

Technical Report Title:

**Determination of the Pendulum
Test Value (PTV) for sample
specimens referenced as:**

▪ **MG-F Floorart**

Test procedure(s) in accordance with:

BS 7976-2:2002+A1:2013
Pendulum testers – method of operation.

UKSRG Guidelines-5:2016
The assessment of floor slip resistance.

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Change History

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| Date | Revision | Details | Section | Author | Registered Client Recipient |
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1 SCOPE

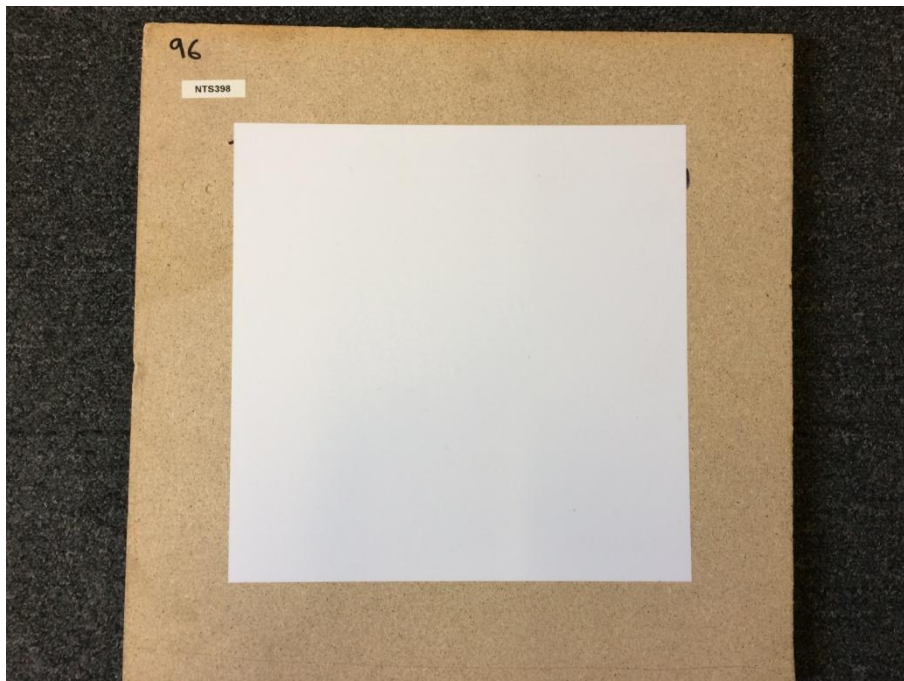
We were commissioned by Metamark UK Limited to determine the Pendulum Test Value (PTV) of the following sample specimens, referenced as:

- NTS398 MG-F Floorart - Shod
- NTS397 MG-F Floorart - Barefoot

Pendulum slip tests were therefore undertaken using standard HSE techniques in accordance with BS 7976-2:2002+A1:2013, and the UK Slip Resistance Guidelines (UKSRG) – Issue 5:2016, where appropriate. For each individual sample specimen, a full set of Pendulum slip tests was completed in three directions (180°, 90° and 45°). Tests were carried out in dry and wet surface conditions using a calibrated Pendulum tester, rubber slider 96 which is a hard shoe heel type material of moderate slip resistance and is the primary test rubber when evaluating flooring materials for pedestrian use, slider 55 which is used to simulate barefoot users and a Surtronic micro-roughness tester.

Testing in wet surface conditions was completed using potable water applied by a hand held sprayer. It was assumed that this type of contamination would be representative of the worst case scenario encountered by pedestrian walking on the material. No cleaning of the specimens was carried out by our technician prior to testing in the “as-found” condition.

