SLIP – THE PEDESTRIAN PROBLEM

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Summary

This paper investigates the walking action and considers the various factors affecting how people walk. It also illustrates test methods of determining the unpolish and polished slip resistant values.

Introduction

Walking is an universal activity, taken for granted as is breathing, sleeping or eating and, like these other basic activities, it serves a vital function. Walking provides mobility, giving access to work, leisure, shops, services and education.

Apart from being a leisure activity confined to ramblers, walking is an essential day to day means of transport and accounts for about one- fifth of journeys to and from work, half of all shopping trips and two thirds of children's journeys to school. Men tend to walk less than women, men are more likely to walk to work while women go shopping. City dwellers walk more than country dwellers.

The street scene concerns every one, a pleasant road, shopping centre or a park can make a considerable difference to the quality of life, enjoyed by people in their area.

In the late 80's, a survey found that 142 in every 1000 people, aged 16 or over- a total of some 6.2 million adults in Britain, had some physical, sensory or mental handicap. About 1 in 10 of the adult population have some form of locomotive handicap. When account is taken of those who are accompanied by small children, encumbered by luggage or shopping, temporarily handicapped by injury or pregnancy, or becoming frail through normal ageing; it is estimated that about 10 million people in the United Kingdom are mobility handicapped in some way.

There has been enormous increase, in recent years, in the number of pedestrian schemes, ranging from closing off streets, to creating pedestrian zones in towns and cities, and the major new developments.
Within the pedestrian area, the most important factor is the walking surface. The ideal footway should be firm, even, well drained and 'low' slip in wet and dry weather.

Mechanics of Walking.

The mechanism of walking is the action of the foot in a combination of turning and slipping movements. As the control of footway surface characteristics is not generally feasible, we need to provide a surface with sufficient friction for the user to feel confident that their foot will not slide out from under them. It must provide sufficient slip so that this foot can move easily in contact with the surface.

If the friction is too low, the walker is uncomfortable and adopts an unnatural gait taking shorter steps and keeping the foot nearly horizontal by sliding the foot along. If the friction is too high, the walker is again unable to proceed comfortably. The foot is unable to rotate and the added grip, may cause the person to stumble.

Movement of the Foot.

The way people walk is determined by the physical characteristics of the person - age, weight, height and whether male or female.
The gait is dependant on the intrinsic way of the person walks, the type of shoe that is worn, whether they are city shoes, sports shoes and if the sole is leather or rubber etc..
Also, the walker's impression of the condition of the walking surface whether it is slippery or non- slippery.

Which ever, the way people walk, it can be summarised into three basic phases and these are:-
a). First contact phase, this where the heel of the shoe comes in contact with the surface.
b). Main contact phase, is when the heel and the sole of the shoe are in contact with the surface.
c). Lift off phase, is where the heel is lifted of the surface and the front of the sole is in contact.
There are many ways in which to analyse walking and the best method is to film the action and then examine the film in slow motion.
The action of walking is where the heel of the leading foot makes heel contact (first contact), and the lagging foot is in full contact. The leading foot rolls forward and the sole of this foot makes full contact (main contact), while the lagging foot has rolled forward and has started to leave the surface moving forward ready to make heel contact. Diagram 1 illustrates this action.

