

FLOOR SLIP POTENTIAL OR HOW TO ASSESS OR SPECIFY YOUR FLOOR

By Dr Malcolm Bailey

The following factors need to be considered in order to determine how safe your floor is likely to be.

- i) The type of activity on that floor and the people that use it.
- ii) What contaminants are likely to get onto the floor.
- iii) What footwear the users are likely to be wearing.
- iv) How effective is the cleaning.
- v) How well does the floor retain that slip resistance with time/wear.
- vi) Environmental and ergonomic considerations.

Unfortunately there is no simple model that can predict whether a floor is likely to cause an accident based on all the factors mentioned above. The interaction of the various factors is complex and whilst it is possible to put forward certain guidelines, it must be understood that such guidelines are based either on neglecting one or more of the factors or assuming a worst case scenario for a particular factor.

Factor 1 The type of activity on the floor and the people who use it

First and foremost, factor number (i) determines the level of slip resistance a person needs from the floor in order that he or she does not slip. All the other factors relate to how or whether the floor can provide that slip resistance.

It must be clearly understood that people are not only different in their need for slip resistance but require different levels of slip resistance from different pedestrian activities. In relation to walking in a straight line, tests show that 50% of the population requires less than 0.19 coefficient of dynamic friction. The other 50% requires somewhere between 0.19 and 0.36. While most people require less than 0.30, 1 person in 1 million may require 0.36 and it is upon this latter statistic that the figure of 36 Pendulum Test Value is currently based.

However, normal straight forward pedestrian activity includes in addition such things as stopping suddenly and turning. These increase the frictional demand and the 1 in 1 million figure is increased to 0.39 from which the 40 Pendulum Test Value is derived.

If people are likely to run, for instance to catch a train or to play sport, then a somewhat higher value will need to be used. Many sporting activities require friction values in the order of 0.55 to 0.60.

Thus, in a busy railway station, a slip resistance of around 0.45 may be justified simply because passengers may be running or walking very fast and the station may well handle a million or more people over a period of a few months. Statistically at least one of those million or so passengers will require a slip resistance in the order of 0.45 if he is walking fast to catch his/her train and in so doing turns to avoid another passenger.

On the other hand in a domestic situation where possibly less than 100 different people are ever likely to walk across that particular floor in the lifetime of the floor, one could well justify the use of a slip resistance of only 0.3. One does however have to be careful if it is known that elderly people may be involved. Although very few tests have been carried out, it is generally thought that the elderly tend to be those requiring the higher statistical values of slip resistance, namely those between 0.19 and 0.36 in straight walking.

The following table shows the requirement for normal walking activity.

1 person in 2 requires 0.19 minimum value of μ
1 person in 20 requires 0.27 minimum value of μ
1 person in 200 requires 0.31 minimum value of μ
1 person in 10,000 requires 0.34 minimum value of μ
1 person in 100,000 requires 0.38 minimum value of μ
1 person in 1,000,000 requires 0.40 minimum value of μ

It should be understood that the statistics refer to different people. Thus a supermarket which has a customer count of 600,000 over a given period will be justified in using a lower overall figure, eg. perhaps only 50,000, simply because many of those customer counts will be the same persons. On the other hand an airline terminal's customer count may well be only double the number of different people using the terminal.

Whilst most people use the 1 in 1 million figure, it may not always be appropriate, particularly if someone is seeking to insist on a relatively low use floor being upgraded in spite of its previous lack of slipping accidents.

Factor 2 *Contaminants which may get onto the floor*

Most floors in the dry clean state provide a slip resistance or frictional restraint of 0.50 or greater. In other words, people are unlikely to slip over on a dry clean floor providing they are not doing something outlandish or are wearing shoes with low friction heels (see the next section). In general the presence of a contaminant will reduce the amount of slip resistance available simply because it provides a lubricating effect between the shoe (or barefoot) and the floor. Contaminants can be solids (eg. dusts) or liquids (eg. water). The most insidious tend to be greases which coat the floor surface (or the shoe heel surface) with an almost invisible film of often very effective lubricant. Into the latter category one can also include polishes which are either deliberately or unintentionally deposited on the floor, usually by cleaners. The unintentional polishes are usually over-spraying of furniture polish; those containing silicone can be very effective lubricants.