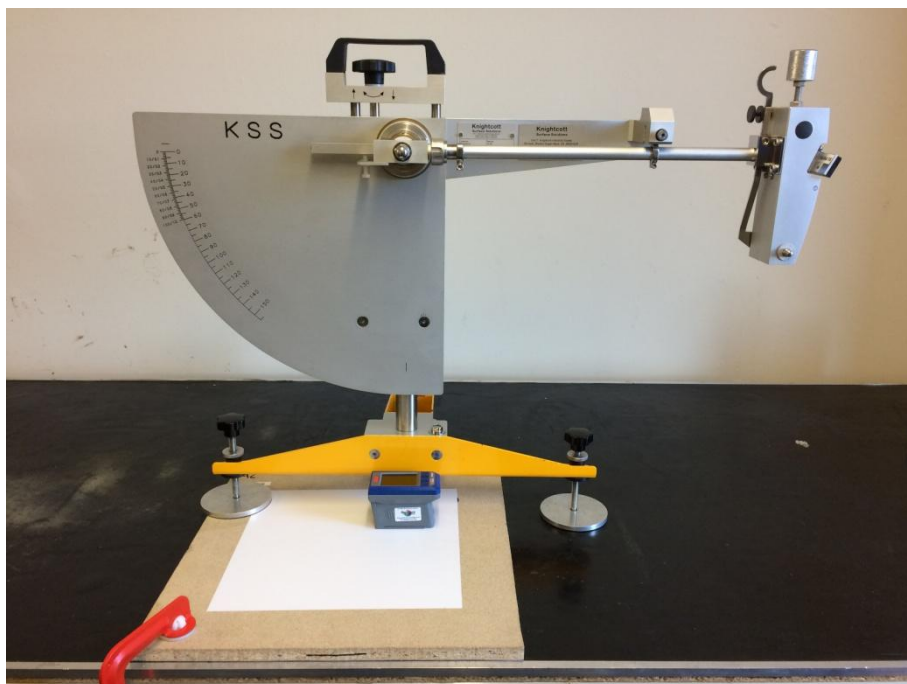
1.1 Photographs of sample specimens



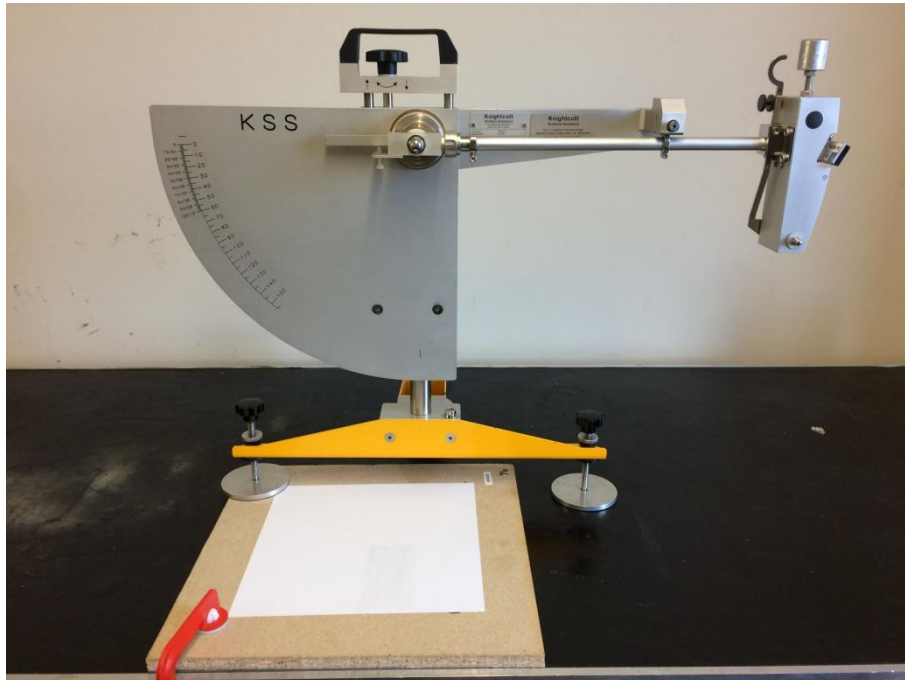
Sample specimen 1: MG-F Floorart - Shod



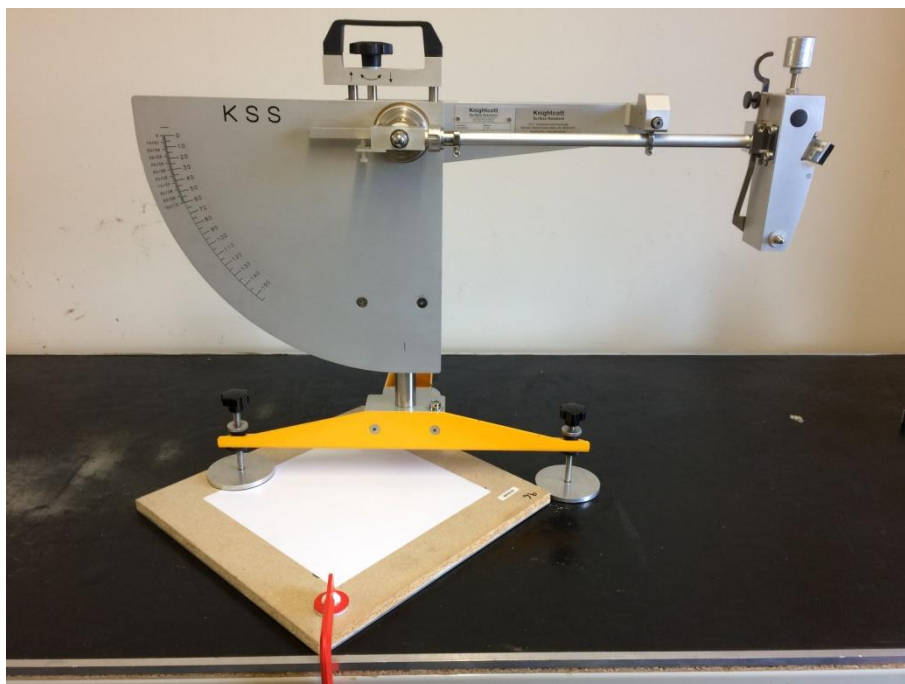
Sample specimen 1: MG-F Floorart - Barefoot



Test Direction 180°.



Test Direction 90°.



Test Direction 45°.

--- END OF SECTION ---

2 ASSESSMENT RESULTS

Pendulum Test Values (PTV) were determined in both dry and contaminated conditions – see Section 1, Scope for full test protocols. Wet conditions were simulated by the application of potable water using a hand held spray - see Section 3.1. The surface roughness (Rz) of each test area was also measured (see Section 3.2).

2.1 Pendulum Test Values

| DETERMINATION OF PENDULUM TEST VALUE | | | | | | | | | | | |
|---|---|-------------------------|----------|----------------|-----|-------------------------|---|--|---|------|-------------------------|
| IN ACCORDANCE WITH BS 7976-2:2001+A1:2013 AND THE UK SLIP RESISTANCE GROUP GUIDELINES, ISSUE 5:2016 | | | | | | | | | | | |
| Description of sample specimen(s) and type of slider used. | Surface | | Temp (°) | Test Direction | PTV | Max. Floor Gradient (°) | Slope Corrected Values [Based on Max. Floor Gradient] | | | | |
