2.4.4** *Slider preparation*

Appendix A of AS 4586—2013 incorporates a modified method of slider preparation, intended to minimize the effects of rubber roughness when assessing very smooth surfaces. This may lead to some pedestrian surfaces yielding different results on surfaces (in the range P2 to P3) from what were achieved under the previous Standard.

#### **2.4.5** *Increased discrimination between slippery surfaces*

The adoption of the new slider preparation method has provided greater discrimination between particularly slippery surfaces. The publication of a revised Standard also presented an opportunity to create a further classification, P0, at the lower (more slippery) end of the scale, thus enabling greater discrimination by specifiers.

#### **2.4.6** *New classification system*

For the two reasons above, it was appropriate to introduce a new classification nomenclature, replacing the previous classifications V, W, X, Y, Z with P5, P4, P3, P2, P1 and P0. P1 and P0 replace the previous Z. This ensures that specifiers and purchasers are able to easily determine whether the classifications are in accordance with the 2013 version of the Standard.

#### **2.4.7** *Standardized test conditions*

If a particular pedestrian surface is normally dry in service, its dry slip resistance will most likely be higher than the wet slip resistance that was determined in the wet pendulum test. However, the purpose of testing wet is to provide a standardized method of classifying the nature of the surface, rather than for predicting the in-service slip resistance in particular applications.

#### **2.4.8** *Pendulum test normally wet*

Because the wet condition is when most slips occur and many floor surfaces permit the ponding of water (becoming wet either accidentally or intentionally), the standardized pendulum test is carried in water-wet conditions.

#### **2.4.9** *Internal textile floor coverings may be tested dry*

The exception to the requirement that the pendulum test to be carried out wet is that of textile floor coverings, which are intended to be normally dry, and hence may be tested using the pendulum test in dry conditions. This is considered a reasonable concession, given that, even if internal textile floor coverings were to become accidentally wet, it would absorb the water and exhibit properties similar to the dry condition.

#### **2.4.10** *External textile floor coverings have to be tested wet*

Textile floor coverings that are expected to get wet (e.g. rubber-backed carpet tiles used in change rooms, artificial grass, etc.) will need to be tested wet.

#### **2.4.11** *Laboratory tests*

The slip resistance values (SRVs) of tiles, pavers, concrete, steel, timber, resilient surfaces, textile floor coverings and similar surfaces are easily determined by the wet pendulum test method in a number of Australian laboratories.

NOTE: The wet-barefoot inclining platform test method and oil-wet inclining platform test method are also laboratory tests.

#### **2.4.12** *Site tests*

The slip resistance values (SRVs) and subsequent classification of materials may also be derived directly from on-site in situ tests on a level or sloping surfaces using the wet pendulum test method. This is particularly useful for on-site verification (before service) of concrete, steel or timber floors constructed in-situ, and for site-applied resin-based floor coatings.

#### **2.4.13** *Use of test results from prototype tests*

Subject to certifier agreement and adequate quality assurance, surface materials may be prototype tested, and the results used multiple times. For applications where the surface slip resistance is reliant on granular particles being cast over the wet coating rather than mixed into the coating material, stringent quality control will need to be applied during application, with reference to control samples that have been laboratory applied.

#### 2.4.14 Slider 55 value below 20 not included

Slider 55 does not give the same level of discrimination between particularly slippery surfaces as does Slider 96. For this reason, slip resistance values (SRVs) below 20, obtained using a Slider 55, have been omitted from Table 1.

#### 2.4.15 Slope correction in determining SRV

Slip resistance value (SRV) is the mean British Pendulum Number (BPN) for a sample that has been tested and calculated in accordance with Appendix A of AS 4586—2013. It is the value from tests of a level surface or, if of a sloped surface, the value after correcting for slope.

Item (j) of Paragraph A9 (Test report) of Appendix A of AS 4586—2013 requires:

*'(j) The mean BPN for each test specimen, including the direction of test and slope corrected values, where appropriate.'*

Where practicable, the wet pendulum test should be performed on a level surface when testing surfaces that have uniform properties in all directions. If this is not practicable, the direction of swing should preferably be across a slope rather than up or down the slope.

When testing surfaces that do not have uniform slip resistance in all directions (i.e. they are anisotropic), the test program should reflect both the predominant direction of pedestrian traffic and the direction of lowest slip resistance. If these do not coincide, the test may need to be repeated to determine the slip resistance in more than one direction.

#### 2.4.16 Design for sloping surfaces

Slip is more likely to occur on a sloped surface than on a level surface with the same slip resistance value (SRV). Consequently, surfaces for sloped applications need to be characterized by the slope design value (SDV), which is greater than the SRV.

NOTE: For further explanation, refer to Clause 6.

### 2.5 Dry floor friction test method

The dry floor friction test method employs a simple apparatus that drags a small slider across a dry pedestrian surface, giving a continuous reading of the apparent coefficient of friction of the specimen. This is assessed by determining the dynamic friction between the specimen and a slider moving at a constant speed of  $1 \pm 0.1$  m/min across the surface, by measuring the ratio of the tangential force to the vertical load.

