**Slip Resistance of Hard Flooring**

**FOREWORD**

A Technical Working Group of The Tile Association has prepared the Technical Paper "Slip Resistance of Hard Flooring"

The Paper has been written with the aim of providing advice for all parties involved in the process of designing and using floor areas with ceramic tiling, and should be used in conjunction with current and forthcoming British, European and International Standards on tiles, tile related products and tile installation.

The Tile Association gratefully acknowledges the support given by distributors, tiling contractor and manufacturer members of the Association, together with invaluable assistance offered by Ceram Research, Radlett Consultants, The Stone Federation Great Britain and the National Federation of Terrazzo Marble and Mosaic Specialists.

1. **INTRODUCTION**

Currently there is little guidance or recommendations regarding minimum dynamic coefficient of friction or "slip resistance" values for ceramic hard floor coverings within the relevant ceramic tile British Standards, which can be relied upon for measuring such values in all conditions i.e. wet, dry, polished, textured or profiled.

This document sets out what is considered to be best practice guidelines for the use of ceramic floor tile together with natural stone and terrazzo.

1.1 **HISTORY OF PROBLEM**

Slip resistance has, in recent years, become more widely regarded as being an essential property to be specified in flooring materials. This has come about by increased legislation, e.g. Workplace Regulations 1992, and the growing prevalence of civil litigation following pedestrian slipping accidents. Further regulatory requirements are currently being discussed under European Standards but it is anticipated that this work will take some years to materialise.

1.2 **PURPOSE OF TECHNICAL PAPER**

There exists a wide range of instruments and apparatus, which are designed for measuring static or dynamic coefficient of friction, slip resistance, or surface roughness etc.

Values obtained from various test methods do not correlate with one another. It is therefore important to choose the right test for the application.

The purpose of this document is to give useful practical guidelines.

2. **SCOPE OF DOCUMENT**

This document covers all hard flooring products as fully defined below.

The hardness, porosity and surface finish all have a significant bearing on the slip resistance of the floor and its durability.

2.1 **Fired Ceramic Flooring Products**
Ceramic fired flooring products are categorised in a number of different ways either by the way they are manufactured; dry pressed or extruded, by the level of vitrification upon firing; fully vitrified, vitrified or semi vitrified, or the raw materials that are used in the manufacturing process. The classifications below are the common terms, which the industry uses and recognises, albeit a mixture of the way they are manufactured, degree of vitrification and or composition. It is important to note that all products in this category are ceramic.

**Porcelain/Fully Vitrified**

Fully vitrified floor tiles which can either be unglazed or glazed characterised by the tile's low water absorption below 0.5% (Bla) Porcelain tiles are normally dry pressed using a body made from Kaolin clays, feldspar, silica and colouring oxides fired to around 1200 degrees.

**Vitrified and Semi-Vitrified**

Tiles, which can either be unglazed or glazed. Tiles in this category can be either dry pressed or extruded and have water absorption of between 0.5 to 3% (vitrified) Class Blb – dry pressed, and 3% to 6% (semi-vitrified), Class BIIa – dry pressed.

**Quarry/Klinker**

Traditionally tiles made by the extrusion process, normally unglazed. Manufactured from natural clays or marls fired to a vitrified or semi vitrified state.

**Terracotta**

Like quarry tiles, Terracotta is made from local natural clays with a minimum of processing. The literal translation of terracotta is ‘cooked earth’ and such products tend to be unglazed and have a water absorption normally greater than 10%.

### 2.2 NON-FIRED FLOORING PRODUCTS

**Terrazzo**

Available as tiles or laid in situ form. Traditionally, aggregate of varying sizes of marble or granite set into a white or OPC cement, ground, polished to give the desired finish. May also be available in a resin binder.

**Agglomerate**

Factory produced tiles to specific sizes comprising small pieces of marble or granite set into a resin matrix. Not usually polished after installation.

