

A study of the characteristics of cementitious surface toppings and applied concrete

Prepared by the **Health and Safety Laboratory**
for the Health and Safety Executive 2007

A study of the characteristics of cementitious surface toppings and applied concrete

Mr Rob Shaw
Health and Safety Laboratory
Harpur Hill Industrial Estate
Harpur Hill
Buxton
SK17 9JN

Slips & trips are the most common cause of major injuries at work and they occur in almost all workplaces; 95% of major slips result in broken bones. In a typical year, slips and trips account for 33% of all reported major injuries and 20% of over-3-day injuries to employees. The construction sector has a higher rate of slips and trips than any other sector. Rarely is there a single cause of a slipping accident, and so a holistic approach to reducing the number of slip accidents is required. The major contributing factor in a slip accident is the interaction of the pedestrians heel and the floor surface. The potential for slip will depend on the footwear worn, the nature of the floor surface and the presence of any contamination.

Cementitious floors are present in many work places, particularly in the construction sector and in warehouses. The slip resistance of these surfaces will depend on the application technique used, and therefore the surface finish obtained. The aim of this study was to assess the slip resistance of cement floors applied using a variety of techniques and to determine whether the application of dry shake techniques such as surface hardeners and dust inhibitors effects the slip properties of the surface.

This report and the work it describes were funded by the Health and Safety Executive (HSE). Its contents, including any opinions and/or conclusions expressed, are those of the author alone and do not necessarily reflect HSE policy.

© Crown copyright 2007

First published 2007

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means (electronic, mechanical, photocopying, recording or otherwise) without the prior written permission of the copyright owner.

Applications for reproduction should be made in writing to:
Licensing Division, Her Majesty's Stationery Office,
St Clements House, 2-16 Colegate, Norwich NR3 1BQ
or by e-mail to hmsolicensing@cabinet-office.x.gsi.gov.uk

CONTENTS

1. Introduction	5
2. Experimental Procedures.....	6
3. Results	7
4. Discussion	10
5. Conclusions and Recommendations.....	11
Appendix A: Slip Resistance Data	12
Appendix B: UKSRG Guidelines	31
Appendix C: HSE Information Sheet Slips & Trips 1	32

EXECUTIVE SUMMARY

Slips & trips are the most common cause of major injuries at work and they occur in almost all workplaces; 95% of major slips result in broken bones. There are many separate factors which contribute to the slip potential of a particular workplace. These include the floor surface, footwear worn by pedestrians, contamination present and management regimes such as cleaning. The aim of this study was to analyse the slip resistance of a range of cement floor finishes and determine the effects of different application techniques and applied toppings in order to further the knowledge of HSE and HSL.

A range of surfaces were measured using standard HSL/HSE techniques to determine their slip resistance characteristics. Previous HSE/HSL work involving cementitious surfaces was reviewed.

The following conclusions were reached and further work identified:

- The slip resistance of cementitious floor surfaces is dependant on surface finish.
- In contaminated conditions appropriate levels of surface roughness will be required to offer a pedestrian slip resistance.
- Inconsistent finishes in smooth surfaces such as power floated concrete may prove hazardous to pedestrians if not visually obvious.
- The presence of dust on a smooth cement surface may not be obvious but can present a slip hazard. Steps must be taken to reduce the incidence of dust on such surfaces and appropriate cleaning regimes implemented for the adequate removal of dust.
- Further study into the topic is required, specifically more work on the effects of surface toppings.
- More measurements on cementitious floors with surface hardeners and dust inhibitors.
- A study of the effectiveness of dust inhibitors at reducing the incidence of dust on concrete surfaces.

1. INTRODUCTION

Slips & trips are the most common cause of major injuries at work and they occur in almost all workplaces; 95% of major slips result in broken bones. In a typical year, slips and trips account for 33% of all reported major injuries and 20% of over-3-day injuries to employees. The construction sector has a higher rate of slips and trips than any other sector. Rarely is there a single cause of a slipping accident, and so a holistic approach to reducing the number of slip accidents is required. The major contributing factor in a slip accident is the interaction of the pedestrians heel and the floor surface. The potential for slip will depend on the footwear worn, the nature of the floor surface and the presence of any contamination.