This test provides a quick and simple assessment of the slip resistance of dry surfaces; however, the results of the dry floor friction test are not appropriate for surfaces in the wet condition. If a pedestrian surface is liable to become wet, and remain wet and unattended for any significant length of time, the wet pendulum test method, wet-barefoot inclining platform test method or the oil-wet inclining platform test method (as appropriate) should be used.

A new nomenclature was also introduced in AS 4586—2013 (see Table 2) for the dry floor friction test, replacing classifications F and G with D1 and D0.

**TABLE 2**  
**CLASSIFICATION OF PEDESTRIAN**  
**SURFACE MATERIALS ACCORDING TO THE**  
**AS 4586—2013 DRY FLOOR FRICTION TEST**

Classification	Floor friction tester mean value
D1	$\geq 0.40$
D0	$< 0.40$

## 2.6 Wet-barefoot inclining platform test method

Pedestrian surfacing products intended for applications, which become wet during normal usage and are subject to barefoot traffic, may be classified by the wet-barefoot inclining platform test method.

Barefoot test operators walk down (forward) and up (backwards) the test surface on the platform using half steps. During the test there is a continuous regulated flow of water (with wetting agent) on the test surface. The operator controls the gradual increase in platform angle.

The wet-barefoot inclining platform test classifies surfaces by the specific angle at which slip occurs on the material under controlled laboratory conditions. The measurement and reporting of this angle provides a means of classification, and is not a suggestion that the material is safe to walk on at the slope reported in the test results. Pedestrian surfaces should not be installed at the angles reported in this test.

There are a number of Australian testing laboratories with the necessary testing apparatus, thus enabling the laboratory verification of an overseas classification, if required.

Wet-barefoot inclining platform tests performed overseas may be deemed compatible with AS 4586—2013, in the appropriate circumstances and with appropriate quality assurance.

## 2.7 Oil-wet inclining platform test method

Pedestrian surfacing products, intended for a range of industrial applications, may be classified by the oil-wet inclining platform test method.

Test operators, wearing regulated footwear with highly profiled soles, walk down (forward) and up (backwards) the test surface on the platform using half steps. Prior to conducting each test, the test surface is coated with oil. The operator controls the gradual increase in platform angle.

Similar to the wet-barefoot inclining platform test, the oil-wet inclining platform test classifies surfaces by the specific angle at which slip occurs on the material under controlled laboratory conditions. The measurement and reporting of this angle provides a means of classification, and is not a suggestion that the material is safe to walk on at the slope reported in the test results. Pedestrian surfaces should not be installed at the angles reported in this test.

There are a number of Australian testing laboratories with the necessary testing apparatus, thus enabling the laboratory verification of an overseas classification if required.

Oil-wet inclining platform tests performed overseas may be deemed compatible with AS 4586—2013, in the appropriate circumstances and with appropriate quality assurance.

## 2.8 Verifying compliance with the wet pendulum test method and dry floor friction test method

### 2.8.1 General

The slip resistance of pedestrian surfaces and surfacing material may vary between and within lots.

Clause 5.3 of AS 4586—2013 states:

*‘Pedestrian surfaces that are classified in accordance with Table 2 and, where appropriate, Table 3 shall meet the following criteria: ...’*

The intention is to provide guidance on the interpretation results of the wet pendulum test and dry floor friction (Table 2 and Table 3 of AS 4586—2013 respectively), since they will be the most common tests routinely carried out in Australia.

Some Australian laboratories can also perform the oil-wet inclining platform and wet barefoot inclining platform.

### 2.8.2 Wet pendulum test

Item (a) of Clause 5.3 of AS 4586—2013 states:

*‘(a) The mean test results shall be as follows:*

*(i) For the classifications in Table 2, the mean of the test results shall be—*

*(A) within the relevant criteria set out in the table; and*

*(B) each individual result shall be equal to or above the lower limit for the classification or, if below the classification, within the mean of the result minus 20%.*

*If either criteria is not met, the lot shall be considered to be of lower classification.’*

It is necessary to ensure that both the mean slip resistance, measured by the wet pendulum test, is within the bands specified in Table 2 of AS 4586—2013 and that the variability is low. The requirement of mean slip resistance within the bands is achieved by Items (a)(i)(A) and (a)(i)(B) of Clause 5.3 limits the variability in slip resistance measured by the wet pendulum test. It is acceptable for one (or more) individual results to fall below the lower band limit, provided it is not more than 20% below the mean.

*Example:* The following example demonstrates the use of these criteria. The two sets of results qualify as Classification P4 using the wet pendulum with slider 96.

	57			50	
	50			50	
	49			49	
	49			46	
	<u>45</u>			<u>40</u>	
Mean	50	$45 \leq 50 \leq 54$	Mean	47	$45 \leq 47 \leq 54$
Minimum	45	$45 \geq 45$	Minimum	40	$40 \geq (1 - 0.2) \times 47 = 38$

Compliance of the first set of results is straight-forward, but the second is more complicated. Although one result is below the minimum for the range, it is still greater than the sample mean minus 20% (i.e. 80% of the sample mean). Therefore, it is satisfactory.