| | Condition | Contamination | | | | | Slip Potential [Each Direction] | Overall Classification [Based on Lowest Direction] | | | |
| | | | | | | | | Slip Potential | Slip Risk ⁵ | | |
| (1) NTS398 MG-F Floorart – using slider 96. | As found conditions, no cleaning carried out prior to test. | Dry surface. | N/A° | A ¹ | 76 | N/A | Low | Low | ≥ 1 in 1,000,000 users. | | |
| | | | | B ² | 75 | | Low | | | | |
| | | | | C ³ | 75 | | Low | | | | |
| | | | | D ⁴ | N/A | | N/A | | | | |
| (2) NTS397 MG-F Floorart – using slider 55. | | | 18.0° | A ¹ | 102 | N/A | Low | | | | |
| | | | | B ² | 101 | | Low | | | | |
| | | | | C ³ | 124 | | Low | | | | |
| | | | | D ⁴ | N/A | | N/A | | | | |
| (1) NTS398 MG-F Floorart – using slider 96. | As found conditions, no cleaning carried out prior to test. | Wet with potable water. | N/A° | A ¹ | 35 | N/A | Moderate | Moderate | Between 1 in 10,000 and 1 in 100,000 users. | | |
| | | | | B ² | 32 | | Moderate | | | | |
| | | | | C ³ | 32 | | Moderate | | | | |
| | | | | D ⁴ | N/A | | N/A | | | | |
| (2) NTS397 MG-F Floorart – using slider 55. | | | 18.0° | A ¹ | 16 | N/A | High | | | High | Less than 1 in 2 users. |
| | | | | B ² | 17 | | High | | | | |
| | | | | C ³ | 19 | | High | | | | |
| | | | | D ⁴ | N/A | | N/A | | | | |