Cementitious floors are present in many work places, particularly in the construction sector and in warehouses. The slip resistance of these surfaces will depend on the application technique used, and therefore the surface finish obtained. The aim of this study was to assess the slip resistance of cement floors applied using a variety of techniques and to determine whether the application of dry shake techniques such as surface hardeners and dust inhibitors effects the slip properties of the surface.

2. EXPERIMENTAL PROCEDURES

Visits were undertaken to evaluate the slip resistance in a range of premises with different cementitious floor surfaces. Previous site work involving cementitious floors was also evaluated.

A series of full forensic slipperiness investigations were undertaken using standard HSL / HSE techniques in accordance with the Guidelines Recommended by the United Kingdom Slip Resistance Group, (Issue 2, 2000 and Issue 3, 2005) where applicable. Due regard was also given to the protocols outlined in BS 7976:2, 2000. Data generated during the assessments is reproduced in Appendix A. Tables used during interpretation are given in Appendix B.

Measurements of floor surface “Pendulum Test value” (PTV also known as SRV, closely related to Coefficient of Dynamic Friction) were made using a calibrated Pendulum slipperiness assessment instrument. Data was generated [i] in the as-found, dry condition, and [ii] after application of low volumes of potable water to the flooring by hand-spray. Two test slider materials were used as appropriate; Slider 96, also known as Four-S rubber (Standard Simulated Shoe Sole, developed by the UKSRG to represent a footwear material of moderate performance), and TRRL rubber, also known as slider 55 (which is used as a secondary standard shoe soling material by the Health & Safety Laboratory and the UK Slip Resistance Group). Data was generated in three complementary test directions where appropriate in order to account for the presence of floor surface directionality. Further testing was undertaken using a calibrated surface microroughness transducer, set to the Rz parameter.

The UKSRG Guidelines have been used to interpret the surface microroughness and Pendulum Test Value results given (relevant tables and excerpts are reproduced in Appendix B). Due regard was also given to HSE’s Slips & Trips 1 Information Sheet (Appendix C).

The test results presented relate only to the floor areas under study at the time of testing. The performance of installed flooring materials may change significantly during their lifetime; slip resistance is critically dependent on the level and type of contamination, treatment, maintenance and effective cleaning subsequent to installation.

3. RESULTS

The following table summarises surface roughness and Pendulum Test Values for the range of surfaces tested. All PTV results are generated with slider 96 rubber, which represents a shod pedestrian (the most frequent user in all of the areas studied). Full results for each area studied can be found in Appendix A.

Floor Type	Rz Surface Roughness(μm)	Condition	Direction	PTV (slider 96)	Notes
Power floated concrete	6.0	Dry	I	70	
		Dry	II	73	
		Dry	III	73	
		Wet	I	9	
		Wet	II	11	
		Wet	III	11	
Power floated concrete	6.3	Dry	I	61	
		Dusty	I	47	
		Dusty	II	41	
		Dusty	III	46	
		Wet	I	21	
		Wet	II	29	
Installed cement paver	13.7	Damp	I	40	
		Wet	I	26	
Power floated concrete, with hardener	16.8	Dry	I	50	Greasy, difficult to get totally clean
		Dry	II	49	
		Dry	III	45	
		Wet	I	19	
		Wet	II	25	
		Wet	III	21	
Power floated concrete, worn	17.8	Dry	I	65	Porous
		Dry	II	64	
		Dry	III	63	
		Dusty	I	60	
		Wet	I	39	
		Wet	II	47	
		Wet	III	41	
Power floated concrete	19.9	Dry	I	62	
		Dusty	I	45	
		Wet	I	30	

Rough concrete	23.5	Dusty	I	56	
		Dusty	II	54	
		Dusty	III	54	
		Wet	I	45	
		Dusty and wet	I	40	
Rough concrete	38.0	Dusty	I	56	
		Dusty	II	58	
		Dusty	III	58	
		Wet	I	54	
		Dusty and wet	I	50	
Power floated concrete, worn	39.8	Dry	I	52	
		Dry	II	47	
		Dry	III	51	
		Wet	I	38	
		Wet	II	48	
		Wet	III	36	
Rough concrete, with epoxy/aggregate coating	49.4	Dry	I	69	
		Wet	I	69	
Rough concrete, etched	55.5	Dry	I	57	
		Water/chrome tan	I	56	
Rough concrete, with aggregate	58.3	Wet	I	40	
		Wet	II	41	
		Wet	III	40	
Uninstalled cement paver	68.2	Dry	I	66	
		Wet	I	57	
Patterned concrete paver	N/A	Wet	I	40	
		Wet	II	45	
		Wet	III	44	
Profiled concrete paver	N/A	Wet	I	67	
		Wet	III	54	
		Wet	IV	49	
Power floated concrete, with epoxy/aggregate coating	N/A	Wet, paste, paper pulp	I	43	

Figure 3.1 Table of surface roughness and PTV data for the range of surfaces studied.