### 2.8.3 Dry floor friction test

Item (a)(ii) of Clause 5.3 of AS 4586—2013 states:

*‘(ii) For Classification D1 in Table 3—*

*(A) the mean of the test results shall be equal to or greater than 0.4; and*

*(B) each individual slope corrected result shall be equal to or greater than 0.35.*

*If either of these criteria is not met, the lot shall be considered to be Classification D0.’*

The sample shall meet the requirements of both Items (a)(ii)(A) and (a)(ii)(B) of Clause 5.3; that is, it the Standard requires that the sample have a mean with the specified band and a low variability. Because the dry floor friction test has only two bands, the simultaneous achievement of a mean within the specified band and low variability is more easily identified than with the wet pendulum test; that is, to achieve D1 the mean is required to be above 0.4 and for all results to be above 0.35.

*Example:* The following set of results qualifies as Classification D1. There are eight readings in this example corresponding to a sample length of 800 mm with individual results at 100 mm lengths.

	0.47	
	0.44	
	0.40	
	0.43	
	0.39	
	0.41	
	0.37	
	<u>0.36</u>	
Mean	0.41	$0.41 \geq 0.40$
Minimum	0.36	$0.36 \geq 0.35$

#### 2.8.4 Sampling

Item (b) of Clause 5.3 of AS 4586—2013 states:

*‘(b) The classification in accordance with Table 2 or 3 shall be determined by—*

- (i) selecting and testing at least five specimens at random as specified in Appendices A and B; or*
- (ii) carrying out continuous testing and process control in accordance with AS 3942.’*

Item (b) of Clause 5.3 enables the sampling and acceptance/rejection to be made—

- on the basis of a sampling from a single lot as might occur on a site or in a warehouse; or
- within a continuous process control regime during manufacture.

#### 2.8.5 Redefining a lot

In the case of sampling five specimens from a single large lot, there is a risk that the inadvertent random selection of a single non-complying specimen could cause the unwarranted rejection of the whole lot. Item (c) of Clause 5.3 is intended to give the supplier/manufacturer a second chance. Two options are given:

*‘(c) When testing individual lots, if a particular test fails to produce the expected classification it shall be permissible to—*

- (i) disregard the first sample, resample a minimum of 10 specimens from the whole lot, retest and apply the criteria to the new sample; or*
- (ii) subdivide the lot into smaller lots of different quality, resample, retest and reclassify each of the smaller lots.’*

Option (c)(i) enables the supplier/manufacturer to disregard the first test and carry out a second test, but with increased the precision by doubling the number of specimens tested to 10.

Alternatively, Option (c)(ii) enables the supplier/manufacturer to identify and remove (to a separate lot) items that are clearly identified as non-complying; thus removing the possibility of them lowering the classification of what is otherwise a suitable lot. The items that have been removed would be given a lower classification.

*Example:* Figure 1 provides a diagram that represents a single lot, that is classified as P3 using a wet pendulum test with slider 96. If the particularly slippery items are identified and separated into a separate small lot of Class P3, the main lot can then be classified as P4.

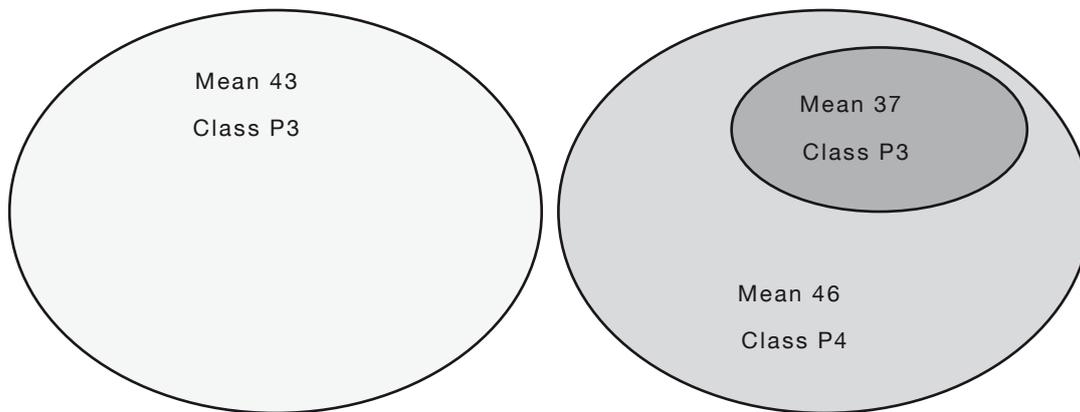


FIGURE 1 EXAMPLE OF REDEFINITION OF A LOT

### 3 AS 4663—2013

#### 3.1 Purpose

AS 4663—2013 provides methods of measuring the frictional characteristics of existing pedestrian surfaces, including the effects of sealers, polishes or etchants (if applied), in wet and dry conditions.

This Handbook does not specifically cover gratings, although it is possible to use the test methods for some gratings.

Because existing surfaces could have experienced changes to their slip resistance due to wear, contamination, sealers, polishes or etchants, a pre-use classification in accordance with AS 4586—2013 cannot be automatically inferred from the results of testing to the Standard.