¹Test Direction A = 180° parallel to the principle direction, see photographs.

²Test Direction B = 90° to same.

³Test Direction C = 45° to same.

⁴Test Direction D = only applicable to surfaces with a raised geometric surface, when tested using the Pendulum.

--- = Not tested due to either space restrictions due to design, or test direction not applicable or wet weather/surface conditions.

⁵ When considering the Pendulum Test Value (PTV) and slip potential results, care should be taken when interpreting results that are close to the boundaries of the categories. The slip potential presented by a floor with a PTV of 35 is not significantly different from one with a PTV of 37. However, the slip potential presented by a floor with a PTV of 23 is considerably higher than one with a PTV of 26, when considering the biomechanical data currently available.

⁵ Current UKSRG guidance suggests that the reading in the direction that gives the lowest PTV is likely to indicate the lowest slip resistance that a pedestrian would experience when walking at different angles and so should be considered when assessing the slip potential and design of any in-situ surfaces using this material.

⁵ The risk ratios and results above are based on the basic condition of a reasonably active pedestrian aged between 18 -60 years, walking in a straight line at moderate pace, not rushing, turning, carrying, pushing or pulling a load. Moving away from this basic condition creates additional risks to users of the area and therefore increases slip potential. If such risks are identified then the likelihood of a slip accident occurring is even higher than stated.

2.2 Surface Roughness (Rz) Readings

| Surface Roughness (Rz) Readings | MEAN |
|--------------------------------------|--------|
| (1) NTS398 MG-F Floorart - Shod. | 8.2 µm |
| (2) NTS397 MG-F Floorart - Barefoot. | 9.7 µm |

2.3 Technician Observations

No technician observations were recorded as part of this assessment.

--- END OF SECTION ---

3 EXPLANATION OF ASSESSMENT METHODS

Research carried out by the Health and Safety Laboratory (HSL), in conjunction with the UK Slip Resistance Group (UKSRG), has shown that it is possible to assess the characteristics of floor surface materials needed for satisfactory slip resistance. The Health and Safety Laboratory has developed a set of “reliable and robust” test methods that forms the basis of our assessment protocols.

3.1 BS 7976-2:2002 + A1:2013 Pendulum Testers, Method of Operation

Pendulum testing is carried out in accordance with BS 7976-2 and the UKSRG Guidelines 2011, where appropriate. These industry standard methods of testing are essentially the same but with a slight difference between the two methods of preparation of the rubber sliders.

A prepared rubber slider attached to a weighted “shoe” is allowed to swing from a horizontal point of release. The slider is mounted on a spring loaded bracket and makes contact with the floor for a known distance of 124 ± 1 mm.