If we plot surface roughness against wet PTV we see a clear trend. As surface roughness increases so does wet PTV.

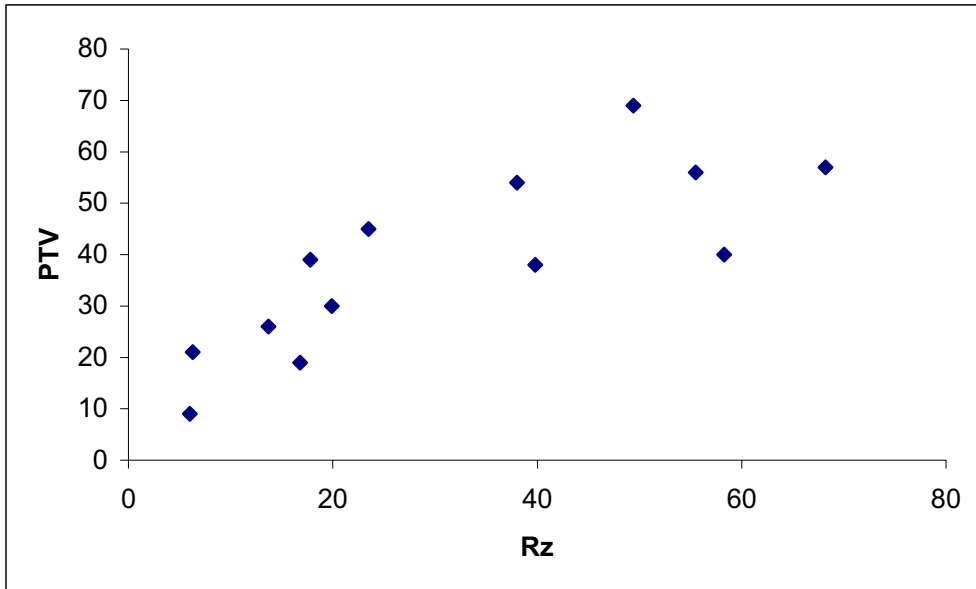


Figure 3.2 Graph of surface roughness v wet PTV in direction I only

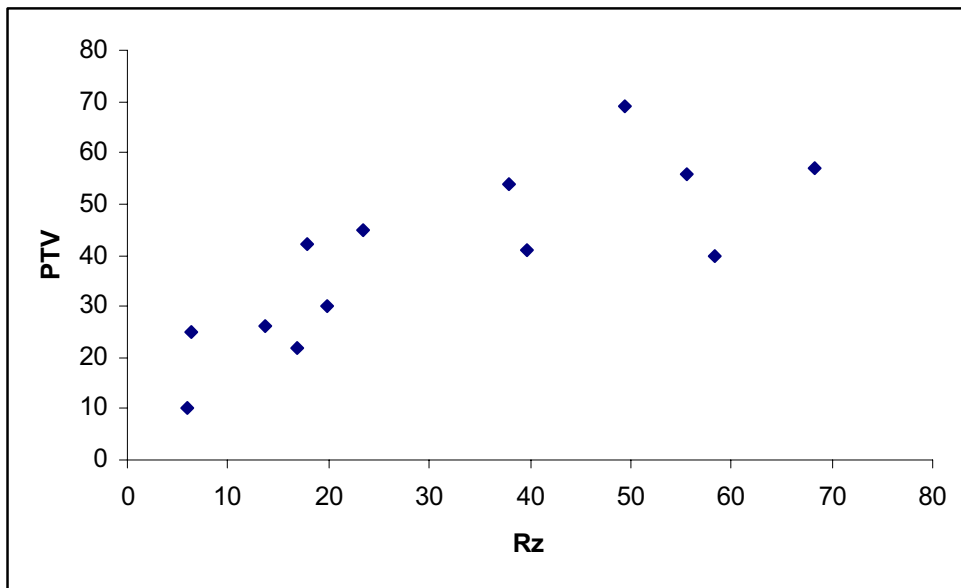


Figure 3.3 Graph of surface roughness v average wet PTV

4. DISCUSSION

The correlation between Rz and wet PTV was plotted for all surfaces on which both values could be obtained. Two graphs were produced of Rz against wet PTV in direction I only (Figure 3.2) and Rz against wet PTV where the average of the three directions was taken (Figure 3.3). Where possible on site, direction I is the main direction of pedestrian travel. If the floor surface is clean and dry it can be reasonably expected that the floor will present a low slip potential. The slip potential in contaminated conditions is therefore more important when considering the slip resistance of a surface.

A rougher surface has a better chance of breaking through a squeeze film of contaminant and making contact with a pedestrians heel. The more viscous the contaminant the greater the level of roughness required to offer a high level of slip resistance. Cementitious floor surfaces appear to behave in a similar manner to other hard surfaces observed in previous HSL/HSE lab work and site visits. As Rz surface roughness increases so does PTV in contaminated conditions.

The main limitation of this study is the relatively small number of floors measured. Although the trend shown in Figures 3.2 and 3.3 is quite clear we still know very little about the effects of various surface toppings. Only one dutyholder in the premises visited knew the exact specification of the floor. From this work it would appear that surface hardeners do not alter the slip resistance of a surface, which is still dependant on the level of surface microroughness, however as only one floor was known for sure to have been treated with a surface hardener this is far from conclusive evidence.

One of the main problems seen with power floated concrete floors was the inconsistent nature of the application. Almost all floors studied had rougher and smoother patches within the overall finish. One of the biggest contributing factors in a slipping accident is a change in the level of slip resistance underfoot without an accompanying visual difference to warn the pedestrian to change their gait. This may mean that power floated concrete floors are more dangerous than consistent surfaces with similar levels of slip resistance.

