

Assessing the slip resistance of flooring

A technical information sheet

HSE information sheet

Introduction

This technical document considers a number of test methods for assessing floor slip resistance and describes those used by HSE/HSL in more detail. It is intended for organisations which need to perform accurate measurements of floor slipperiness, such as manufacturers and research and testing bodies. It will also help employers and other dutyholders with assessing slip risks in workplaces by helping them to interpret flooring manufacturers' test data. This should allow them to make an informed decision in choosing new floors. In the light of this information, manufacturers and suppliers of flooring are recommended to review the floor slip resistance information they provide when producing flooring data sheets for customers.

Background

Slips and trips consistently account for around 1 in 3 non-fatal major injuries, and for over 1 in 5 over-3-day injuries in workplace areas throughout Great Britain, a total of at least 35 000 injuries per annum (one serious slip accident every 3 minutes). HSE statistics suggest that most of these accidents are slips, most of which occur when floor surfaces are contaminated (water, talc, grease, etc).

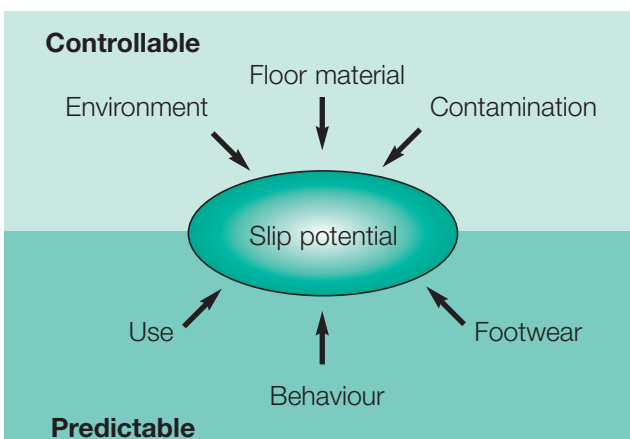


Figure 1 Slip potential model

Slips and trips information sheet

Research by the Health and Safety Laboratory (HSL) on behalf of HSE has shown that a combination of factors can contribute to slip accidents. A slip potential model has been developed, in which the relative importance of the factors contributing to a slip are assessed and quantified (see Figure 1).

This document describes methods of assessing the slipperiness of floors, including profiled floors and stairs. It aims to give enough information to correctly select a method to test the slipperiness of the floor and interpret the results.

The assessment of slipperiness: The HSE approach

The law requires that floors must not be slippery so they put people's safety at risk (The Workplace (Health, Safety and Welfare) Regulations 1992).¹ It was thought that the characteristics of floor surface materials needed for satisfactory slip resistance were difficult to assess. However, research carried out by HSL, in conjunction with the UK Slip Resistance Group (UKSRG) and the British Standards Institution, has shown they are not. The slipperiness of flooring materials can be accurately assessed by using commercially available, portable scientific test instruments.

On behalf of HSE, HSL has developed a reliable and robust test method using these instruments to assess floor surface slipperiness in workplace and public areas. The method has been used as the basis of significant HSE and local authority action, from advice to improvement notices and prosecution.

The methodology is based on using two instruments:

- a pendulum coefficient of friction (CoF) test (HSE's preferred method of slipperiness assessment, see Figure 2);
- a surface microroughness meter (see Figure 3).

This methodology is ideally suited to both laboratory-based assessment, and for use on installed floors.

The data generated may be strengthened by considering additional test data where appropriate.