### 2.3 NATURAL FLOORING STONE

**Marble**

A metamorphosed limestone in which calcite forms the greater part and other minerals in a minor quantity give the colour and other decorative features. Pure marble is white and shows little or no preferred direction of parting or fracture. For internal use only in the United Kingdom.
Slate

A dense fine-grained rock produced by metamorphosis of fine-grained sedimentary mudstones, siltstones and marls. Slates are characterised by distinct cleavage planes, which allow the rock to be split into smooth, very thin sheets. Can also be supplied as cut tiles with a smooth finish.

Limestone

A sedimentary rock composed mainly of Calcite (CaCO₃). Limestones are among the most abundant sedimentary rocks in the world and when hard enough to be mechanically ground to a polished finish. Limestones are frequently incorrectly classified as Marble.

Travertine

A true Travertine is a limestone formed as a result of the precipitation of calcite from surface or ground waters. However, more frequently in the decorative stone industry the term is used to describe beige linear veined and pitted marbles.

The more heavily pitted and voided travertines are normally pre-filled with coloured mortar or resign prior to cutting and polishing.

Sandstone

A sedimentary rock composed of quartz (silica) grains. There are many different types of sandstone. The most popular which is characterised by the inclusion of mica flakes concentrated within distinct layers is called Flagstone.

Quartzite

A metamorphosed sandstone where the quartz grains and matrix are recrystalized into a dense silica rich rock.

Granite

In the decorative stone industry this term is used to describe a whole variety of dense coarse to medium grained igneous rocks. A true granite is a coarse grained igneous rock composed of quartz, feldspar and mica.

Conglomerate

A sedimentary rock composed of rounded granules, pebbles, cobbles or boulders set in a natural matrix, which is generally silica based. The pebbles of a conglomerate are commonly hard rocks such as granite or quartzite. When the pebbles are angular the rock is commonly referred to as a breccia.

2.3.1 TREATMENT OF NATURAL STONE

It is common practice to treat these natural materials, especially the more porous stones such as limestone with sealers or impregnators as a barrier against staining.
Applications of such sealers may initially change the slip resistance of the stone until any residue left of the surface wears off. Some floor treatments can reduce the slip resistance, sometimes to potentially dangerous levels in wet conditions.

3. **ENVIRONMENT AND LOCATION**

Careful consideration should be given at the design stage to the anticipated and likely prevailing service conditions the finished floor surface will have to endure. There are a number of different factors, listed but not in any particular order, which have to be considered when selecting a flooring product for a particular application –

Internal and external  
Wet or dry  
Aesthetics and colouration  
Contamination of the floor finish  
Coordination with other finishing materials e.g. wall tiles  
Durability and wearing properties  
Ease of cleaning and maintenance  
Method of bedding and compatibility with substrate  
Product conformance to appropriate standards  
Ramped floors have more demanding slip resistance requirements  
Size and scale of flooring units  
Slip resistance (as supplied and ongoing throughout life of installation), See clause 6.1

The selection of product should aim to satisfy the above and ensure that the flooring material selected is fit for purpose. Slip resistance should be one of the most important design considerations as the safe movement of people over the flooring is crucial. There are suitable textures and patterns to suit a wide range of requirements.

Detailed below are a number of location types and some of the specific factors relating to these area classifications:

**Uncovered External Floors e.g. balconies, patios, paths, steps and staircases**

Such floors in the UK will be subject to the elements and have to endure frequent contact with water, sub-zero conditions of frost, ice and snow. Frost resistant tiles meeting pr ISO EN BS 14411 should always be specified for this purpose. During certain parts of the year the floor surface may be contacted with organic contaminants such as leaves and algae thereby altering the slip resistance characteristics.

Such locations should conform to current health and safety legislation, Building Regulations and disability requirements, where appropriate.

Detailed information on stairs, ladders and walkways is available in British Standard BS5395-1:2000.

**External Ramps**

Generally for disabled access. The same maximum gradient of 1 in 12 is recommended for disabled access ramps.

**Partially Covered External e.g. porches, covered entrances and underpasses**

The same prevailing conditions as ‘uncovered’. Windy conditions will inevitably lead to contact with the elements, ingress of rain etc.
Internal Ramps and Steps

Careful consideration should be given to current Building Regulations for internal ramps. A maximum gradient of 1 in 12 is recommended.