Another problem with concrete floors, especially newer surfaces, is the generation of dust. Most of the power floated surfaces studied had significant level of dust present on the surface. This reduced the dry Pendulum Test Values obtained and quickly built up on the soles of workers shoes. Often cleaning regimes were not effective enough to remove dust from the surface.

5. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

- The slip resistance of cementitious floor surfaces is dependant on surface finish.
- In contaminated conditions appropriate levels of surface roughness will be required to offer a pedestrian slip resistance.
- Inconsistent finishes in smooth surfaces such as power floated concrete may prove hazardous to pedestrians if not visually obvious.
- The presence of dust on a smooth cement surface may not be obvious but can present a slip hazard. Steps must be taken to reduce the incidence of dust on such surfaces and appropriate cleaning regimes implemented for the adequate removal of dust.

Recommendations

- Further study into the topic is required, specifically more work on the effects of surface toppings.
- More measurements on cementitious floors with surface hardeners and dust inhibitors.
- A study of the effectiveness of dust inhibitors at reducing the incidence of dust on concrete surfaces.

APPENDIX A: SLIP RESISTANCE DATA

Area 1: Power floated concrete, warehouse

Smooth Patch



Rz Surface Roughness: 6.3 μm

Pendulum SRV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	SRV
As-found	Dusty	Direction I	47
As-found	Dusty	Direction II	41
As-found	Dusty	Direction III	46
As-found	Wet	Direction I	21
As-found	Wet	Direction II	29
As-found	Wet	Direction III	24
As-found	Dusty	Direction I	45
Cleaned	Dry	Direction I	61
Cleaned	Wet	Direction I	24

Rough Patch



Rz Surface Roughness: 19.9 μm

Pendulum SRV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	SRV
As-found	Dusty	Direction I	45
As-found	Wet	Direction I	30
Cleaned	Dry	Direction I	62
Cleaned	Wet	Direction I	27

Area 2: Power floated concrete surface; several measurements taken



[i]

Pendulum SRV New Four-S Rubber Slider

Condition	Contamination	Test Direction	SRV
As-found	Dry	Direction I	54
As-found	Dry	Direction II	43
As-found	Dry	Direction III	36
As-found	Dry	Direction I	36

Slider Reconditioned

Condition	Contamination	Test Direction	SRV
As-found	Dry	Direction I	64
As-found	Dry	Direction II	41
As-found	Dry	Direction III	42
As-found	Dry	Direction I	42
As-found	Wet	Direction I	19