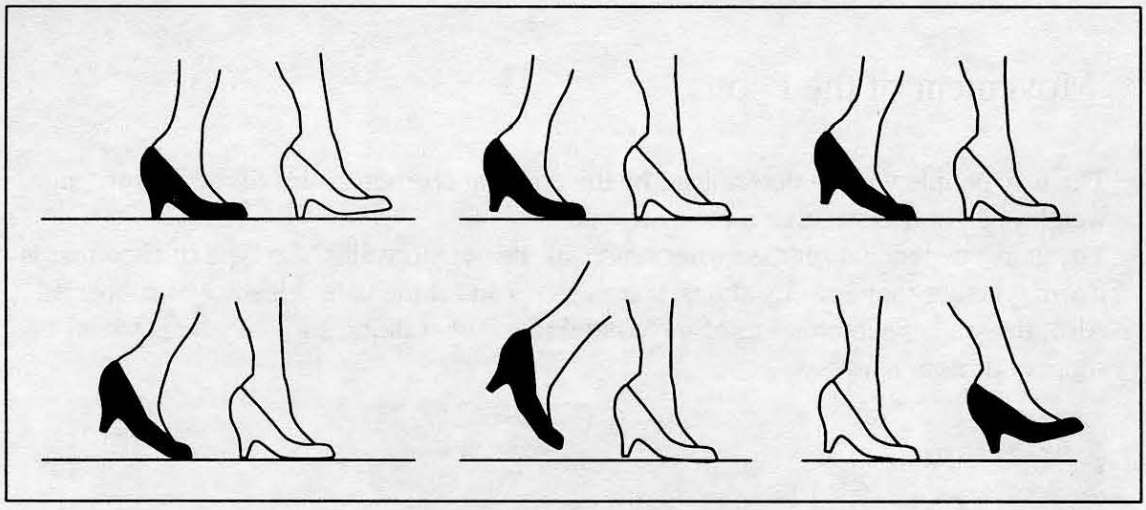


Diagram 1

When a step is taken, as soon as the heel strikes the floor the vertical force, due to the person's weight, rapidly increases and slipping can occur in this period. The rotation of the foot is then very rapid with the transfer of the weight from the heel on to the sole and then on to toes . At the beginning of slipping, which occurs within one twentieth of a second after the foot has struck the floor, the angle between the foot and the floor is about 65°.

To summarise the action ,there are three cases of the foot movement on the ground

- absence of slipping (grip), the heel velocity is cancelled out.
- slipping without loss of balance, (skid - slip - stick), the heel velocity passes through a minimum but remains sufficiently low enough not to cause the pedestrian to fall. They may not be aware of the slip.
- slipping with loss of balance, the heel velocity passes through the minimum before increasing rapidly.

Factors involved in slipperiness

As stated previously, slipperiness is a combination of the foot characteristics and the surface conditions.
Using basic physics, the measure or physical resistance is the coefficient of friction of the two materials. Slipperiness is a combination of foot wear and surface conditions and involves the coefficient of friction of these two surfaces which are affected by:-

- the type and hardness, temperature and humidity of the floor.

- the type and hardness, temperature and humidity of the shoe.

- the load applied to the foot and its relative velocity.

- the ambient temperature, pressure and relative humidity

- the change from one surface to another.

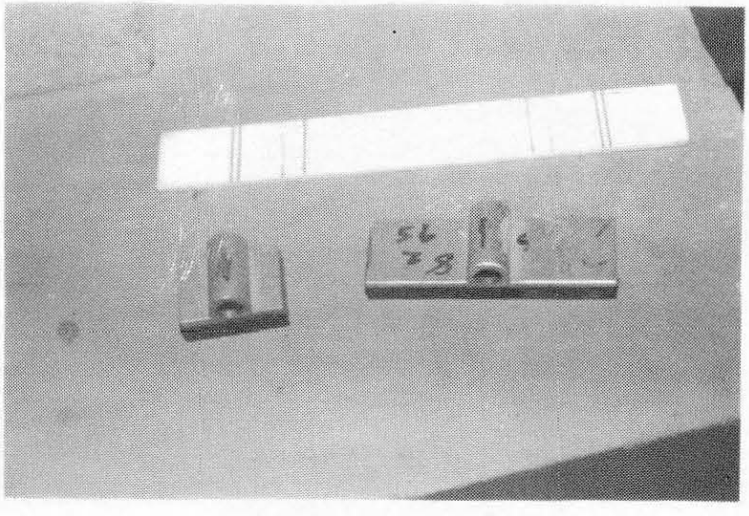
Coefficient of Friction

Research over the years has indicated that a coefficient of around 0.4 between the heel and the floor makes slipping improbable. The Greater London Council, in their evaluation, produced the following table :-

Pendulum Value	Category
65 and above	Very good
35 - 65	Good
25 - 34	Marginal
24 and below	Unsatisfactory

Laboratory test method for determining the slipping coefficient

This test method has two parts, the measurement of the unpolished slip resistance value and the polished paver value. The measurement of these values on the specimen, is made with the pendulum friction test equipment using a 76mm wide slider for the unpolished value and a 31,8mm wide slider for the polished value.(photograph 3)