Detailed information on stairs, ladders and walkways is available in British Standard BS5395-1:2000.

Tiles are also manufactured in the form of step nosing, step tread with textured and profiled surfaces.

Internal Dry Conditions with direct contact from external conditions e.g. receptions, conservatories, rail subways, shopping malls, car workshops and showrooms.

On the face of it such areas are deemed dry or only subject to occasional spillage and wetting when cleaned. However, transient contact with contamination and moisture trafficked from outside can adversely affect the performance of the floor finish in such areas. Prolonged abrasion from grit trafficked from outside can compromise the appearance and surface texture of the floor which combined with moisture can lead to a reduction in the coefficient of friction of the floor. Adequate protection in the form of interposing foot cleaning devices such as mat wells and appropriate barrier matting can help to ensure that floor areas designated as dry, remain dry.

Internal Dry conditions e.g. corridors, office floors and toilets, exhibition halls, supermarkets and airport concourses

Infrequent contact with water is immediately removed and the floor is cordoned off when the floor is cleaned.

Internal Frequent contact with moisture. e.g. kitchens, food preparation areas, washrooms, public toilets and dry change areas

The likelihood of contact with moisture is high and likely to be combined with other contaminants such as shampoo/soapy residues, kitchen fats/oils and foodstuffs.

Internal Constant contact e.g. commercial showers, wet changing rooms and pool surrounds

Such conditions are generally barefoot but can also be trafficked by soft-soled footwear.

Surface contamination is likely to arise from pool salts, shampoo residues and body fats and oils. Pool surrounds should be laid to adequate falls to minimise water retention – bearing in mind that a nominally flat floor will reservoir water – falls with a gradient of up to 1:30 may be necessary in order to satisfactorily remove surface water. Drainage channels and outlets should be adequate for the volume of water that may be present at peak usage times.

Internal Submerged conditions e.g. hydrotherapy and general pool tank bases, footbaths and baptismal fonts

Such conditions have to meet the demands of moisture temperature changes and the pool water chemistry. The build up of pool water salts has to be considered in the ongoing maintenance and performance of the tank base. Normally barefoot areas, shallow water areas e.g. “beach” areas of leisure pools where there may also be the combined effects of wave machine turbulence, steep gradients and increasing buoyancy as the water deepens. The highly textured surface of the floor tiles required in these areas in order to minimise the
risk of slipping may cause chaffing to skin and swimwear to children sitting or kneeling in these areas – particularly if wave generating machines are operating.

4. **THE PHYSICS OF SLIP**

4.1 **PEDESTRIAN REQUIREMENTS**

Research carried out by the Building Research Station in the late 1950’s showed that for normal ambulatory activities people required a range of values of the Coefficient of Dynamic Friction to be developed between the shoe and the floor.

They found that the lowest values the people needed were in the order of 0.1 while, based on a statistical analysis, 1 person in 1 million would require as much as 0.37. The average person requires around 0.2. It should be noted that people require different slip resistance at different times within that range. Based on the BRS work and analysis of accidents, it is commonly accepted that a figure of 0.4 is required for safety. Only in certain well defined circumstances should this be reduced.

4.2 **DEVELOPMENT OF FRICTION**

The coefficient of friction is developed by the interaction of the shoe, in particular the heel, and the floor surface. It is an extremely complex interaction and there is no means by which it can be accurately predicted from a general knowledge of the two materials concerned. It has to be found by testing. It is also critically dependent on the presence of a lubricant or contaminant. The most common contaminant is water and since most but not all slipping accidents occur in the wet, testing of a floor is normally conducted in this state. If other contaminants, e.g. oils fats etc. are anticipated, for example in kitchens, it may be necessary to use these lubricants in any tests. Dry slipping can occur in certain situations so it is important to check on this aspect.