Pendulum SRV Worn Four-S Rubber Slider

Condition	Contamination	Test Direction	SRV
As-found	Dry	Direction I	75
As-found	Dry	Direction II	63
As-found	Dry	Direction III	60
As-found	Wet	Direction I	11
As-found	Wet	Direction III	20
As-found	Damp	Direction III	66

[ii]

Condition	Contamination	Test Direction	SRV
As-found	Dry	Direction I	60
As-found	Wet	Direction I	16

Rough area by join

Condition	Contamination	Test Direction	SRV
As-found	Dry	Direction I	60
After cleaning with scrubber dryer	Dry	Direction I	64

[iii]

Pendulum SRV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	SRV
As-found	Dry	Direction I	45
As-found	Water-wet	Direction I	20

[iv]

Pendulum SRV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	SRV
As-found	Dry	Direction I	50
As-found	Water-wet	Direction I	30

[v]

Pendulum SRV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	SRV
As-found	Dry	Direction I	61
As-found	Water-wet	Direction I	14

[vi]

Pendulum SRV (Four-S Rubber Slider)

Smooth area

Condition	Contamination	Test Direction	SRV
As-found	Dry	Direction I	53
As-found	Water-wet	Direction I	19

Rougher area

Condition	Contamination	Test Direction	SRV
As-found	Dry	Direction I	60
As-found	Water-wet	Direction I	21

[vii]

Pendulum SRV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	SRV
As-found	Dry	Direction I	60
As-found	Water-wet	Direction I	42

[viii]

Pendulum SRV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	SRV
As-found	Dry	Direction I	57
As-found	Water-wet	Direction I	16

[ix]

Pendulum SRV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	SRV
As-found	Dry	Direction I	52
As-found	Water-wet	Direction I	23

Area 3: Old power floated concrete floor, worn

Rz Surface Roughness: 17.8 µm

Pendulum SRV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	SRV
As-found	Dusty	Direction I	60
As-found	Wet	Direction I	39
As-found	Dry	Direction I	65
As-found	Dusty and wet	Direction I	45
Swept	Dry	Direction I	65
Swept	Dry	Direction II	64
Swept	Dry	Direction III	63
Swept	Wet	Direction I	39
Swept	Wet	Direction II	47
Swept	Wet	Direction III	41
Swept	Damp	Direction I	70
Cleaned	Dry	Direction I	64
Cleaned	Wet	Direction I	37

Area 4: Treated cement floors



Floor Type: Powerfloated concrete with dry shake hardner

Rz Surface Roughness: 16.8 μm (mean)

PTV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	PTV
As-found	Dust/grease	Direction I	35
Cleaned	Dry	Direction I	50
Cleaned	Dry	Direction II	49
Cleaned	Dry	Direction III	45
Cleaned	Wet	Direction I	19
Cleaned	Wet	Direction II	25
Cleaned	Wet	Direction III	21



Floor Type: Concrete With Epoxy / Aggregate Coating

Rz Surface Roughness: 49.4 μm (mean)

PTV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	PTV
As-found	Dry	Direction I	69
Cleaned	Wet	Direction I	69

Contaminated Edge

PTV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	PTV
As-found	Wet	Direction I	71

Area 5: Rough cement floor with aggregate



[i]

Rz Surface Roughness: 58.3 μm (mean)

SRV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	SRV
As-found	Greasy Water	Direction I	44
As-found	Greasy Water	Direction II	34
As-found	Greasy Water	Direction III	34
Cleaned	Water	Direction I	40
Cleaned	Water	Direction II	41
Cleaned	Water	Direction III	40

[ii]

SRV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	SRV
As-found	Greasy Water	Direction I	40
As-found	Greasy Water	Direction II	36
As-found	Greasy Water	Direction III	42

[iii]

Rz Surface Roughness: 55.5 µm (mean)

SRV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	SRV
As-found	Dry	Direction I	57
As-found	Chrome tan/water	Direction I	56

Area 6: Concrete paving slabs

[1]



Surface type: Patterned concrete paver

Pendulum Tests (Rubber Slider 96)

Condition	Contamination Test	Direction	PTV
As-found	Wet	Direction I	40
As-found	Wet	Direction II	45
As-found	Wet	Direction III	44