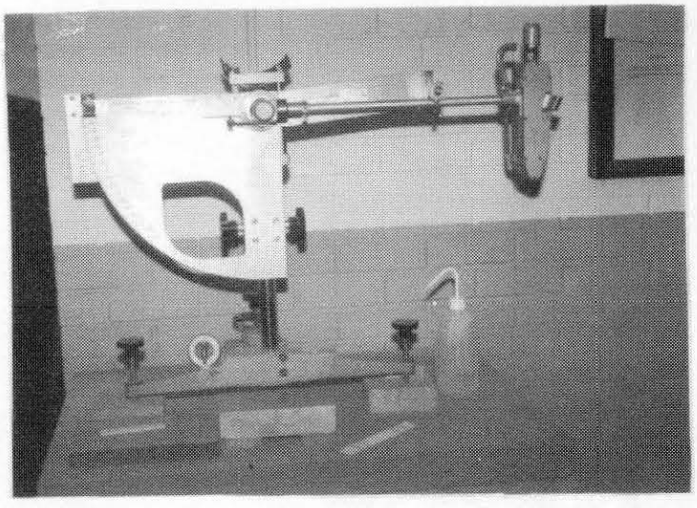


photograph 3

The Unpolished Slip Resistance Value

The friction tester is placed upon a firm level surface and is levelled by adjusting the screws so that the pendulum support column is vertical. The height of the pendulum arm is adjusted so that in traversing the specimen the rubber slider is in contact with it over the whole width of the slider and over a length of 126,0mm.(photograph 4). Both the surface of the specimen and the rubber slider, are wetted with copious supply of clean water. The pendulum and the pointer is released from the horizontal position, catching the pendulum arm on its return swing. The position of the pointer on the test scale is recorded. This procedure is repeated five times, rewetting the specimen each time, and recording the mean value of the last three readings. The specimen is

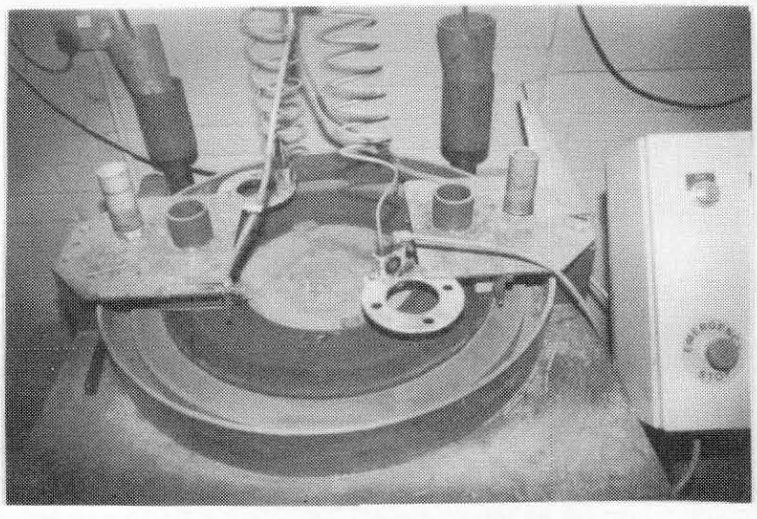
relocated after rotating through 180° and the friction test is repeated. The average of these two readings is the Unpolished Slip Resistance value (USRV).



Photograph 4

Polished Paver Value Determination

The method to obtain a laboratory value for the Slip resistance under the action of polishing by the passage of feet, the method incorporates the use of the flat bed polishing machine.(photograph 5). This enables the slip resistance of a polished paver to be expressed as the PPV(polished paver value), in a similar manner to the assessment of the polished stone value(PSV) of aggregate particles, measured on a curved surface.



Photograph 5

The test consists of two elements,.

a). First part: samples of paver are subject to a polishing action in an accelerated polishing machine

b). Second part: the state of polishing reached by each sample is measured by means of a friction test as previously illustrated, except the rubber slider is 32,8mm wide and the sweep is 76mm. The readings are taken off the small scale attached to the side of the large scale.

The specimens are placed face down in the metal holders on the rubber annulus at positions diametrically opposite each other.
To achieve consistent polishing, the specimen is weighted down to provide a contact stress of 2276 N/m^2 over the area of the final prepared contact surface.
The machine is switch on at a rate of 29 rpm and simultaneously feeds water and corn emery on to the rubber annulus, so that it is spread evenly over the surface immediately at the front of each specimen. After 700 revolutions, the specimens are removed and all traces of the corn emery is washed off. The specimens are placed back in the machine in the same position and the test is repeated using emery flour. After 700 revolutions, all traces of the flour is removed and the slip resistance is measured as before.