4.3 **THE ROLE OF THE SHOE**

In the dry, most but by no means all shoe sole/heel materials give good values of friction on most flooring surfaces. However there are some notable exceptions such as nylon, hard polyurethane and pvc soles/heels. The flooring industry considers that in dry conditions, the worst acceptable material is leather but uses a rubber referred to as Four S (Standard Simulated Shoe Sole) rubber as a basic standard for testing floor surfaces. Four S is equivalent to a mid range rubber heel in terms of the coefficient of friction developed on flooring materials.

In wet conditions or where contamination is involved, absorbent materials such as leather behave differently to non absorbent ones such as rubber. In the latter case and where the floor surface is relatively smooth, the material nature of the rubber or plastic is far less important than in the dry – the slip resistance will depend more on the roughness of the rubber/plastic surface. Most rubbers tend to wear smooth but some special formulations known as microcellular/rubbers/plastics retain their roughness and give significantly better slip characteristics in wet conditions.

Below is a table taken from BS5395-1:2000 demonstrating slip resistance of some floor and some shoe finishes.

<table>
<thead>
<tr>
<th>Floor Type (Unprofiled)</th>
<th>PVC</th>
<th>Urethane and rubbers</th>
<th>Microcellular urethane and rubbers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>XXX</td>
<td>XX</td>
<td>X</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>Stainless steel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polished or glazed ceramic</td>
<td>XXX</td>
<td>XX</td>
<td></td>
</tr>
<tr>
<td>Finished timber</td>
<td>XXX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smooth resin</td>
<td>XXX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Matt ceramic</td>
<td>XXX</td>
<td>XX</td>
<td>X</td>
</tr>
<tr>
<td>Terrazzo</td>
<td>XX</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>PVC/Vinyl</td>
<td>XX</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Concrete</td>
<td>XX</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Paving stones</td>
<td>XX</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

**Key**
- XXX Most slippery
- XX Less slippery
- X Least slippery

Note 1: The table is intended only as a guide. The samples used to generate the information were ex-factory.

Note 2: The slip resistance of floors and shoe soles can change with wear. However, microcellular urethane shoe soles are often unaffected by wear. Expert advice should be sought for specific situations.

### 4.4 THE ROLE OF THE BARE FOOT

In dry conditions the bare foot gives good values of friction on most flooring surfaces.

In wet conditions where the floor finish is rough textured or profiled, the bare foot can give better values of friction than when shod because of the sole of the foot will deform more readily than the sole of a shoe to suit the surface texture of the flooring finish – particularly so when the texture is in the form of raised profiles around which the foot can gain some mechanical traction.

Where the floor finish is smooth and it becomes wet, the bare foot can sometimes give poorer values of friction than the shod foot, due in part, to the smaller surface contact area of the toes, ball and heel of the bare foot compared to the sole and heel contact area of a normal shoe.

### 4.5 THE ROLE OF THE FLOOR

There are a wide variety of floor surfaces, most of which give satisfactory slip resistance in dry conditions. In clean dry conditions a smooth shiny surface can give very high slip resistance against a soft rubber – indeed far higher than a rough surface. However in wet or contaminated situations, the shiny surface becomes far less slip resistant compared to the rougher surface, which might only lose a small proportion of its slip resistance. A very smooth shiny surface can normally be regarded as likely to be dangerous in wet or contaminated situations – however there are exceptions.

The biggest problem with floor surfaces is predicting their wear under pedestrian traffic. Slip tests are generally conducted on new material, the surface of which may change significantly during the lifetime of the product.

### 4.6 TESTING

There are a wide variety of test methods, which are used to determine the coefficient of friction/slip resistance of flooring surfaces. In the dry, many of these correlate quite well with one another; however in the wet there is generally little correlation at all between test methods. Until quite recently, the reason for this was uncertain but it is now known that it is due to the way that the lubricating film of water (or other liquid) is created between the heel or slider and the floor. Each test method essentially creates its own characteristic lubricating film thickness during the test, and in the majority of cases the film thickness bears no relation to the film created by a person slipping. The only machine, which by chance creates the same film thickness, as created in normal walking is the TRL Pendulum.
The Greater London Council in the 1970’s found that Pendulum results correlated well with the known accident record of a large number of sites, which they had tested. However the standard test method has limitations in the assessment of certain textured and profiled tiles.