The results of these tests may be used to give guidance on the slip resistance of the surface in its existing in-service condition. In other words, AS 4663—2013 provides a management tool for existing surfaces rather than a design and construction tool for new surfaces.

For some surfaces, where the lapsed service time is short, the wear is apparently negligible, the traffic is known to be minimal and the surface is clean, the results from a test to AS 4663—2013 could be similar to the results of tests carried out before service. In such cases, an informed prediction of the probable AS 4586—2013 wet pendulum test classification could be made. This would be subjected to qualification, and should only be done on the advice of an expert, experienced in recognizing, wear, traffic and surface cleanliness, and their effects on slip resistance.

AS 4663—2013 may also be used for evaluating surface applications and treatments, including products such as sealers, polishes and etchants that modify the surface characteristics of pedestrian surfaces.

The method specified for the measurement of wet slip resistance is to be used for all external areas and those internal pedestrian surfaces where such measurements are required. It does not contemplate various shoe sole materials, characteristics of individual gaits, or other factors that may also contribute to slip hazards.

### 3.2 Methods of test

AS 4663—2013 provides two methods for determining the slip resistance of existing in situ pedestrian surface materials, as follows:

- (a) Wet pendulum test method
- (b) Dry floor friction test method.

The dry floor friction test provides a quick and simple assessment of the slip resistance of a dry surface, and is therefore useful for management and maintenance of such surfaces.

The wet pendulum test is normally carried out under water wet conditions, although in the case of internal textile floor coverings it is appropriate for it to be carried out in dry conditions and reported as such.

Apart from the method of interpretation and reporting, there are no major differences between Appendices A and B of AS 4663—2013 and AS 4586—2013.

## 4 NATIONAL CONSTRUCTION CODE SLIP RESISTANCE REQUIREMENTS

### 4.1 National Construction Code

The National Construction Code (NCC) has been developed to incorporate all on-site construction requirements into a single code. The NCC comprises the Building Code of Australia (BCA), as Volumes One and Two; and the Plumbing Code of Australia (PCA), as Volume Three.

- Volume One pertains primarily to Class 2 to 9 buildings.
- Volume Two pertains primarily to Class 1 and 10 buildings.
- Volume Three pertains primarily to plumbing and drainage associated with all classes of buildings.

Only Volumes One and Two have requirements in respect to slip resistance, and those requirements are only relevant to some pedestrian surfaces.

### 4.2 Relationship between the National Construction Code and other regulations

Because the NCC specifies slip resistance in only a limited number of applications within buildings (i.e. stair treads, stair nosings and some ramps), it cannot be considered to be comprehensive in the sense of providing a slip-safe environment in all situations.

The NCC includes extensive additional requirements relating to access, ramps and paths. Reference should be made those parts of the NCC dealing with these matters, including reference to AS 1428.1.

Other legislation, by-laws and ordinances affecting pedestrian surfaces both inside and outside buildings, workplace health and safety regulations, and designers' and builders' duty of care also dictate the selection of slip-resistant pedestrian surfaces for slip resistance in many additional applications.

### 4.3 National Construction Code compliance

#### 4.3.1 General

The NCC is a performance-based code. The relevant performance requirements for slip resistance are part DP2 in Volume One and part P2.5.1 in Volume Two of the BCA.

The performance requirements may be achieved by complying with the deemed-to-satisfy (DtS) provisions (Clause 4.3.2) or by formulating an alternative solution (Clause 4.3.4).

#### 4.3.2 National Construction Code compliance via deemed-to-satisfy provisions

The deemed-to-satisfy provisions in Volume One apply to ramps steeper than 1:14, treads, landing surfaces or nosings or landing edge strips. In Volume Two, the deemed-to-satisfy provisions apply to tread surfaces and nosing strips.

The slip-resistance classifications that have NCC deemed-to-satisfy status are set out in Table 3A.

**TABLE 3A**  
**MINIMUM WET PENDULUM TEST OR OIL-WET INCLINING PLATFORM CLASSIFICATIONS THAT ARE DEEMED TO SATISFY THE BUILDING APPLICATIONS IN THE NATIONAL CONSTRUCTION CODE**

Location	Wet pendulum test	Oil-wet inclining platform test
<b>Stair Treads and Stairway Landings in Buildings Covered by NCC Volumes One and Two</b>		
Stair treads and a stairway landing (when dry)	P3	R10
Stair treads and a stairway landing (when wet)	P4	R11
<b>Nosings for Stair Treads and Stairway Landings in Buildings Covered by NCC Volumes One and Two</b>		
Dry stair tread, a stair non-skid nosing strip and a stairway landing	P3	
Wet stair tread, a stair non-skid nosing strip and a stairway landing	P4	
<b>Ramps in Buildings Covered by NCC Volumes One and Two</b>		
Ramps not steeper than 1:14 gradient (when dry)	P3	R10
Ramps not steeper than 1:14 gradient (when wet)	P4	R11
Ramps steeper than 1:14 up but not steeper than 1:8 (when dry)	P4	R11
Ramps steeper than 1:14 up but not steeper than 1:8 (when wet)	P5	R12

NOTE: NCC compliance is demonstrated by achieving the values set out in this Table for either the wet pendulum test or the oil-wet inclining ramp test. It is not necessary to meet both criteria.