In the dry, dust or powder contamination is not infrequently encountered, particularly in industrial situations. The effect of such dusts on slip resistance is by no means easy to predict. Some very fine powders such as flour or talc seem to work by filling up the tiny undulations in the floor surface, reducing the roughness component of dry friction generation and at the same time preventing any adhesion which is often associated with very smooth surfaces.

Some powders/dusts act very like a layer of tiny ball bearings over the surface, whilst others are more angular in shape and may mechanically interact with the floor surface to assist in developing frictional forces. In view of the many types of dust and floor surfaces, it is impossible to predict to what extent the slip resistance will be affected. Whilst testing is the only way to discover the effect of a particular combination, it is important to recognise that the quantity of dust on the floor can affect the result and one will need to replenish the dust after each test run since the slider will tend to push most of it out of the way during the test. Also, one will get a different result from an initially clean slider compared with one which is allowed to form a build up of dust on its working contact area during the tests.

This latter phenomenon is often a problem in carpeted stores where customers' shoes pick up fibres from the carpet on the underside of the heel. Hence when they step onto the shiny thermoplastic walkway surface, the heel no longer has the surface properties of rubber but of a fabric.

By far the most common contaminants however are water-based, typically rainwater brought into the building on people's feet or dripped from their umbrellas. It can also come from....

- Condensation on a cold floor
- Leaks from pipes or condensation dripping off such a pipe
- Spills of drinks – typically if the cup/glass is filled to the brim
- Water used to mop the floor in cleaning.

The presence of water on the floor will, on virtually every type of floor, mean that the slip resistance in the wet is less than in the dry. However, while this will mean that many floors are slippery in the wet, it does not mean that all floors will be sufficiently slippery to be a risk to pedestrians. A large number of floor types are and need to be satisfactory for use in wet contaminated conditions, for instance in changing rooms, around swimming pools or where they might be unavoidably exposed to the weather.

There are many other liquid-based contaminants which will generally have an even more marked effect in reducing slip resistance than water-based contaminants. The more viscous the contaminant, the more effective they are in acting as a lubricant, although there comes a point when very viscous liquids can be so sticky as to prevent slipping. Typically the worst contaminants are oil-based, for instance engine oils, cooking oils and substances based on these.

Some 'solid' materials or products can be regarded as contaminants, typically meat, fruit and vegetables, due to the liquid or fats/oils they contain and which exude from them when they are stepped upon.

There is no formula or means of accurately predicting the effect of any of the contaminants discussed on any type of flooring material. The only sure way is to carry out tests to determine the slip resistance of that combination. As will be discussed at the end of this document, there are essentially three ways of dealing with contaminants, either the floor must be sufficiently slip resistant in the presence of the contaminant, or

the contaminant must be prevented from getting onto the floor, or people must be prevented from walking on the floor when there is contaminant on it.

Factor 3 Footwear

Footwear, and in particular the material and pattern of the rear of the underside of the heel, is just as important as the flooring material in preventing slips. However, there are a number of problems facing the owner or specifier of a floor. These are ...