Pendulum

The pendulum CoF test (also known as the portable skid resistance tester, the British pendulum, and the TRRL pendulum, see Figure 2) is the subject of a British Standard, BS 7976: Parts 1-3, 2002.²

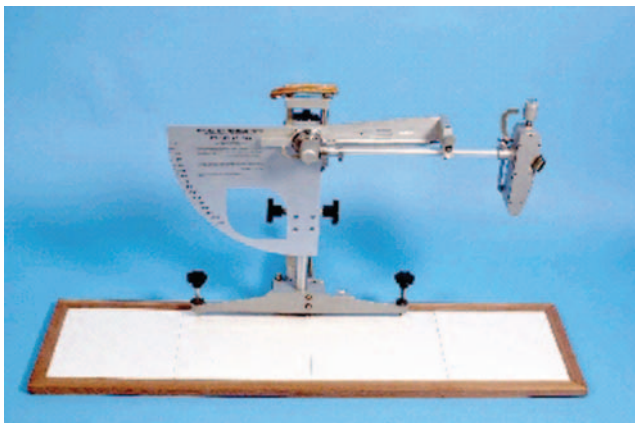


Figure 2 The pendulum CoF test

This instrument, although often used in its current form to assess the skid resistance of roads, was originally designed to simulate the action of a slipping foot. The method is based on a swinging, imitation heel (using a standardised rubber soling sample), which sweeps over a set area of flooring in a controlled manner. The slipperiness of the flooring has a direct and measurable effect on the pendulum test value (PTV) given (previously known as the Slip Resistance Value).

The preparation of the standard rubber sliders is detailed in BS 7976 and the UKSRG guidelines.³ There is a small difference between the two methods of slider preparation, and in certain limited situations the two methods may give slightly different results. HSE and the UKSRG believe the changes in the latest version of the UKSRG guidelines (2005) are best practice.

Research has confirmed the pendulum to be a reliable and accurate test, leading to its adoption as the standard HSE test method for the assessment of floor slipperiness in dry and contaminated conditions. However, to use it reliably needs a suitably trained and competent person to operate it and to interpret the results.

Interpretation of pendulum results

Pendulum results should be interpreted using the information reproduced in Table 1 (from UKSRG, 2005).

	PTV
High slip potential	0–24
Moderate slip potential	25–35
Low slip potential	36 +

Table 1 Slip potential classification, based on pendulum test values (PTV)

Practical considerations

Information generated by the pendulum using Slider 96 rubber, also known as Four-S rubber (Standard Simulated Shoe Sole) is sufficient for assessing slipperiness in most circumstances. However, for assessing barefoot areas, unusually rough or profiled floors, the use of Slider 55 rubber, also known as TRRL rubber (a similar but softer, more malleable compound) may be advantageous.

Although using the pendulum on heavily profiled flooring materials, stair treads and nosings is possible, doing so can be difficult, and should only be undertaken by experienced operators.

The pendulum test equipment is large and heavy, so consider the manual handling of the equipment carefully for testing in the field.



Figure 3 Surface microroughness meters (left to right: Mitutoyo SurfTest SJ201P, Surtronic Duo, Surtronic 25)

Surface microroughness

An indication of slipperiness in water-contaminated conditions may be simply obtained by measuring the surface roughness of flooring materials. Roughness measurements may also be used to monitor changes in floor surface characteristics, such as wear. Research has shown that measurement of the Rz parameter allows slipperiness to be predicted for a range of common materials. Rz is a measure of total surface roughness, calculated as the mean of several peak-to-valley measurements.

Interpretation of surface roughness

When surface microroughness data is used to supplement pendulum test data, the roughness results should be interpreted using the information reproduced in Table 2 (from UKSRG, 2005). Where only roughness data is available, use it in conjunction with the Slips Assessment Tool (SAT) detailed below.

Rz surface roughness	
Below 10 µm	High slip potential
10–20 µm	Moderate slip potential
20 + µm	Low slip potential

Table 2 Slip potential classification, based on Rz microroughness values (applicable for water-wet pedestrian areas)

Practical considerations: Roughness meters

Research has shown that the Rz roughness parameter gives a good indication of floor slipperiness in water-contaminated conditions. The measurement of Rz using a hand-held meter is simple and quick. It is possible to measure other roughness parameters that give a more complete picture of floor surface slipperiness (this is the subject of ongoing research). Although the use of portable, commercially available roughness meters (see Figure 3) for assessing floor surface slipperiness is increasing, they are unsuitable for use on carpet, undulating or very rough floors.