The Health and Safety Executive has issued the following statement. "The pendulum is the preferred method of test of the UK government for assessing floor surface slipperiness in the workplace throughout Great Britain".

4.7 FACTORS AFFECTING THE FORMATION OF THE FILM

Roughness of the surface of the floor is one of the main factors, which prevents the liquid film from giving its lubricating effect. However it needs to be the right kind of roughness. The difficulty is that most simple roughness meters, which are used for this type of measurement do not differentiate between the rolling hills type of surface and mountainous type topography. One can get the same reading of roughness from two such surfaces but the rolling hills will be a slippery surface while the sharp peaked mountainous type will be slip resistant. Hence while roughness readings may be of assistance in assessing a surface, these are only part of the answer.

It is clear from the description above that cleanability of the surfaces can vary dramatically dependent on the nature of the surface roughness. The viscosity of the liquid contaminant is also important. In general the more viscous the liquid the thicker will be the lubricating film and the more rough the surface needs to be to give slip resistance.

The main contaminant in dry conditions is dust. As yet there is no “standard” dust used for testing, hence one must use dust collected at the test site although clearly this is not ideal. Dust can cause a significant reduction in slip resistance especially if the dust contains hard particles and the floor surface is hard. In such circumstances the dust particles roll along the floor between the floor and the heel.

4.8 STANDARDS RELATING TO TESTING

The Pendulum test is described in a number of British Standards, in particular BS8204 Parts 2 to 4 and BS7976, which details both the operation and calibration of the instrument.

The following criteria should be used for guidance purposes:

<table>
<thead>
<tr>
<th>Slip Resistance Value (SRV) using 4S Rubber</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-25</td>
<td>Dangerous or high potential for slipping</td>
</tr>
<tr>
<td>25-35</td>
<td>Marginal or moderate potential for slipping</td>
</tr>
<tr>
<td>35-65 Safe or low potential for slipping</td>
<td></td>
</tr>
<tr>
<td>65+</td>
<td>Very safe extremely low potential for slipping</td>
</tr>
</tbody>
</table>

It should be noted that the boundary values between one criteria and the next are not significant in themselves, thus there is no major difference between a floor which as a SRV of 24 and one which has an SRV of 26. All that one can say is that the latter has a slightly lower potential for slip than the former but that they are both likely to cause someone to slip.

5. TEST METHODS

Many methods have been devised for measuring pedestrian slip resistance of flooring materials, and the results given by different test methods on a range of surfaces often do not
correlate well. The methods listed here are those most commonly quoted in architects’ specifications, suppliers’ literature, and technical papers on the subject, and some guidance is given here regarding the applicability of the tests to various situations.

Testing of tiles should be undertaken at competent test houses. All site testing should include an "as found" and an "after thorough cleaning" test.

The most commonly used test methods are as follows:

5.1 DYNAMIC TEST - TORTUS

This method measures the dynamic coefficient of friction by means of a slider moving at constant speed over a horizontal surface. A portable self-powered mobile instrument moves over the surface to be measured, and records the frictional drag on the slider, which is weighted with a fixed load. The slider is tipped with shoe rubber (Four S rubber). The test can be carried out on wet or dry surfaces. Results are quoted as coefficient of friction values, usually values between about 0.1 and 0.9.

It was formerly favoured in the UK for use on ceramics, but its use in the wet has been discredited since values on some surfaces in the wet are misleadingly high. This test is still currently the main one in use in Italy, despite its limitations in the wet.

There are other instruments, which work on a similar basis to the Tortus, i.e. by dragging a slider across the surface, and they suffer from similar shortcomings when used in the wet.

5.2 RAMP

In this method, a lubricated inclined platform is adjusted to a gradually increasing gradient, and the angle is measured at which a person walking on it slips. There are two test methods, one (DIN 51097) where the operator is barefoot and the lubricant is water, and the other (DIN 51130) where the operator is shod with rubber-soled boots and the lubricant is engine oil (10W30). The tiles have to be fixed and grouted onto the platform, and the operator needs to be experienced in the test in order to get reproducible results.