The rubber slider that contacts the floor is constructed of “4S” rubber (Standard Simulated Shoe Sole) also referred to as “Slider 96” and is designed to replicate the most common slipping motion experienced by pedestrians wearing shoes. A softer, more malleable rubber called “Slider 55” can be used to simulate a barefoot slip. Profiled surfaces are tested with both Slider 96 and Slider 55, on the basis that profiles have been shown to give a wide range of slip resistance values with different footwear. The height to which the shoe travels after contacting the floor gives a reading of the Pendulum Test Value (PTV), formally known as the Slip resistance Value (SRV). Pendulum testing is one of the few methods that model the formation of a hydrodynamic squeeze film between the floor and sole, a known major factor in a wet slip.

Test surfaces are subject to eight measurements of the PTV with the first three being discounted from any calculations. Tests are normally carried out in the [A] principal direction, [B] at 45° to the principal direction and [C] at 90° to the principal direction. A fourth direction is also measured when testing profiled surfaces. All testing is carried out in both dry and wet conditions as is intended to give a representative view of the floors intended service conditions. A total of at least 48 measurements are recorded and a mean PTV value is generated for wet and dry tests based on the performance in different directions.

The Pendulum Test Value (PTV) for each direction is calculated as the mean of five swings using the formula:

$$PTV = \frac{(v_4 + v_5 + v_6 + v_7 + v_8)}{5}$$

where v_4 to v_8 are individual values for each swing, or where there is significant variation through v_1 to v_8 it may be necessary to draw attention to the first readings. Although the dry results may not be of interest to the client it should be noted that the wet results might be reduced slightly if the dry testing was not undertaken as it is known that the slider is conditioned by the flooring material during the course of the dry tests.

When using “Slider 55” is it becomes necessary to correct the PTV value as PTV_{corr} using the table below:

| Surface Temperature (°C) | PTV Correction to PTV_{corr} |
|--------------------------|--------------------------------|
| 8 to 11 | Subtract 3 units |
| 12 to 15 | Subtract 2 units |
| 16 to 18 | Subtract 1 unit |
| 19 to 22 | No correction |
| 23 to 28 | Add 1 unit |
| 29 to 35 | Add 2 units |

The PTV for each location is the mean of three individual PTV or PTV_{corr} determinations. A slip potential classification can then be applied using the UKSRG Guidelines, see the table below.

| Pendulum Test Value (PTV) | Slip Potential |
|---------------------------|----------------|
| 0 – 24 | High |
| 25 – 35 | Moderate |
| 36 + | Low |

To further help reduce the slip potential it is important to understand the friction requirements of pedestrians. Data published by the Building Research Establishment (BRE): *Floors and flooring – performance, diagnosis, maintenance, repair and avoidance of defects* (P.W Pye & H.W Harrison 2003) showed that people have different friction requirements. This range of requirements was analysed and related to risk. If the Pendulum Test Value (PTV) is 36 the risk of slipping is one in a million, as the PTV reduces the risk increases and at a PTV of 19 the risk is one in two, see the table below.

| Risk | Minimum PTV | Slip Potential |
|---------------|-------------|----------------|
| 1 : 2 | 19 | High |
| 1 : 20 | 24 | High |
| 1 : 200 | 27 | Moderate |
| 1 : 10,000 | 29 | Moderate |
| 1 : 100,000 | 34 | Moderate |
| 1 : 1,000,000 | 36 | Low |

The risk ratios above are for the basic condition of a reasonably active pedestrian aged between 18 -60 years, walking in a straight line at moderate pace, not turning, carrying, pushing or pulling a load. Moving away from this basic condition will increase the required Pendulum Test Value. Similarly, if a sloping surface has to be negotiated then the PTV requirements will be greater and must be increased by:

$$100 \times \tan \alpha$$

where α is the slope angle. For example, a three degree slope (about 1 in 20 gradient) the tangent is 0.05. Therefore, the require PTV increases by 5 units and a PTV of 41 or above would only be considered acceptable.