The figures quoted in Table 2 relate to floor surface slipperiness in water-contaminated conditions. If there are other contaminants, differing levels of roughness will be needed to lower slip potential. As a general rule, a higher level of surface roughness is needed to maintain slip resistance with a more viscous (thicker) contaminant. Note that the figures in Table 3 are typical Rz surface microroughness levels at which floors are likely to result in a low slip potential, as a

function of contaminant type and should not be used on their own for specifying floors.

Minimum roughness (Rz)	Contaminant
20 µm	Clean water, coffee, soft drinks
45 µm	Soap solution, milk
60 µm	Cooking stock
70 µm	Motor oil, olive oil
above 70 µm	Gear oil, margarine

Table 3 Typical Rz surface microroughness levels for a low slip potential, as a function of contaminant type

Where the size of the pendulum tester limits its use, such as on stairs, surface microroughness can be used to compare the surface with an area of the same surface that can be tested using the pendulum.

Slips assessment tool (SAT)

HSE and HSL have produced a PC-based software package to assess the slip potential presented by level pedestrian walkway surfaces. The SAT prompts the user to collect surface microroughness data from the test area, using a hand-held meter. The SAT supplements the surface microroughness data (Rz) with other relevant information from the pedestrian slip potential model. This includes the causes of floor surface contamination, the regimes used to clean the floor surface (both in terms of their effectiveness and frequency), the footwear types worn in the area, along with associated human factors and environmental factors. On completion, a slip risk classification is supplied to the user; this gives an indication of the potential for a slip. SAT is designed to assist in the decision-making process when considering the risk of slipping in a defined area, and can be used iteratively to show the influence of different control measures. However, it should not be relied upon when considering the performance of just the flooring; in this instance a suitable CoF test should be used. The SAT software can be downloaded free from www.hsesat.info.

The UKSRG ramp test

The UKSRG ramp test (Figure 4) is designed to simulate the conditions commonly encountered in typical workplace slip accidents. Clean water is used as the contaminant and footwear with a standardised soling material is used, although barefoot testing may also be undertaken. The test method involves using test subjects who walk forwards and backwards over

a contaminated flooring sample. The inclination of the sample is increased gradually until the test subject slips. The average angle of inclination at which slip occurs is used to calculate the CoF of the flooring. The CoF measured relates to the flooring used on a level surface. It is possible to assess bespoke combinations of footwear, flooring and contamination relating to specific environments using this method; HSL also use the ramp to assess the slipperiness of footwear.



Figure 4 The UKSRG ramp CoF test

Other ramp tests

Many European flooring manufacturers use ramp-type tests to classify the slipperiness of their products before sale. Such tests are generally carried out using German National Standard test methods (DIN 51097:1992⁴ and DIN 51130:2004⁵).

DIN 51097 involves the use of barefoot operators with a soap solution as the contaminant, and DIN 51130 uses heavily-cleated EN:ISO 20345 safety boots with motor oil contamination. HSE has reservations about these test methods, as neither uses contaminants that are representative of those commonly found in workplaces and the way the results are sometimes interpreted and applied (see below) is a cause for concern.

Floor surface materials are often classified on the basis of the DIN standards. The classification schemes outlined in DIN 51130 (Table 4) and DIN 51097 (Table 5) have led to some confusion, resulting in the wrong floor surfaces sometimes being installed.