The barefoot test results are quoted as a letter rating, A, B or C, which relates to the ramp angle as follows:


Failure to achieve 12° means that no rating can be given.

The shod test results are quoted as an R value, which relates to the ramp angle as follows:

R9: 3 - < 10°
R10: 10 - < 19°
R11: 19 - < 27°
R12: 27 - < 35°
R13: 35°+

Note that these values should not be taken to imply safe use when fixed on ramps at these angles. These are merely conditions of testing, and the angles do not refer to conditions of use.
R9 is in practice a very broad ranging category because it includes some quite slippery tiles as well as some with moderate slip resistance. This classification is therefore not so useful for specifying tiles where lower levels of slip resistance are required.

The R values are often quoted together with a V value, which is known as the displacement volume. This is an indication of the free volume trapped between a flat surface and the textured surface of the tile, and is highest for the most heavily profiled tiles. This gives an indication of the degree of soiling which can be accommodated in the surface of the tile, whilst still retaining contact with the shoe.

These tests have been incorporated into insurance requirements of the German National Accident Insurance Board. The barefoot test is also commonly regarded to be the most useful guide to barefoot slip resistance in the wet. The shod test with oil is regarded as useful for assessing profiled tiles.

Since a special ramp has to be constructed using the tiles to be tested, this test cannot be carried out on site. It is therefore only useful for determining factory gate values.

5.3 PENDULUM

This method determines the dynamic friction between the specimen and the slider on the end of a swinging pendulum, which is tipped with rubber. The test is normally carried out using the same rubber (Four S) as the Tortus, although sometimes for heavily textured surfaces values are quoted using TRRL\(^1\) rubber. The apparatus is portable, and so tests can be carried out on site as well as in the laboratory. Calibration and preparation of the slider are important considerations to get meaningful results.

Results are quoted as the Slip Resistance Value (SRV) (normally around 10 to 90) which is roughly 100 times greater than the coefficient of friction. The actual formula is: Coefficient of friction = 3P/(330–P), where P is the slip resistance value. However, it should not be assumed that this equation will convert pendulum results to Tortus values, since the conditions of test are markedly different.

The pendulum test does not have the tendency to overestimate slip resistance in the wet which the Tortus has, and is therefore the preferred method of test on site in the wet, though caution should be used in using results for barefoot applications, and for heavily textured surfaces.

5.4 STATIC TEST – PULL METER

This method measures the static coefficient of friction by determining the force required to move a slider from a static position on a horizontal surface. It is commonly used in the USA, ASTM C – 1028 standard test method, but is little used in Europe, and it shows no advantages over the other tests.

6. INTERPRETATION OF RESULTS

6.1 EXISTING RECOMMENDATIONS

Factory gate / installed values – variation

\(^1\)Transport Road Research Laboratory
The values quoted by manufacturers for slip resistance of tiles relate to the test results on tiles as supplied (factory gate values). These values may change during service as a result of the following factors:

1. The abrasive action of the grouting process on the surface of the tile will alter the factory gate value.
2. Build up of body fat in barefoot situations
3. Build-up of residues from cleaning materials
4. Exposure to chemicals, which etch the surface (fluorides)
5. Wear of the surface
6. The application of sealants, impregnators or waxes, which may be correctly or incorrectly applied.

It is important, therefore, to consider the conditions to which the tiled surface will be exposed after fixing, and to be aware that the cleaning regime is an important part of maintaining the slip resistance of the floor.

There is no published data relating to the change of slip resistance during service, and it is therefore recommended to seek advice from the manufacturers or suppliers of the tiles regarding suitability of tiles for a given situation, based on experience of the performance of tiles in service.