#### 4.3.3 National Construction Code compliance based on previous tests

AS 4586—2013 specifies a method of conditioning sliders, which is different from that specified in AS/NZS 4586:2004. The purpose of this change is to provide increased precision with less variability, especially on those surfaces that are potentially more slippery. Therefore, the classification of some surfaces using AS 4586—2013 could differ from the corresponding classifications using AS/NZS 4586:2004. This is to be expected.

Notwithstanding, the NCC Volume One and NCC Volume Two include the following note.

*Note: Test reports based on the 2004 edition of AS/NZS 4586 and issued prior to the 2013 edition of AS 4586 being referenced in the BCA remain valid. Test reports prepared after the BCA reference date of the 2013 edition of AS 4586 must be based on that version. For the purposes of assessing compliance, the slip-resistance classifications of V, W and X in reports based on the 2004 edition of AS/NZS 4586 may be considered to be equivalent to slip resistance classifications of P5, P4 and P3 respectively in the 2013 edition of AS 4586.*

This arrangement is intended to permit the orderly introduction of deemed-to-satisfy provisions into the NCC, and to provide manufacturers and suppliers sufficient time to verify products to the requirements of AS 4586—2013. The stated equivalence between AS 4586—2013 and AS/NZS 4586:2004 is for purposes of establishing compliance with the NCC, and should not be interpreted as inferring that any particular pedestrian surface will give exactly the same mean values of the wet pendulum test when tested to both the 2013 and 2004 versions of the Standard.

#### **4.3.4 National Construction Code compliance via alternative solutions**

This path to compliance is defined in NCC, BCA Volume One Parts A0.8, A0.9 and A0.10 and NCC, BCA Volume Two Parts 1.0.8, 1.0.9 and 1.0.10. Compliance with the performance requirements is achieved by means other than as specified in the DTS provisions.

Such alternative solutions may be based on (but are not limited to) a scientific study of the combination of pedestrian surface, expected pedestrian traffic, footwear, maintenance, 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 the particular surface in the particular application.

The compliance of such an alternative solution with the NCC performance requirement may be determined by one or more of the assessment methods set out in NCC, BCA Volume One, Part A0.9 or BCA Volume Two, Part 1.0.9. The most likely options are Item (c), Comparison with the deemed-to-satisfy provisions, or Item (d), Expert judgement.

#### **4.3.5 Verification of compliance**

Verification of compliance should be consistent with sound quality assurance practices, preferably based on AS/NZS ISO 9001. This includes quality management auditing, management review, training, non-conformance reporting, corrective action, preventive action, identification and traceability, in addition to process control.

Process control includes, but is not limited to, quality control based on sampling and testing.

For slip resistance of manufactured products such as tiles, pavers, textile floor coverings, resilient coverings and similar surfaces, the quality control would normally include sampling and testing to Appendix A (wet pendulum test) or Appendix D (oil-wet inclining platform test) of AS 4586—2013 at the point of manufacture.

For slip resistance achieved through processes performed on a construction site (e.g. on-site constructed concrete or timber, or on-site-applied finishes), verification may be achieved through either—

- (a) site sampling and testing to Appendix A of AS 4586—2013 (wet pendulum test); or
- (b) other practical measures including, but not limited to, the following:
  - Site use of sample boards, which have been previously laboratory tested to Appendix A of AS 4586—2013 (wet pendulum test).
  - Comprehensive photographic record of completed work.

- Mandatory sign-off on quality by the applicator (increasing accountability).
- Documented training for applicators.
- Enhanced supervision.

## 5 SELECTION OF PEDESTRIAN SURFACE MATERIALS

### 5.1 General

Tables 3A and 3B describe slip resistance considered suitable for particular applications, based on the wet pendulum test method and oil-wet inclining platform test method as specified in AS 4586—2013.

For other applications not listed herein, guidance may be obtained from various scientific papers, references, overseas Standards and the like. This includes values derived from the wet pendulum test, wet barefoot inclining platform test and oil-wet inclining platform test.

### 5.2 Classifications for particular applications

Table 3B provides guidance for pedestrian surfaces for particular applications. The values represent a consensus view of Committee BD-094, although not all experts agree on all values. The values in Table 3B have been determined by the following process:

- Applications and corresponding values were selected initially from HB 197:1999.
- A subcommittee of Committee BD-094 modified some applications and values, and these were further modified during the review process.
- The contents of Table 3B are subject to further review by Committee BD-094, in its ongoing project to provide guidance on specifying and testing for slip resistance.

For completeness, Table 3A is also reproduced here from the previous Section.

There are some fundamental differences in the purpose and nature of Tables 3A and 3B.