Classification	R9	R10	R11	R12	R13
Slip angle (°)	6-10	10-19	19-27	27-35	> 35

Table 4 DIN 51130 R-Value slipperiness classification

Classification	A	B	C
Slip angle (°)	12-17	18-23	> 24

Table 5 DIN 51097 slipperiness classification

A common problem stems from the misconception that the 'R' scale runs from R1 to R13, where R1 is the most slippery, and R13 the least slippery. HSE have been involved in cases where R9 floors have been specified as specialist anti-slip surfaces. In reality, the R scale runs from R9 to R13, where R9 is the most slippery, and R13 the least slippery. Floor surfaces that are classified by the DIN 51130 standard as R9 (or in some instances R10) are likely to be unacceptably slippery when used in wet or greasy conditions. Further problems may arise from the wide range of CoF within a given classification, for example R10 covers a CoF range from 0.18 to 0.34, which represents a very wide range of slip potential. The same limitations apply to DIN 51097 for barefoot areas.

The EN13845:2005⁶ standard for slip resistance of safety floors addresses some of the shortcomings of the DIN tests above, but one area of concern is the different thresholds set for shod (20° = CoF 0.36) and barefoot (15° = CoF 0.27) conditions. The level of friction needed by a person to walk without slipping is thought to be the same whether the person is barefoot or wearing shoes. Flooring reported to 'pass' this standard for barefoot use may actually present a moderate slip potential.

Roller-coaster tests

HSL have evaluated two new instruments for the assessment of floor slip resistance on a wide range of installed floor surfaces, in dry, wet and contaminated conditions.⁷ The instruments have been dubbed 'roller-coaster tests' as both involve a trolley rolling down a ramp and skidding across the floor surface. The first was developed by SlipAlert LLP (and is commercially available), the second was a laboratory prototype. The results show good agreement with the pendulum, provided that Slider 96 is used as the test slider

material. Roller-coaster tests are more portable than the pendulum and may be used by people with little or no experience of floor surface assessment. A large test area is required, however, which can limit their applicability in some situations. As the test slider can travel a significant distance over the floor surface, it measures the average slip resistance of the area tested. This may limit the ability of these tests to identify small areas of slippery flooring surrounded by more slip-resistant flooring; it may be important to identify such small areas during an investigation. However, if visual inspection reveals areas with differing visual appearance (due to wear or inconsistency), microroughness measurements may be taken to highlight these differences. Furthermore, although it may be difficult to demonstrate the effect of a liquid spill on the slip resistance of the floor using these test methods, the effects of such spills can be accurately measured.

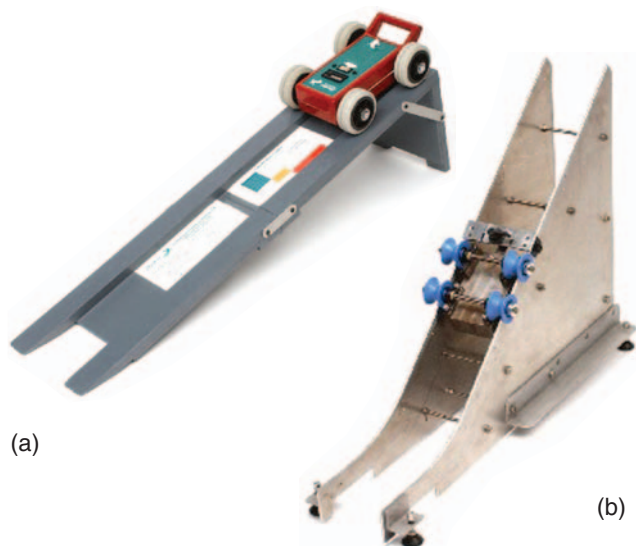


Figure 5 Roller-coaster slip tests
(a) SlipAlert CoF test (b) The laboratory prototype CoF test

Sled-type tests

The instruments that have been dubbed 'sled tests' involve a self-powered trolley that drags itself across the floor surface, measuring the CoF as it moves. Laboratory-based assessments have strongly suggested that several tests currently available (particularly those based on 'sled-type' principles) can produce misleading data in wet conditions. Information from such tests shows that some smooth flooring appears to be less slippery in wet conditions than when dry; this is clearly at odds with everyday experience. Such tests may give credible results in dry conditions, though it should be stressed that the vast majority of slipping accidents occur in wet, contaminated conditions.