### 6.2 SUGGESTED VALUES

<table>
<thead>
<tr>
<th></th>
<th>Tortus</th>
<th>Ramp</th>
<th>Pendulum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Shod</td>
<td>min 0.4</td>
<td>R9</td>
<td>Min 40</td>
</tr>
<tr>
<td>Wet Shod</td>
<td>Not applicable</td>
<td>Min R10</td>
<td>Min 40</td>
</tr>
<tr>
<td>Wet Barefoot</td>
<td>Not applicable</td>
<td>B – Pool Surrounds</td>
<td>Not currently applicable although alternative rubbers are being trialed</td>
</tr>
</tbody>
</table>

Industrial situations such as workshops or food preparation areas will require more heavily textured and slip resistant tiles. In such cases it will be necessary to seek the manufacturers advice.
As far as ramps are concerned the following suggested values apply:

<table>
<thead>
<tr>
<th></th>
<th>Tortus</th>
<th>Ramp</th>
<th>Pendulum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Ramp</td>
<td>0.48</td>
<td>R10</td>
<td>48 (dry)</td>
</tr>
<tr>
<td>5° maximum gradient</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>External Ramp</td>
<td>Not applicable</td>
<td>R11</td>
<td>48 (wet)</td>
</tr>
<tr>
<td>5° maximum gradient</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notwithstanding the above suggested values it has to be stressed that certain finishes e.g. glazed floor tiles in domestic bathrooms or polished marble in hotel bathrooms, may not meet the recommended figure in the wet and additional precautions to prevent slipping, such as non-slip bathmats and notices will need to be made.

In certain locations i.e. domestic and hotel bathrooms, conservatories, domestic kitchens and utility rooms, where smooth surface, highly polished and glazed tiles are highly desirable from a point of view of cleaning and aesthetics and are acceptable when dry but do not meet the above figure when wet, precautions such as additional matting should be taken when wet.

These factors should be considered at the design stage.

7. DESIGN CONSIDERATIONS AND FACTORS AFFECTING SLIP

The design and selection of flooring materials is, perhaps, affected by more separate and at times conflicting considerations than almost any other part of the building process.

Of primary concern is the need to comply with relevant Health and Safety legislative requirements and increasingly with EEC Construction Product Directives and fitness for purpose.

These concerns will, inevitably, require a risk assessment to be carried out on the intended use of the flooring which, in turn, will have an impact on the type of floor finish that can be safely installed, coupled with other measures that can be taken to reduce the likelihood of people slipping.

The following are some of the factors that should be taken into account in reaching a decision on the type of flooring material and the finish that may be required on that material to assist in slip prevention.
• Adequate barrier matting at a building entrance can prevent water tracking in from the exterior and rendering a floor which is non slip in the dry but dangerous when wet.
• Inadequate cleaning regimes can lead to dust and dirt acting as a “lubricant” even on dry floors.
• Tracking of surface applied polymers and waxes from adjacent floor finishes can turn safe floors into unsafe ones.
• Consideration of user footwear and the slip characteristics of the various sole materials in common use. In some situations staff users of a floor will be provided with suitable footwear which may affect the decision on the type of tile finish required.
• Public barefoot areas, which can get wet, may require a surface profile to provide slip resistance.
• Certain locations such as domestic and hotel bathrooms may require additional non-slip matting when wet.
• Some tiles incorporating coarse particles at the surface which are adequate for shod traffic may not be suitable for barefoot areas because of possible abrasion to bare skin.
• There is an inevitable trade off between cleanability and surface roughness which aids wet slip resistance. Highly textured surfaces may need a more rigorous cleaning and maintenance regime.
• With some smaller sized tiles, additional slip resistance can be provided by incorporating joints of up to 10 mm wide which can be grouted with fillers containing silicon carbide.
• Tile size can have a bearing on slip resistance. Very frequent cement grouted joints, as for instance with mosaic, can be an aid to slip resistance.
• Any steps in a tile installation will require even and adequate treads, with nosings clearly visible and a non slip surface depending on usage.
• If falls or inclinations are necessary, slopes greater than 1:35 will require increased slip resistance.
• Where excessive water is present, or likely to be present, as on pool surrounds, beach areas or showers or externally, adequate falls as well as a slip resistant surface will be necessary.
• Although the choice of colour is almost limitless with ceramics and very wide with other natural and manufactured materials, technical suitability should never be sacrificed for a specific colour.
• It is important to establish that the slip resistance properties of the floor type under consideration will endure over the anticipated life expectancy of the floor.
• Disabled users of the floor will require additional factors to be taken into account.
• Before deciding on a finish consider the possibility of changes of use after completion e.g. where an existing dry changing room might be transformed into wet changing rooms.