- a) In the majority of situations the floor owner has no control whatsoever of the type and state of the footwear worn by those who will walk over his floor.
- b) Whilst many shoe heels are made from a rubber or plastic which has average to good friction generating properties in the dry, it does not apply to all shoe heels, particularly those imported into the UK.
- c) Most heels have little or no direct means of inhibiting the lubricating effect of contaminants. Even most so-called safety shoes do not have this feature. However, such footwear is available; one of the best goes under the name of 'Shoes for Crews' and in an industrial situation where only a limited number of people use the floor, providing those staff with that type of footwear can be a viable means of dealing with a potential slip problem.
- d) Not only does the floor owner have no control of the type of shoe, he usually has no control over the extent of wear on the back of the heel. Hence, even if the heel may have originally been patterned and provided some inhibiting effect to lubrication this can quickly wear off. Because the back of the heel is where the most stressful contact with the ground occurs, it is where wear takes place quickest. One therefore has to assume that the critical heel contact area on most people's shoes will be flat.
- e) Because most people who are involved in a slipping accident either cannot remember where they bought their shoes, or could never prove that they bought them at that particular shop, or instinctively believe that 'their' shoes could never cause them to slip, they automatically blame and try to sue the owner of the floor. It should be noted that some heels are made of a very hard plastic material which not only gives very poor slip resistance in the wet but also can give low values in the dry.

Although the author has helped to successfully defend a number of floor owners where this has happened it is still a very costly matter for the floor owner in terms of both wasted time and money. In the majority of flooring situations therefore where the floor owner has no control over footwear he has to assume that users will have only an average heel in terms of its frictional characteristics and will have little or no inhibiting effect on any lubrication by a contaminant. Both the Pendulum and SlipAlert are based on this assumption.

Factor 4 *Effectiveness of cleaning*

The cleaning of a floor can play a critical part in how it develops its slip resistance, both in the dry and in the wet. Unfortunately, although many cleaning firms are realising that cleaning is not just about removing the dirt and making the floor look good, many floors are left ready for use in a potentially slippery state. The following points need to be considered.

Firstly, the chemicals used to clean the dirt from the floor. It is essential that such chemicals do not in any way affect the surface of the flooring material in doing their job of releasing the dirt or removing the stain or scuff mark. Whilst that may sound obvious, the author has on more than one occasion found chemicals being used which state on the container that they should not be used on that type of floor but have been used because it has been found to be highly effective in removing dirt and the cleaners use it on *'all the other floors'*.

It is also essential that such chemicals do not leave a residue on the floor and, particularly if they are oil-based, they will need to be properly rinsed off with clean water. Such residues can slowly build up and in effect become the surface layer of the floor and which may have totally different frictional characteristics from the original floor in both dry and wet/contaminated states.

Secondly, the mechanical means of applying/agitating the chemicals. The traditional mop and bucket is still with us. This may be reasonably effective for smooth shiny floors but is certainly not suitable for any floor which has a reasonably wet/contaminated slip resistance. Even on smooth shiny floors a mop and bucket approach often results in the dirt or contaminant being spread as a thin layer over the surrounding floor rather than being removed. BS 8204 Part 6 for synthetic resin flooring systems recommends that powered mechanical methods are used, ie. rotary scrubbers/driers on that type of floor system.

However, it is important that the right action is used – some use horizontal disks, others use revolving drums which may suit some floors better. In both cases it is vital that the correct brushes/pads are used for the particular floor surface being cleaned. The brushes/pads have to be sufficiently abrasive to remove the dirt but not such as to affect the floor surface. Where two different floor surfaces are used side by side and which need different brushes/pads but are cleaned by the same machine, specifiers and cleaning contractors should ask themselves if the cleaner is really going to change the brushes/pads every time he goes from one surface to the other.

It must be recognised that cleaning is the one factor which can change the slip resistance of a floor surface in the short term. A change in personnel or the chemical or the routine can, without anyone at the time realising it, affect the slip resistance of the floor and could potentially lead to an accident to an innocent user of the floor. It is for that reason that regular monitoring of the slip resistance is highly recommended.

Factor 5 *How well does the floor retain its slip resistance*

The action of walking on a floor can cause it to become polished or it can become more matt or it can remain with the same surface texture as when it was first laid. The problem is that there is no accepted method of producing accelerated wear on flooring so that the only guide as to what is likely to happen is from experience. The matter is made even more difficult by the fact that a floor can wear differently in different locations.