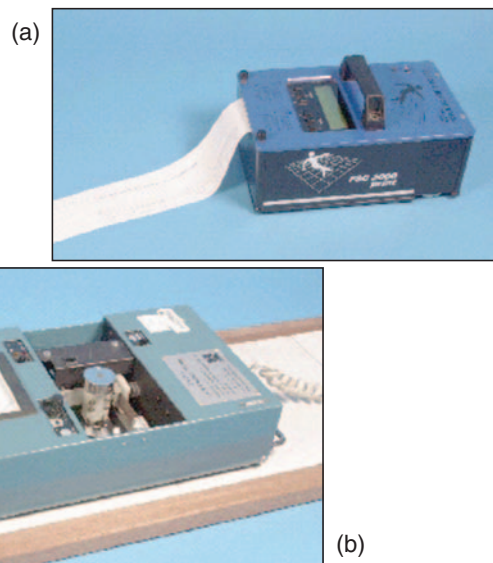


Figure 6 Sled-type tests
(a) The FSC2000 (b) the Tortus test

Interpretation of manufacturers' data

Most slip resistance information provided by flooring manufacturers is produced from as-supplied products (ie ex-factory). The slipperiness of flooring materials can change significantly due to the installation process (due to grouting, burnishing, polishing), after short periods of use, due to inappropriate maintenance or longer-term wear. Furthermore, data quoted simply as CoF should be viewed with uncertainty, as the type of CoF test used can have a critical affect on the validity of the data.

The test data needed to characterise a floor should relate to the floor as finished for the intended use and with any contamination present in normal use.

References and further reading

References

- 1 *Workplace health, safety and welfare. Workplace (Health, Safety and Welfare) Regulations 1992. Approved Code of Practice L24 HSE Books 1992 ISBN 0 7176 0413 6*
- 2 *BS 7976-1:2002 Pendulum testers. Specification British Standards Institution 2002 ISBN 0 580 40144 8*
BS 7976-2:2002 Pendulum testers. Method of operation British Standards Institution 2002 ISBN 0 580 40145 6
BS 7976-3:2002 Pendulum testers. Method of calibration British Standards Institution 2002 ISBN 0 580 40146 4

3 *The assessment of floor slip resistance* Issue 3
United Kingdom Slip Resistance Group, 2005

4 DIN 51097: 1992 *Testing of floor coverings; determination of the anti-slip properties; wet-loaded barefoot areas; walking method; ramp test* German National Standard 1992

5 DIN 51130: 2004 *Testing of floor coverings; determination of the anti-slip properties; workrooms and fields of activities with slip danger; walking method; ramp test* German National Standard 2004

6 EN13845:2005 *Resilient floor coverings: Polyvinyl chloride floor coverings with particle based enhanced slip resistance. Specification* British Standards Institution 2005 ISBN 0 580 46677 9

7 *Evaluation of the Kirchberg Rolling Slider and SlipAlert Slip Resistance Meters* Available at www.hse.gov.uk/research/hsl_pdf/2006/hsl0665.pdf

Further reading

Safer surfaces to walk on, reducing the risk of slipping
CIRIA C652 2006

Slips and trips: Guidance for employers on identifying hazards and controlling risks HSG155 HSE Books 1996 ISBN 0 7176 1145 0

Slips and trips: Guidance for the food processing industry HSG156 HSE Books 1996 ISBN 0 7176 0832 8

More information about slips and trips can be found at www.hse.gov.uk/slips and at www.hsl.gov.uk/capabilities/pedestrian.htm.

Further information

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This document contains notes on good practice which are not compulsory but which you may find helpful in considering what you need to do.

This document is available web only at: www.hse.gov.uk/pubns/web/slips01.pdf.

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