- Table 3A applications and values have been determined by the Australian Building Codes Board for use in regulations based on the NCC. It provides the minimum wet pendulum test or oil-wet inclining platform test classifications that are deemed-to-satisfy specific applications in buildings covered by the NCC. These values may be used as acceptance criteria in a range of situations, including those where the building incorporates only the minimum regulated NCC requirements for handrails, lighting and the like.
- Table 3B applications and values have been determined by Committee BD-094 for use in applications that are not regulated by the NCC. It provides wet pendulum test or oil-wet inclining platform test classifications for applications where the NCC does not specifically require slip resistance. The applications listed are some of those for which slip resistance is warranted for reasons other than NCC compliance. The use of these values should be in the context of design, which also considers abnormal wear, maintenance, abnormal contamination, the presence (or otherwise) of water or other lubricants, the nature of the pedestrian traffic (including age, gait and crowding), the footwear (or lack thereof), slope, lighting and handrails.

**TABLE 3A**  
**MINIMUM WET PENDULUM TEST OR OIL-WET INCLINING PLATFORM**  
**CLASSIFICATIONS THAT ARE DEEMED-TO-SATISFY THE BUILDING**  
**APPLICATIONS IN THE NCC**

Location	Wet pendulum test	Oil-wet inclining platform test
<b>Stair Treads and Stairway Landings in Buildings Covered by NCC Volumes One and Two</b>		
Stair treads and a stairway landing (when dry)	P3	R10
Stair treads and a stairway landing (when wet)	P4	R11
<b>Nosings for Stair Treads and Stairway Landings in Buildings Covered by NCC Volumes One and Two</b>		
Dry stair tread, a stair non-skid nosing strip and a stairway landing	P3	
Wet stair tread, a stair non-skid nosing strip and a stairway landing	P4	
<b>Ramps in Buildings Covered by NCC Volumes One and Two</b>		
Ramps not steeper than 1:14 gradient (when dry)	P3	R10
Ramps not steeper than 1:14 gradient (when wet)	P4	R11
Ramps steeper than 1:14 up but not steeper than 1:8 (when dry)	P4	R11
Ramps steeper than 1:14 up but not steeper than 1:8 (when wet)	P5	R12

NOTE: NCC compliance is demonstrated by achieving the values set out in this Table for either the wet pendulum test or the oil-wet inclining ramp test. It is not necessary to meet both criteria.

**TABLE 3B**  
**WET PENDULUM TEST OR OIL-WET INCLINING PLATFORM**  
**CLASSIFICATIONS FOR APPLICATIONS WHERE THE NCC DOES NOT**  
**REQUIRE SLIP RESISTANCE**

Location	Wet pendulum test	Oil-wet inclining platform test
<b>External Pavements and Ramps</b>		
External ramps including sloping driveways, footpaths etc. steeper than 1 in 14	P5	R12
External ramps including sloping driveways, footpaths, etc., under 1:14, external sales areas (e.g. markets), external carpark areas, external colonnades, walkways, pedestrian crossings, balconies, verandas, carports, driveways, courtyards and roof decks	P4	R11
Undercover car parks	P3	R10
<b>Hotels, Offices, Public Buildings, Schools and Kindergartens</b>		
Entries and access areas including hotels, offices, public buildings, schools, kindergartens, common areas of public buildings, internal lift lobbies		
Wet area	P3	R10
Transitional area	P2	R9
Dry area	P1 (see Note 3)	R9
Toilet facilities in offices, hotels and shopping centres	P3	R10
Hotel apartment bathrooms, en suites and toilets	P2	A
Hotel apartment kitchens and laundries	P2	R9
<b>Supermarkets and Shopping Centres</b>		
Fast food outlets, buffet food servery areas, food courts and fast food dining areas in shopping centres	P3	R10
Shop and supermarket fresh fruit and vegetable areas	P3	R10
Shop entry areas with external entrances	P3	R10
Supermarket aisles (except fresh food areas)	P1 (see Note 3)	R9
Other separate shops inside shopping centres—wet	P3	R10
Other separate shops inside shopping centres—dry	P1 (see Note 3)	R9
<b>Loading Docks, Commercial Kitchens, Cold Stores, Serving Areas</b>		
Loading docks under cover and commercial kitchens	P5	R12
Serving areas behind bars in public hotels and clubs, cold stores and freezers	P4	R11
<b>Swimming Pools and Sporting Facilities</b>		
Swimming pool ramps and stairs leading to water	P5	C
Swimming pool surrounds and communal shower rooms	P4	B
Communal changing rooms	P3	A
Undercover concourse areas of sports stadiums	P3	R10
<b>Hospitals and Aged Care Facilities</b>		
Bathrooms and en suites in hospitals and aged care facilities	P3	B
Wards and corridors in hospital and aged care facilities	P2	R9