8. CLEANING AND MAINTENANCE

Ceramic floor finishes need little maintenance and can be kept clean by regular sweeping, then washing with warm water to which a neutral or nearly neutral detergent has been added. Final thorough rinsing with clean water is essential.

Depending on the texture of the tile consideration should be given to the type of cleaning machine to be used. In certain cases oscillating or rotary mechanical scrubbing machines should be considered. The regular use of scrub and rinse cleaning machines fitted with abrasive pads may damage the tiled surface and result in gradual loss of thickness in the wear layer. When using such machines care should be taken to ensure that the final rinse is with clean water only.
Household or commercial cleaning agents such as cleaners containing bleach must never be used to clean stone, these cleaning products will burn or discolour stone finishes. Use only impregnators, sealants and cleaning products that are available from specialist companies and applied strictly in accordance with the manufacturers’ advice.

After extensive use, polished granite and marble floors can be machine re-polished by a specialist contractor, which will restore them to an almost new appearance.

In order to maintain the surface quality of tiles in barefoot areas it is important that a strict cleaning regime is implemented, the soiling that collects is a mixture of body fats, skin, scale and other deposits which require regular treatment using appropriate products specifically designed for cleaning tiles.

Immediately after cleaning has taken place appropriate signage and cordonning off procedures should be undertaken.

The Tile Association has produced a document "The Cleaning of Ceramic Tiles" which gives detailed advice on cleaning and maintenance.

9. **BIBLIOGRAPHY/SOURCES OF REFERENCE**

BS5385 Parts 1-5 The Code of practice for fixing wall and floor tiles

BS5395:1 2000 Stairs, ladders and walkways. Code of Practice for the design, construction and maintenance of straight stairs and winders.

BS6431 Parts 1-23 Ceramic Floor and Wall Tiles

BS7976:2002 Method of calibration and operation of the Pendulum test

BS8204 Parts 1-6 Screeds bases and in situ flooring

BS EN ISO 10545 – Ceramic Tiles (Test Methods)

prISO EN BS 14411 Draft International Standard on Ceramic Tiles – definitions, classification, characteristics and markings

DIN 51097
DIN 51130
German standards relating to the Ramp Test

British and German Standards are available from British Standards Institution, 389 Chiswick High Road, London W4 4BR

“Flooring, Paving & Sets” Published by the Building Research Establishment, Garston, Watford WD2 7JR ISBN 1 8608 1372 0

“The Measurement of Floor Slip Resistance” Published by RAPRA Technology. ISBN 1 8595 7227 8

“Slips and Trips” Guidance for employers on identifying hazards and controlling risks, published by Health & Safety Executive. ISBN 0 7176 1145 0

“Slips and Trips” Guidance for the food processing industry, published by Health and Safety Executive ISBN 0 7176 0832 8
10. APPENDIX - DEFINITION OF TERMS

A, B or C  Barefoot test results obtained using the ramp test

ASTM  American Standard Test Method

Class BIa )  Dust pressed tiles with varying water absorption as defined in BS EN ISO 14411 (draft) or BS6431
Class BIa )
Class BIb )
Class BIb )

Coefficient of Dynamic Friction  Figure developed by the interaction of the shoe, particularly heel, and the floor surface

Factory Gate Value  Value quoted by tile manufacturers of tiles tested as supplied and before installation

R9-13  Shod test results obtained using the ramp test

SRV  Slip Resistance Value

TRL Pendulum  Transport Research Laboratory Pendulum test

TRRL  Transport Road Research Laboratory

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