The Building Research Establishment at Garston, Hertfordshire carried out a great deal of research into the subject in the 1960s with the intention of producing a machine which could be used to artificially induce accelerated wear on a floor sample. They concluded that there were too many factors which affected the degree and type of wear and that to try to standardise a particular set of wear parameters could lead to seriously misleading information about the flooring being relied upon by potential specifiers. In other words, it was possible that a floor could perform well in a test but badly in a real situation and vice versa.

The important message from this is that floors can change their surface properties with time, albeit over periods of months or years as opposed to days or weeks. However, both specifiers and floor owners need to be aware of this and be alert to monitoring their floors, particularly near doorways and near where a large amount of pedestrian traffic can be expected.

Factor 6 *Ergonomic and environmental considerations*

Ergonomics, although a very useful science in many aspects of industry, has a very limited use in relation to walking and in particular dealing with the general public. People can change the amount of friction/slip resistance that they need by walking guardedly as one might do on ice. This can be important if the floor can be seen to be wet and thus likely to be slippery. In certain commercial situations, staff can be persuaded to walk and not to run, and the need to push or pull loads across the floor can be designed out. Beyond that however one is dealing with a wide range of people who may well have reason to run or walk very quickly or turn suddenly.

The environment has a very limited effect on people slipping. However, environments can be changed to prevent or limit the amount of contamination which gets onto the floor and to enable people to be able to see isolated spills and take avoiding action.

Under this heading come such preventative measures as monitoring the ambient temperature to ensure condensation does not occur on the floor or pipe work, providing external canopies over doorways, provision of adequate matting so that rainwater is not brought into the building on people's shoes, and matting in areas where spills or contaminants are likely to get onto the floor, eg. around coffee machines and self-service fruit and vegetable displays, etc.

DESIGN AND/OR MANAGEMENT

In an ideal world every floor should have a minimum slip resistance in both dry and contaminated conditions such that it is greater than the maximum people are likely to need to walk or run across that floor. For general purposes this is a PTV of 40, although for sports halls and similar floors a PTV of 60 may be required.

This however would rule out the use of a large number of otherwise very acceptable flooring materials for the simple reason that floors are not chosen on the basis of their slip resistance alone. Certainly a number of floors have to be chosen on that basis, for instance in swimming pools, changing rooms, industrial kitchens, and places where there is no means realistically of preventing contamination of the floor.

On the whole, floors are a compromise based on factors such as aesthetic appearance, cost, durability, ease of cleaning, as well as their slip resistance. As a result, the majority of flooring solutions do not have a sufficiently high slip resistance in contaminated conditions to ensure that everyone who walks across that floor in those conditions can do so safely. In such cases there are five possible solutions.

The first solution is to consider the use of specialised footwear. In an industrial or commercial situation, where a limited and controlled number of staff use the floor and they can all be issued with the special footwear, this is often the cheapest and most reliable solution. However, it is important that shoes are available for visitors and that regular checks are made on the state of wear of the soles and heels of the shoes issued to the staff. Replacements should be readily available so that no one is permitted to walk on the floor in their own footwear simply because there is no special footwear available for them.

The second solution, and the most common, is to take a series of management and environmental measures to ensure as far as is reasonably practicable the floor does not become contaminated. Such measures have been outlined previously but will include provision of adequate matting. Entrance mats should be large enough to ensure at least four footfalls (2 per foot) and these should be monitored in wet weather as they can easily become saturated. In such cases janitorial or security staff need to be aware that they should bring out supplementary mats which themselves need to be checked on a regular basis to ensure that they are doing their job. Mats need to be provided where spillages are likely and staff need to be made aware of the potential danger, such that if they see a spillage on the floor, it is primarily their responsibility to ensure that it is attended to as soon as possible and that other staff (or customers) are prevented from inadvertently stepping into the spilled contaminant. Whenever this solution is adopted it is important that those running/managing the floor are made fully aware of the fact that the responsibility for slip prevention lies with them.