## NOTES TO TABLE 3B:

- 1 The slip resistances of pedestrian surface materials set out in Table 3B are intended as guidance in the context of design for pedestrian safety, taking account other factors including abnormal wear, maintenance, abnormal contamination, the presence (or otherwise) of water or other lubricants, the nature of the pedestrian traffic (including age, gait and crowding), the footwear (or lack thereof), slope, lighting and handrails.
- 2 The contents of Table 3B are subject to further review by Committee BD-094, in its on-going project to provide guidance on the specification and testing of slip resistance.
- 3 The minimum classifications listed in Table 3B are P1 and R9. It is inappropriate for Table 3B to list the lower classification, P0, since there is no lower limit on Classification P0.  
Notwithstanding, some smooth and polished floor surfaces, which do not achieve Classification P1, may be considered to provide a safe walking environment for normal pedestrians walking at a moderate pace, provided the surfaces are kept clean and dry; however, should these surfaces become contaminated by either wet or dry materials, or be used by pedestrians in any other manner, then they may become unsafe. Therefore, the type of maintenance, the in-service inspection of floors, other environmental conditions and use should be taken in to account when selecting such products.
- 4 When using the oil-wet inclining platform 'R' classifications, consideration should also be given to the determination and use of volumetric displacement 'V' classifications. In some cases, a specifier may choose either a particular combination of R and V values, or a more severe R value alone. For example, either R10 + V4, or R11.

### 5.3 Background to specifications based on AS 4586—2013 tests

The following definitions apply to Tables 3A and 3B.

- (a) *Dry areas* Those areas in which appropriate control measures ensure an area remains dry and clean when in use.
- (b) *Transitional areas* Those areas that are intended to be kept dry such as by the provision of design features (awnings, drains, mats, air locks, etc.) appropriate to the physical location, climate and general exposure to water, as maintained in a dry and clean condition by the facilities manager.
- (c) *Wet areas* Those areas that are not defined as a dry or transitional area, which may be either constantly or intermittently wet or otherwise contaminated.

The test methods in AS 4586—2013 are means of classifying pedestrian surface materials, and do not necessarily replicate the exact circumstances of particular combinations of footwear or skin and surface material, with or without contamination, surface wear and liquid on the surface

The NCC deemed-to-satisfy provisions for stair treads, ramps, and stair nosings have been reproduced in this Handbook as Table 3A. The wet pendulum test classifications and inclining platform classifications of the NCC have been developed by a process involving expert advice, public review, consideration of stakeholder advice and committee deliberation.

The wet pendulum test classifications and most of the inclining platform classifications in Table 3B have been developed through Committee BD-094 discussion and consensus.

### 5.4 Other design considerations

When designing stairs and ramps, in addition to the particular requirements for slip resistance in the NCC designers should consider the following:

- A cross-slope in floors at the top or bottom of flights of stairs could increase the risk of tripping or slipping.
- Trip hazards may be created inadvertently by nosings and thresholds.
- Where practicable, stair treads should have slip resistance at least equal to or greater than that of the floor at the top or bottom of the stairs.

- The surface of stair treads should be of uniform material.
- The geometry of stair rises and goings of stairs must comply with the NCC.
- Provision of handrails must be consistent with the requirements of the NCC.

### 5.5 Verification of compliance

Similar to the case for verifying compliance with the NCC, compliance with other specifications should be consistent with sound quality assurance practices, preferably based on AS/NZS ISO 9001.

Quality control options include—

- sampling and testing to AS 4586—2013 at the point of manufacture;
- sampling and testing to AS 4586—2013 on site; or
- combination of prototype testing to AS 4586—2013, together with rigorous site control measures.

## 6 DESIGNING FOR RAMPS AND OTHER SLOPING SURFACES

### 6.1 General

When a person walks at constant speed on a level surface (see Figure 2), there is a small tangential force and a maximum of normal force. If the walker accelerates or decelerates, the tangential force increases and the likelihood of a slip increases.

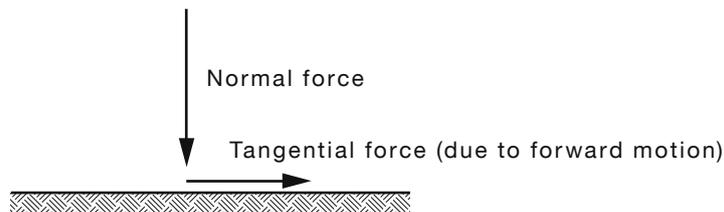


FIGURE 2 LEVEL SURFACE

If the surface slopes (see Figure 3), the normal force decreases and the tangential force increases, thus increasing the likelihood of a slip.