Slip resistance results

As small elemental products are made from processed naturally occurring material, let us first examine the slip characteristic of this parent material.

Parent material	UPPV	PPV
Sandstone 1	45	54
Sandstone 2	61	48
Slate	34	48
Granite	20	17
Limestone 1	80	45
Limestone 2	75	50

From the above results careful selection is needed when choosing material for inclusion in concrete products, for example, if using an all limestone mix then it has been proven both by test and in practice that polishing creates a slipping problem.

It is important that when choosing aggregates we use different sources of material so that they work with each other to provide a good slip resistance value.
Examples of this, is the combination of hard mud stone and naturally occurring sand where after the test has a PPV of 65.

Further evaluation have been performed on a variety of concrete samples and the results are shown

Material (concrete mix)	UPPV	PPV
Sandstone	75	70
Limestone	51	44
Sand/gravel	68	60
Granite	63	51

Effects of surface treatment

By changing the surface texture, it is possible to change the values of slip resistance. As previously stated, if we make the surface to good in slip resistant value terms, then it makes it difficult for some pedestrians to be actively mobile.An example of the change of surface texture from smooth(ex mould) to lightly shot blasted resulted in the slip values going from 70 to 92.

Maintenance of the surface

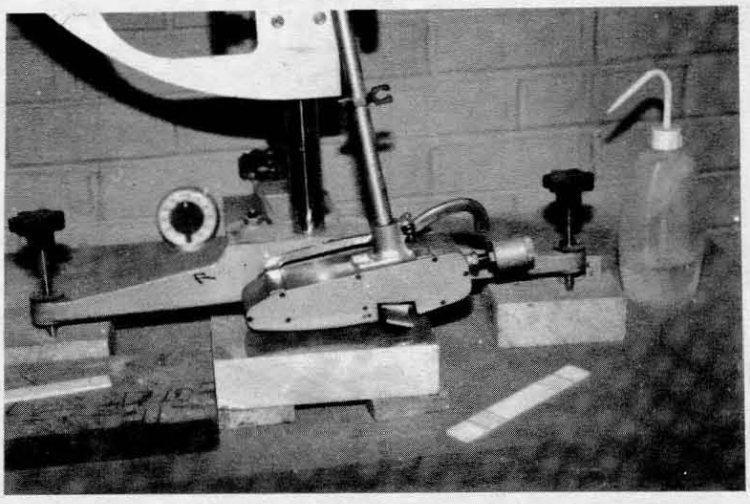
The condition of the surface, whether there is the presence of surface water and/or dirt accumulation affects the slipperiness. Dirt accumulation can influence the surface texture feature, absorb grease and water and can act as a solid lubricant. It can absorb atmospheric moisture and become sticky causing the foot to adhere to it, unexpectedly leading to stumbling or tripping accidents.

It important to have a maintenance programme in place for regular washing and cleansing of the surface. An example of this is in a pedestrian walkway, the results before washing were 30 and after washing were 55 pendulum values.

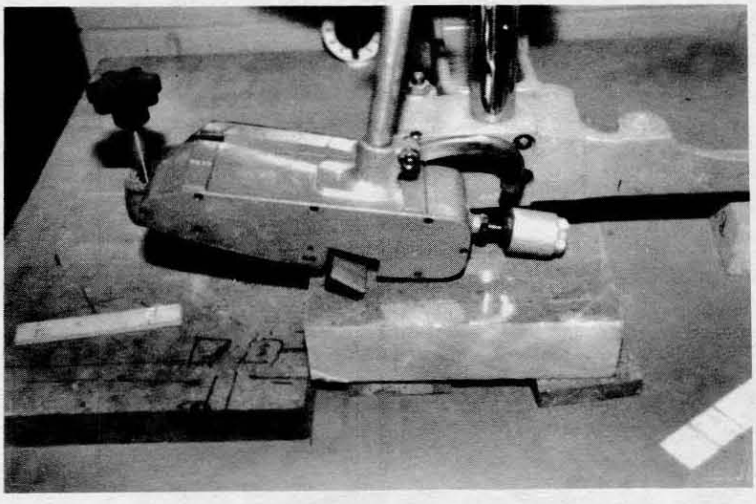
Conclusion

It is possible to predict the performance of a product in service by a laboratory test and using these result produce a product that is safe to use in practice, for all the different user requirements.

Photograph 6.
Contact of slider.



Photograph 7.
After contact of slider



Photograph 8.
Scale reading