The third solution is related to the previous solution. Often the only time a floor becomes wet is when it is being cleaned. In such cases pedestrians should be prevented from walking over that area of floor by suitable temporary barriers until the floor is fully dry. Many cleaners merely rely upon a 'wet floor' warning sign. In practice, and particularly if the floor has a slip resistance in the wet of less than 25 PTV, it is possible to slip over even when walking carefully or defensively on such floors. A further

problem with such signs is that people either fail to notice them or simply take no notice of them. From a legal aspect, the use of such a sign is a blatant and public admission that the floor is dangerous.

The fourth solution is more drastic and involves either replacing the floor or treating it to give it the necessary slip resistance. In certain cases this may be the only or most reliable solution particularly when the volume of pedestrian traffic is so great that it is unrealistic to rely on matting to prevent ingress of rainwater onto the floor. In such cases replacement does not necessarily mean that the old floor has to be taken up. Overlaying or over-tiling is commonly used and problems of levels at footways, etc., can be relatively simply overcome with good design.

Increasingly, floors are being treated to give increased slip resistance. There are a wide variety of such treatments available. In all such cases it is important that the contractor demonstrates by testing using a Pendulum or SlipAlert that he has achieved the desired result. As with any flooring, subsequent maintenance and cleaning of the floor are critical to it continuing to provide the desired level of slip resistance, and regular monitoring is essential as some treatments are not as durable as others.

The fifth and final solution to the problem of a floor which does not have the necessary degree of slip resistance in contaminated conditions is to do nothing on the basis that if someone does slip over then the insurance will pick up the bill for the claim. Whilst a number of slipping claims are only in the region of £ a few thousand, a significant number involve £ tens or hundreds of thousands; insurance companies are not philanthropists and claims almost invariably lead to increased premiums.

Until relatively recently it was uneconomic or indeed impractical to regularly monitor one's floors for slip resistance. That, however, has changed and nowadays it is possible for the floor owner/manager to work from a basis of knowledge of the performance of his floor rather than a basis of ignorance and being caught by surprise when an accident occurs. Regular testing using SlipAlert can show how the floor is performing in both contaminated and dry conditions so that it is both easy and quick to identify a potential problem. Just like a certain well known make of wood care product, SlipAlert does what it says!

SPECIFYING A FLOOR

Specifiers should be aware that all manufacturers, whether it be ceramic tiles, synthetic resin flooring or thermoplastic/resilient flooring, quote average 'factory gate' values of slip resistance for their products. This is because it is the most consistent way of measuring their product and because there is no universally agreed test or method of simulating possible changes in the early life of the product nor the processes which may take place during the laying operation.

It must be recognised that in the case of ceramic tiles, not only do individual tiles vary slightly but the action of cleaning off the very abrasive grout after laying can change the slip resistance properties of certain tiles. Similarly, with synthetic resin flooring, quoted slip resistance values are invariably based on laboratory produced samples and indicate what can be achieved. What is actually achieved and the variation over the floor will be dependent on the floor layer. In the case of thermoplastic/resilient floors, slip resistance can vary within a single sheet but it can also change during its early life under the influence of initial trafficking and cleaning.

Hence it is unrealistic to expect any floor when tested in its early life on site to be guaranteed to meet at any and every point where tested the manufacturers' published slip resistance. Allowance must be made for the fact that figures published are an average and the action of laying the floor and changes which take place in the early life of the floor will in most cases cause a reduction in, particularly the wet, slip resistance of that floor. The actual extent of any variation over a floor and the extent of any change/reduction in slip resistance are critically dependent on the product itself and the conditions to which it has been subjected during the laying process and its early life. Specific guidance on these aspects can only be given by the manufacturer based on his experience.

CONCLUSIONS

In order to prevent slipping accident it is important that those who specify, clean, maintain and manage floors understand how slip resistance of those floors is achieved and maintained and what factors can affect those floors. There is no one simple and universal solution to the problem, each floor needs to be considered in relation to the factors outlined in this paper.

Critically, it needs to be understood that floors can change over a period of time and/or the factors affecting the floor can change. Floors need to be regularly monitored and reassessed and in that respect it is vital to work from a basis of knowledge about the current slip resistance performance of the floor rather than either guesswork or just hope.