Pendulum Tests (TRRL Rubber Slider)

Condition	Contamination Test	Direction	PTV
As-found	Wet	Direction I	32
As-found	Wet	Direction II	31
As-found	Wet	Direction III	32

[ii]



Surface type: Profiled concrete paver
Slope: 7.6 degrees

Pendulum Tests (Rubber Slider 96)

Condition	Contamination Test	Direction	PTV
As-found	Wet	Direction I	67
As-found	Wet	Direction III	54
As-found	Wet	Direction IV	49

Pendulum Tests (TRRL Rubber Slider)

Condition	Contamination Test	Direction	PTV
As-found	Wet	Direction I	42
As-found	Wet	Direction III	42
As-found	Wet	Direction IV	45

[iii]

Surface type: Profiled concrete paver, less worn

Pendulum Test (Rubber Slider 96)

Condition	Contamination Test	Direction	PTV
As-found	Wet	Direction IV	50

Pendulum Test (TRRL Rubber Slider)

Condition	Contamination Test	Direction	PTV
As-found	Wet	Direction IV	52

Area 7: Power floated concrete, worn

Temperature: Approx. 5°C

Rz Surface Roughness: 39.8 µm (mean)

Pendulum SRV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	SRV
As-found	Dry	Direction I	52
As-found	Dry	Direction II	47
As-found	Dry	Direction III	51
As-found	Water-wet	Direction I	38
As-found	Water-wet	Direction II	48
As-found	Water-wet	Direction III	36
Cleaned	Water-wet	Direction I	52
As-found	Hydraulic Oil	Direction I	20

Pendulum SRV (TRRL Rubber Slider)

Condition	Contamination	Test Direction	SRV
As-found	Dry	Direction I	78
As-found	Dry	Direction II	82
As-found	Dry	Direction III	86
As-found	Water-wet	Direction I	39
As-found	Water-wet	Direction II	34
As-found	Water-wet	Direction III	41
Cleaned	Water-wet	Direction I	49
As-found	Hydraulic Oil	Direction I	15

Area 8: Concrete, before and after anti-slip treatment

[i]



Floor type: Smooth Concrete

Rz Surface Roughness: 6.0 µm (mean)

Pendulum SRV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	SRV
As-found	Dry	Direction I	70
As-found	Dry	Direction II	73
As-found	Dry	Direction III	73
As-found	Water-wet	Direction I	9
As-found	Water-wet	Direction II	11
As-found	Water-wet	Direction III	11
Cleaned	Dry	Direction I	62
Cleaned	Water-wet	Direction I	11
Cleaned	Poster Paste	Direction I	7

[ii]



Floor type: Anti-Slip Painted Concrete – with ‘grit’ particles

Rz Surface Roughness: N/A
Too much contamination to measure without risking damage to the Surtronic Duo and contamination too difficult (ingrained) to remove.

Pendulum SRV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	SRV
As-found	Damp, some paste, paper/pulp	Direction I	43

Area 9: Cement paving, installed and uninstalled

[i]



Rz Surface Roughness: 13.7 μm (mean)

Pendulum SRV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	SRV
As-found	Damp / Drying	Direction I	40
As-found	Water-wet	Direction I	26

[ii]



Rz Surface Roughness: 68.2 μm (mean)

Pendulum SRV (Four-S Rubber Slider)

Condition	Contamination	Test Direction	SRV
As-found	Dry	Direction I	66
As-found	Water-wet	Direction I	57

Pendulum SRV (TRRL Rubber Slider)

Condition	Contamination	Test Direction	SRV
As-found	Dry	Direction I	91
As-found	Water-wet	Direction I	65

Area 10: Rough concrete, warehouse



[i]

Rz Surface Roughness: 38.0 μm (mean)

PTV (Slider 96 rubber)

Condition	Contamination	Test Direction	PTV
As-found	Dusty	Direction I	56
As-found	Dusty	Direction II	58
As-found	Dusty	Direction III	58
As-found	Dusty and wet	Direction I	50
Cleaned	Dry	Direction I	52
Cleaned	Wet	Direction I	54
As-found	Deep compacted dust	Direction I	54

[ii]

Rz Surface Roughness: 23.5 µm (mean)

PTV (Slider 96 rubber)

Condition	Contamination	Test Direction	PTV
As-found	Dusty	Direction I	56
As-found	Dusty	Direction II	54
As-found	Dusty	Direction III	54
As-found	Dusty and wet	Direction I	40
Cleaned	Dry	Direction I	50
Cleaned	Wet	Direction I	45

APPENDIX B: UKSRG GUIDELINES

EXCERPTS FROM “THE MEASUREMENT OF FLOOR SLIP RESISTANCE - GUIDELINES RECOMMENDED BY THE UK SLIP RESISTANCE GROUP”, ISSUE 2, JUNE 2000.

