

The assessment of pedestrian slip risk

The HSE approach



INTRODUCTION

Slips, trips and falls on level ground (STFL) consistently account for around 1 in 3 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 three minutes). HSE statistics suggest that the majority of these STFL accidents are slips.

Research by the Health and Safety Laboratory (HSL) on behalf of HSE has shown that a combination of factors contribute to slip accidents. A 'slip potential model' has been developed in which the relative importance of the following factors, among others, to a given situation is assessed and quantified:

- floor;
- contamination;
- footwear;
- pedestrian factors;
- cleaning;
- environment.

This document is specifically concerned with methods of assessing the slipperiness of floors.

THE ASSESSMENT OF SLIPPERINESS: THE HSE APPROACH



The law requires that floors must not be slippery, so as to expose any person to a risk to their safety (The Workplace (Health, Safety and Welfare) Regulations 1992).¹ The characteristics of floor surface materials required to provide satisfactory slip resistance have traditionally been considered difficult to assess. However, research carried out by HSE at HSL, in conjunction with the UK Slip Resistance Group (UKSRG) and the British Standards Institution, has shown that this is not the case. The slipperiness of flooring materials can be accurately assessed by using commercially available, portable scientific test instruments.

HSE/HSL has developed a reliable and robust test method using these instruments for the assessment of floor surface slipperiness in workplace and public areas. The method has been used as the basis of significant HSE and Local Authority enforcement, from advice through to improvement notices, or ultimately, prosecution.

The methodology developed is based on the use of two instruments:

- a 'Pendulum' coefficient of friction (CoF) test (HSE's preferred method of slipperiness assessment, see Figure 1); and
- a surface microroughness meter (see Figure 2).

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

PENDULUM

The pendulum coefficient of friction test (also known as the 'portable skid resistance tester', the 'British pendulum', and the 'TRRL pendulum') is now the subject of a British Standard, BS 7976.²

Figure 1 The 'pendulum' coefficient of friction test, HSE/HSL's preferred test method for the assessment of floor surface coefficient of friction



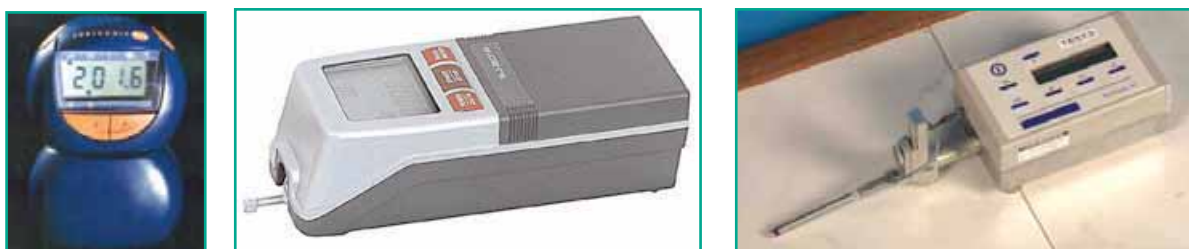
This instrument, although often used in its current form to assess the skid resistance of roads, was originally designed to simulate the action of a slipping foot. The method is based on a swinging, dummy heel (using a standardised rubber soling sample), which sweeps over a set area of flooring in a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

HSL 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. The instrument requires a competent operative both to use it and interpret the results. HSE currently believes this to be the only portable instrument that accurately simulates the action of a foot slipping on a wet floor. However, HSL has a programme to evaluate new test methods.

SURFACE MICROROUGHNESS

An indication of slipperiness may be simply obtained by measuring the surface roughness of flooring materials. Many types of roughness tests exist (see Figure 2), but research has shown that measurement of the 'Rz' parameter (formerly known as 'RzDIN' and 'Rtm') 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. This measurement is simple, quick and a good indicator of floor slip resistance.

Figure 2 Surface microroughness meters



INTERPRETATION OF RESULTS

In most circumstances, both pendulum CoF and surface microroughness readings are required to give an accurate indicator of floor surface slipperiness. Results should be interpreted using the information in Tables 1 and 2 (adapted from United Kingdom Slip Resistance Group, 2000).³

Pendulum classifications given in Table 1 are based on the use of a standardised soling material, known as Four-S rubber ('standard simulated shoe sole'), developed by HSL and the UKSRG). This material was designed to represent footwear materials of 'average' slip resistance; use of more or less slippery soling materials may affect the overall potential for slip.

Table 1 Slip risk classification, based on pendulum test values

Pendulum value	Slip risk
0-24	High
25-35	Moderate
36-64	Low
65 +	Extremely low

Table 2 Potential for slip classification, based on Rz microroughness values (applicable for water-wet, low activity pedestrian areas)

Rz surface roughness (microns)	Potential for slip
Below 10	High
10 or above (but below 20)	Moderate
20 or above	Low

PRACTICAL CONSIDERATIONS: PENDULUM

Information generated by the pendulum using Four-S rubber is sufficient for the assessment of the slipperiness in most circumstances. However, for the assessment of barefoot areas or unusually rough floors, the use of TRRL rubber (a similar but softer, more malleable compound) rather than Four-S rubber may be advantageous. Slider choice need not, however, be limited to either material.

Although use of the pendulum has been proven to be successful on all level and inclined floor surfaces, it is not normally considered to be suited to the assessment of stair treads and nosings due to the size of the test area required. Furthermore, although use of the pendulum on heavily profiled flooring materials is possible, doing so can be difficult, and should only be undertaken by experienced operators. Consider, therefore, the use of alternative test methods in such areas.