An alternative measure of flooring slip resistance is its coefficient of dynamic friction (CoDF). PTV can be converted to CoDF using the formula below. It should be noted that CoDF describes an interaction between two specific surfaces and that this relationship is further complicated by the behaviour of any lubricating film between the two surfaces.

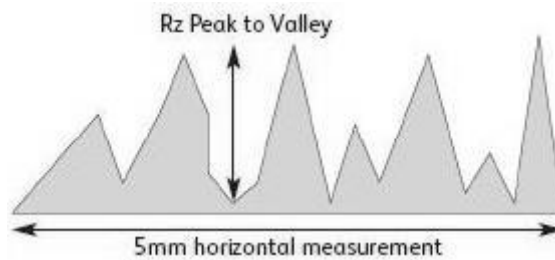
$$CoDF = (3xPTV) / (330-PTV)$$

The pendulum skid tester is one of the few test methods that accurately models the hydrodynamic squeeze film formed in a contaminated slip as experienced by pedestrians. This should be taken into account when comparing CoDF values for contaminated surfaces from other test methods.

3.2 Surface Roughness Measurement (Rz)

Surface roughness, in particular the Rz value describes the mean vertical peak to valley distance over a given horizontal sample. The microscopic construction of a surface affects its ability to puncture the fluid film generated in a slip. It is also a valuable tool to assess the wear level as over time traffic will smooth a floor surface, changing its slip potential.

National Testing use a Surtronic Duo surface roughness meter for assessment. The meter moves a stylus along a 5mm test surface, measuring the floor profile's average vertical peak to valley distance in microns (Rz). A test site will be measured ten times using this method, with samples taken randomly across the surface. Where results indicate a directional profile, ten measurements will be conducted along the profile and ten across the profile. This is in line with UKSRG guidance.



Surface roughness can be used to give a general indication of the slip risk potential of a floor, though it is by no means a comprehensive test. National Testing use surface roughness measurements married to pendulum results to enable accurate on-going monitoring of the surface. The UKSRG published the data shown in the table below to use in conjunction with pendulum testing.

| Surface Roughness Rz (Microns) | Slip Potential |
|--------------------------------|----------------|
| Less than 10µm | High |
| 10 - 20µm | Moderate |
| Greater than 20µm | Low |

Classification for the potential for slipping using Rz roughness in water-wet low level pedestrian areas.

As the viscosity of contaminants increases, the surface roughness required to maintain an acceptable level of slip resistance also increases.

| Minimum Roughness | Contaminant |
|-------------------------|----------------------------------|
| 20 microns | Clean water, coffee, soft drinks |
| 45 microns | Soap solution, milk |
| 60 microns | Cooking stock |
| 70 microns | Motor oil, olive oil |
| Greater than 70 microns | Gear oil, magerine |

Recommended levels of roughness for commonly found contaminants (HSE,2004).

Whilst there is on-going research into the effect of surface roughness on slip resistance it is generally considered that the Rz parameter is a good *indication* of slip risk. Limitations of the Rz measurement are that it does not take into account the density or construction of micro-profile, simply its average height. The stylus measuring peak to valley height may travel around anti-slip particulate or may be too wide to measure the depth of narrow valleys. It is possible for surfaces to have similar Rz values and ultimately differing contaminated slip resistances. Furthermore, Rz does not take into account macro-profiling or the deformation of a softer floor.

National Testing use the relationship between Rz roughness and Pendulum Test Value (PTV) to determine likely thresholds for high, moderate and low slip risk. Where pendulum testing is impossible, such as on stair nosings, Rz measurements married to a similar nearby surface is sometimes the only way to relate a PTV, as recognised by the

UKSRG guidelines. This is based on a linear approximation of the relationship between Rz and PTV, referred to by us at SATRz and is to be considered as a guide only.

--- END OF SECTION ---

4 CONCLUSIONS

NTS398: MG-F Floorart - Shod

Pendulum test results indicate a low-slip risk potential in dry “as-found” and untrafficked surface conditions for shod pedestrian users walking on the nominated sample specimen. The statistical risk of a slip accident occurring on the sample specimens in dry surface conditions is greater than or at least equal to 1 in 1,000,000 users (P.W Pye & H.W Harrison 2003).