IMPORTANT NOTE: Research in the UK by the Health and Safety Executive (HSE) has identified that more than 90% of slipping accidents occur on wet floors, most usually on relatively smooth surfaces. Evaluation of the slip resistance of floors is not an exact science. In addition to selected measuring instruments, it demands the relevant expertise and methodical procedures. In this context these guidelines offer advisory information in respect of measuring the slip resistance of flooring materials under water-wet conditions.

The information within this document, which may be revised as knowledge and understanding of pedestrian slipping increase, does not define the ‘safety status’ of any floor or flooring material at any stage of its service life.

Four-S Pendulum Value	Potential for Slip
25 and below	High
25 to 35	Moderate
35 to 65	Low
Above 65	Extremely Low

TRRL Pendulum Value	Potential for Slip
19 and below	High
20 to 39	Moderate
40 to 74	Low
Above 75	Extremely Low

Rz (Rtm) Surface Roughness*	Potential for Slip
Below 10	High
Between 10 and 20	Moderate
Above 20 and up to 30	Low
Above 30	Extremely Low

*Roughness values applicable for water-wet, low activity pedestrian areas.

EXCERPTS FROM “THE MEASUREMENT OF FLOOR SLIP RESISTANCE - GUIDELINES RECOMMENDED BY THE UK SLIP RESISTANCE GROUP”, ISSUE 3, 2005.

Pendulum Test Value	Potential for Slip
24 and below	High
25 to 35	Moderate
36 and above	Low

Rz (Rtm) Surface Roughness*	Potential for Slip
Below 10	High
Between 10 and 20	Moderate
Above 20	Low

APPENDIX C: HSE INFORMATION SHEET SLIPS & TRIPS 1

Assessing the slip resistance of flooring

A technical information sheet

HSE information sheet

Slips and trips 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).

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.

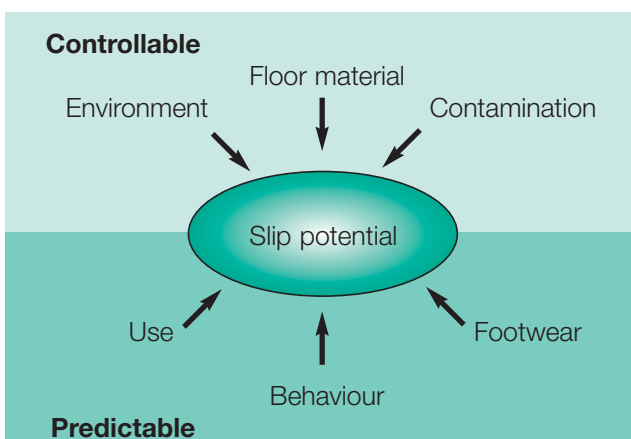


Figure 1 Slip potential model

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

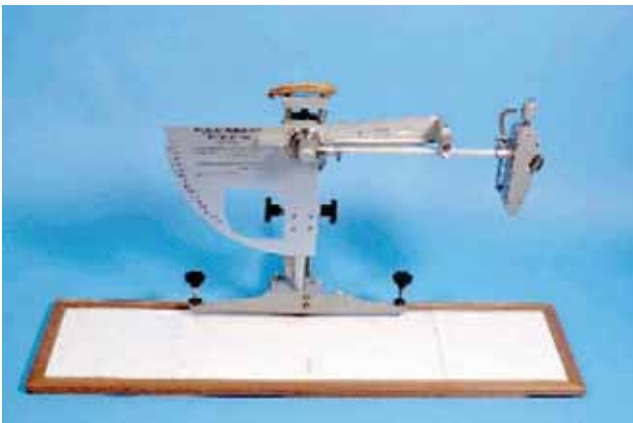


Figure 2 The pendulum CoF test

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.