PRACTICAL CONSIDERATIONS: ROUGHNESS METERS

Research has shown that the use of the Rz roughness parameter is a reliable indicator of floor slipperiness. It is possible to measure other roughness parameters that give a fuller picture of floor surface slipperiness. Further research is currently being carried out to determine whether this 'fuller picture' is necessary.

Although the use of portable, commercially available roughness meters for the assessment of floor surface slipperiness is increasing, they are unsuitable for use on some common flooring types, such as carpet or unusually rough/undulating floors. As such, roughness measurements should only be used as a guide, and should not be used as the sole indicator of the slip potential of flooring materials. However, roughness measurements may be used to monitor changes in floor surface characteristics, such as wear.

The figures quoted in Table 2 relate to floor surface slipperiness in water-wet conditions. If other contaminants are present, differing levels of roughness will be required to lower slip potential. As a general rule, the level of floor surface roughness required is related to the viscosity (or thickness) of the contaminant, as shown in Table 3.

Table 3 Minimum floor roughness levels required for typical workplace contaminants⁶

Minimum roughness	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

OTHER CONSIDERATIONS

Consider other relevant information relating to the slipperiness of the floor to give a more complete picture of pedestrian slip potential. Such information could include the causes and means of preventing 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 (specifically, soling material, tread pattern and condition) and associated environmental and human factors. This slip potential model approach has been shown to be a very powerful tool for the accurate assessment of slipperiness, and can be used as a starting point for a risk assessment-based approach.

OTHER TEST METHODS

HSE/HSL continue to assess newly developed and existing methods for the assessment of slipperiness. Although a small number of reasonably promising tests are available, few have yet produced consistently credible data under either laboratory or site-based conditions.

SLED-TYPE TESTS

Laboratory-based assessments have strongly suggested that several tests currently available (particularly those based on 'sled-type' principles) can produce misleading data. Information from such tests shows that some smooth floorings appear to be less slippery in wet conditions than when dry; this is clearly at odds with everyday experience. Sled tests *are* capable of producing accurate data when used to assess floors in clean, dry or dusty conditions. However, it should be stressed that the vast majority of slipping accidents occur in wet, contaminated conditions.

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: 1992,⁵ see Figure 3). The method involves the use of 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 can be used to calculate the CoF of the level flooring.

Figure 3 The 'HSL DIN ramp' coefficient of friction test



DIN 51097 involves the use of barefoot operators with soap solution as contaminant, and DIN 51130 uses heavily cleated EN345 safety boots with motor oil. HSE has reservations about these test methods, as neither uses contaminants which are representative of those commonly found in workplaces.

The classification scheme outlined in the German National Standard (Table 4) has led to some confusion and misapplication of floor surfaces around the UK.

Table 4 DIN 51130 'R-Value' slipperiness classification regime

Classification	R9	R10	R11	R12	R13
Slip angle	3 ⁰ -10 ⁰	10 ⁰ -19 ⁰	19 ⁰ -27 ⁰	27 ⁰ -35 ⁰	>35 ⁰

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/HSL have been involved in cases where R9 floors have been specified as high performance, 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 which 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.

The ramp-based tests described above have been modified by the HSE/HSL and the UKSRG to address these limitations. The modified test uses clean water as contaminant and footwear with a standardised soling material, and as such is thought to be far more representative. The test method can also be used to assess the slipperiness of footwear, and is currently being drafted for inclusion in a British Standard and the UKSRG guidelines.

SLIPS ASSESSMENT TOOL (SAT)

HSE and HSL have recently developed a PC based package that allows 'non-experts' to assess the slip risk potential presented by level pedestrian walkway surfaces. This Slips Assessment Tool (SAT) prompts the user to collect surface microroughness data from the test area using a hand-held meter. Further information is then fed into the system, such as the floor surface type, the cleaning regime used, the condition of the floor (both in terms of its cleanliness and history), type of footwear worn and human factors relating to pedestrian use. On completion, a 'slip-risk classification' is supplied to the user, this gives an indication as to 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. However, it should not be relied upon when considering the performance of just the flooring. In this instance the pendulum should be used.

In addition, the SAT is also a valuable source of training information, which aims to increase the awareness of the scale of the slips problem, and to familiarise the user with common slip-resistance test methods.

In autumn 2004 HSE/HSL are to make SAT widely available through the Internet, following the completion of an extensive field-testing programme by HSE and local authority inspectors.

INTERPRETATION OF MANUFACTURERS' DATA

It should be noted that most slip resistance information provided by flooring manufacturers is produced from as-supplied products (ie 'ex-factory'). The slipperiness of most flooring materials will normally change significantly on installation, and after short periods of use, maintenance and wear.

Furthermore, data quoted simply as 'CoF' should be viewed with uncertainty as, as described previously, the type of CoF test used can have a critical affect on the validity of the data.

REFERENCES AND FURTHER READING

References

- 1 *Workplace (Health, Safety and Welfare) Regulations 1992 SI 1992/3004*
The Stationery Office 1992 ISBN 0 11 025804 5
- 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 measurement of floor surface slip resistance: Guidelines recommended by the UK Slip Resistance Group* United Kingdom Slip Resistance Group 2000 ISBN 1 85957 2278
- 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 *Preventing slips in the food and drink industries: Technical update on floor specifications* Food Information Sheet FIS22 HSE Books 1999

Further reading

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.htm and at www.hsl.gov.uk/capabilities/pedestrian.htm.

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British Standards are available from BSI Customer Services, 389 Chiswick High Road, London W4 4AL Tel: 020 8996 9001 Fax: 020 8996 7001 Website: www.bsi-global.com

The Stationery Office (formerly HMSO) publications are available from The Publications Centre, PO Box 276, London SW8 5DT Tel: 0870 600 5522 Fax: 0870 600 5533 Website: www.tso.co.uk (They are also available from bookshops.)

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

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