However, when contaminated with potable water Pendulum test results indicate a moderate-slip risk potential in wet “as-found” and untrafficked surface conditions for shod pedestrian users walking on the nominated sample specimen. The statistical risk of a slip accident occurring on the sample specimens in wet surface conditions is between 1 in 10,000 and 1 in 100,000 users (P.W Pye & H.W Harrison 2003).

NTS397: MG-F Floorart - Barefoot

Pendulum test results indicate a low-slip risk potential in dry “as-found” and untrafficked surface conditions for barefoot pedestrian users walking on the nominated sample specimen. The statistical risk of a slip accident occurring on the sample specimens in dry surface conditions is greater than or at least equal to 1 in 1,000,000 users (P.W Pye & H.W Harrison 2003).

However, when contaminated with Potable water Pendulum test results indicate a high-slip risk potential in wet “as-found” surface conditions for barefoot pedestrian users walking on the nominated sample specimen. The statistical risk of a slip accident occurring on the sample specimens in wet surface conditions is less than 1 in 2 users (P.W Pye & H.W Harrison 2003).

When considering the Pendulum Test Value (PTV) and slip potential results, care should be taken when interpreting results that are close to the boundaries of the categories. The slip potential presented by a floor with a PTV of 35 is not significantly different from one with a PTV of 37. However, the slip potential presented by a floor with a PTV of 23 is considerably higher than one with a PTV of 26, when considering the biomechanical data currently available.

Current UKSRG guidance suggests that the reading in the direction that gives the lowest PTV is likely to indicate the lowest slip resistance that a pedestrian would experience when walking at different angles and so should be considered when assessing the slip potential and design of any in-situ surfaces using this material.

The risk ratio quoted above is for the basic condition of a reasonably active pedestrian aged between 18 -60 years, walking in a straight line at moderate pace, not turning, carrying, pushing or pulling a load. Moving away from this basic condition will increase the required Pendulum Test Value and additional control measures may need to be formalised by responsible parties in order to adequately manage any identified risks. Similarly, if a sloping surface has to be negotiated then the PTV requirements will be greater and must be increased by:

100 x tangent α where α is the slope angle.

--- END OF SECTION ---

5 RECOMMENDATIONS

| Test Location | Description of Recommendation |
|---|--|
| <p>All samples specimens tested.</p> | <p>The risk of a slip occurring is dependent on both the slip resistive properties of the floor surface and the environment in which it is situated. All surfaces will wear but how this affects the slip resistance is unpredictable. The only way to be sure is to measure the PTV over time once the floor surface is in use.</p> <p>Therefore, in line with current HSE and CIRIA guidance a Pendulum slip test survey should be completed once the new floor surface is installed to confirm the required in-situ Pendulum Test Value (PTV) has been achieved on the finished flooring area. A subsequent Pendulum slip test survey should also be completed each year thereafter.</p> <p>This information should form part of the end-users annual risk assessment for the area(s) concerned and would prove invaluable in the defence of any legal claim.</p> |

--- END OF SECTION ---

6 DECLARATION

The above assessment was carried out by National Testing Services Limited adhering to the UKSRG, HSE and CIRIA guidelines on pedestrian slip risk assessment, where appropriate. The results given are accurate representations of data acquired on the test date. The results presented only relate to the sample specimen(s) submitted or site measurements recorded at the time of the testing. The results have been interpreted to give slip risk classifications based on parameters recommended by the UKSRG and HSE.

Any opinions, interpretations or recommendations that form part of this report are outside the scope of our UKAS accreditation. National Testing Services Ltd shall not be liable for any subsequent loss or damage incurred by the Client as a result of information supplied in this report.

Area(s) tested by:

Report authorised for and on behalf of National Testing Services Limited by:

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---END OF REPORT ---