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



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.

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.

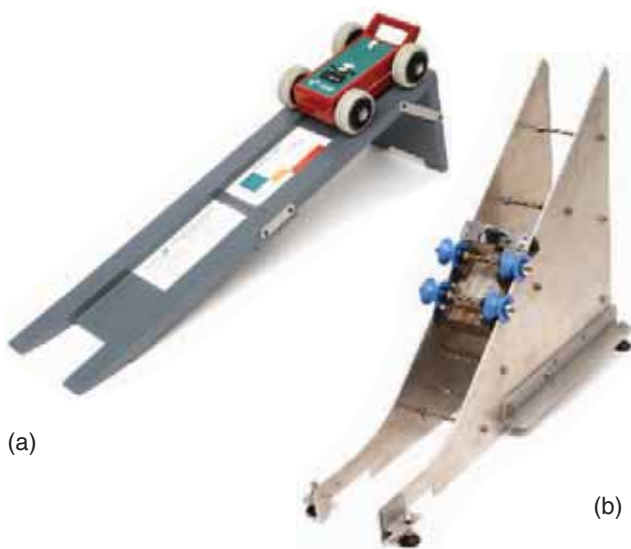


Figure 5 Roller-coaster slip tests
(a) SlipAlert CoF test (b) The laboratory prototype CoF test

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.

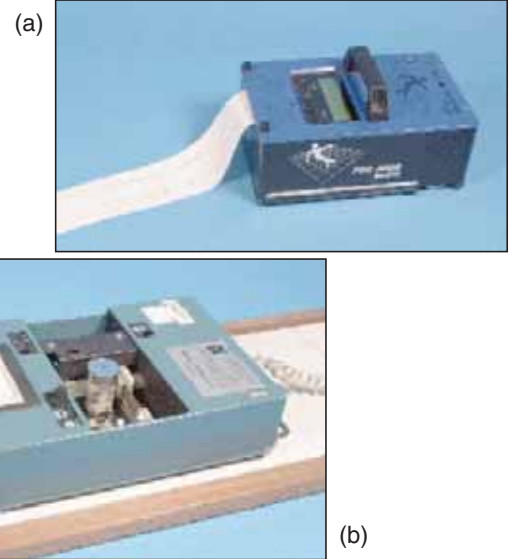


Figure 6 Sled-type tests
(a) The FSC2000 (b) the Tortus test

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

HSE priced and free publications are available by mail order from HSE Books, PO Box 1999, Sudbury, Suffolk CO10 2WA Tel: 01787 881165 Fax: 01787 313995 Website: www.hsebooks.co.uk (HSE priced publications are also available from bookshops and free leaflets can be downloaded from HSE's website: www.hse.gov.uk.)

For information about health and safety ring HSE's Infoline Tel: 0845 345 0055 Fax: 0845 408 9566 Textphone: 0845 408 9577 e-mail: hse.infoline@natbrit.com or write to HSE Information Services, Caerphilly Business Park, Caerphilly CF83 3GG.

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

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.

© *Crown copyright* This publication may be freely reproduced, except for advertising, endorsement or commercial purposes. First published 03/07. Please acknowledge the source as HSE.

A study of the characteristics of cementitious surface toppings and applied concrete

Slips & trips are the most common cause of major injuries at work and they occur in almost all workplaces; 95% of major slips result in broken bones. In a typical year, slips and trips account for 33% of all reported major injuries and 20% of over-3-day injuries to employees. The construction sector has a higher rate of slips and trips than any other sector. Rarely is there a single cause of a slipping accident, and so a holistic approach to reducing the number of slip accidents is required. The major contributing factor in a slip accident is the interaction of the pedestrians heel and the floor surface. The potential for slip will depend on the footwear worn, the nature of the floor surface and the presence of any contamination.

Cementitious floors are present in many work places, particularly in the construction sector and in warehouses. The slip resistance of these surfaces will depend on the application technique used, and therefore the surface finish obtained. The aim of this study was to assess the slip resistance of cement floors applied using a variety of techniques and to determine whether the application of dry shake techniques such as surface hardeners and dust inhibitors effects the slip properties of the surface.

This report and the work it describes were funded by the Health and Safety Executive (HSE). Its contents, including any opinions and/or conclusions expressed, are those of the author alone and do not necessarily reflect HSE policy.