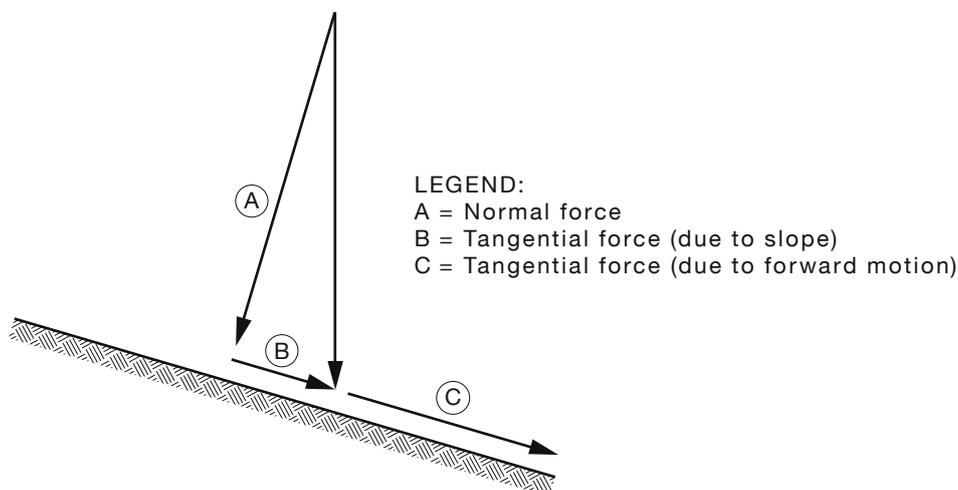


FIGURE 3 SLOPING SURFACE

When designing ramps, the friction requirement has to be established for a level surface, in that specific location, before calculating the requirement for a sloped surface. The lowest value within the specified range for the particular application is often adopted. However, given the range of results within most classifications, the median value may be a more appropriate choice.

Paragraph F1 of Appendix F of AS 4586—2013, states:

*'...The frictional requirement ( $\mu_r$ ) for a ramp for the same type of location is approximately ( $\mu_1 + 0.0125S$ ) or ( $\mu_1 + 1.25 \tan \alpha$ ), where  $S$  is the slope (%) and  $\alpha$  is the angle of the walking surface in degrees.'*

The increase in tangential static force for a body at rest on a slope is  $1.0 \tan \alpha$ . The adoption of  $1.25 \tan \alpha$  represents an additional allowance for movement over the static situation. Various studies identify the changes in friction demand on ramps, which some attribute to the pedestrians reducing their stride and utilized friction demands when they perceive increased risk of slipping.

*Example:* If the required effective coefficient of friction for a surface was 0.4 and the slope was 1:14, the required slip resistance of the surface material is 0.49 (additional 0.089 for a slope of 7.1%). The required coefficient of friction for a sloped surface is:

$$\mu_r = \mu_1 + 1.25 \tan \alpha$$

where

$\mu_1$  = required coefficient of friction for level surface

$\alpha$  = the angle to the horizontal

**TABLE 6**  
**ADDITIONAL FRICTION**  
**REQUIRED FOR VARIOUS SLOPES**

1:...	Slope, $\alpha$		Additional friction $1.25 \tan \alpha$
	Degrees	%	
20	2.9	5.0	0.063
14	4.1	7.1	0.089
8	7.1	12.5	0.156

## 6.2 Dry floor friction test result required to compensate for slope

Since dry floor friction test results are expressed as a coefficient of friction, the additional friction requirements to account for slope may be simply added to the requirement for a level surface.

## 6.3 Wet pendulum test result required to compensate for slope

Calculating a wet pendulum test requirements for a sloped area is more complex since these requirements are expressed in terms of a British Pendulum Number (BPN).

The BPN may be converted to a coefficient of friction, using the following relationship: The coefficient of friction ( $\mu$ ) for a level surface is—

$$\mu = \frac{3P}{(330 - P)}$$

where the BPN is defined as

$$P = \frac{300 \mu}{(3 + \mu)}$$

The required BPN for a sloped surface (SDV) is:

$$\begin{aligned} \text{SDV} &= \frac{330(\mu + 1.25 \tan \alpha)}{(3 + [\mu + 1.25 \tan \alpha])} \\ &= 330 \frac{\left[ \frac{3 \text{ SRV}}{(330 - P1)} + 1.25 \tan \alpha \right]}{\left( 3 + \left[ \frac{3 \text{ SRV}}{330 - \text{SRV}} + 1.25 \tan \alpha \right] \right)} \end{aligned}$$

where

- $\mu$  = coefficient of friction
- SRV = required BPN for a level surface
- $\alpha$  = the angle to the horizontal

**TABLE 7**

**BRITISH PENDULUM NUMBER SDV REQUIRED FOR SLOPING SURFACES**

Required BPN for level surface			54	45	35	25
Slope, $\alpha$						
1:...	Degrees	%				
20	2.8	5.0	59	50	40	31
14	4.1	7.1	61	52	43	33
8	7.1	12.5	66	57	48	39

For example, consider an application requiring an effective slip resistance value (SRV), for a level surface, of P4 (i.e. BPN in the range of 45 to 54). If the slope is 1 in 14, the required slope design value (SDV) is 52, i.e. an additional slope correction value (SCV) of 7.

Alternatively, if one uses a median slip resistance value (SRV) for the classification tests (i.e. 49) instead of the minimum value, the required median value for the sloped surface, slope design value (SDV) would be 56, i.e. an additional slope correction value (SCV) of 7. In other words a surface material with a classification of P5 rather than P4 should be specified.

For ramps or sloped surfaces, it may be preferable to increase the specified slip resistance by one classification rather than carry out such calculations.

## 7 REFERENCED DOCUMENTS

### AS

- 1428 Design for access and mobility  
1428.1 Part 1: General requirements for access—New building work  
4586—2013 Slip resistance classification of new pedestrian surface materials  
4663—2013 Slip resistance measurement of existing pedestrian surfaces

### HB

- 197—1999 An introductory guide to the slip resistance of pedestrian surface materials

### AS/NZS ISO

- 9001 Quality management systems—Requirements

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