SLIP RESISTENCE OF CERAMIC FLOORING

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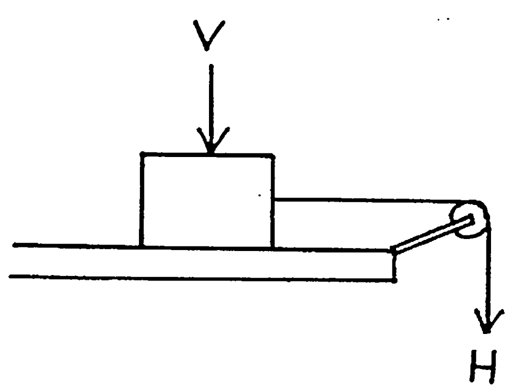
1 INTRODUCTION

This lecture consists of a review of methods of friction measurement contained in the draft ISO standard for ceramictiles, and, particularly in view of the controversy surrounding the dynamic method, particular attention will be devoted to this, known in Britain as the Tortus.

I shall start in a rather elementary way explaining definitions, through to systems of measurement and on to the standard itself.

First of all, what is friction?

Basically the concept is simple; it is the horizontal force resisting motion between two surfaces. The standard experiment performed in school is shown in the following diagram.



$$\mu = \frac{H}{V}$$

The force H is slowly increased until de block moves. Then, the coefficient of friction = H/V, strictly speaking the coefficient of static friction.

It should be noted here that when referring to friction a rigorous definition should be applied. It is not good enough to say that a tile has a coefficient of friction of x. The following parameters must also be defined:

(i) The two surfaces eg, 4S rubber on tile.

(ii) The conditions eg, in dry or in wet.

(iii) The system of measurement eg, dynamic, static, ramp etc.

2 ORIGINAL WORK OF CERAM

CERAM's original investigations into slip resistance involved various trials, all of which were unsatisfactory for various reasons. It was therefore decided to specify the various parameters we needed to cover in the proposed system of measurement.

OBJECTIVE

MEASUREMENT OF SLIP RESISTANCE

1 CERAMIC TILES

2 LEVEL FLOORING

3 DRY AND WET CONDITIONS

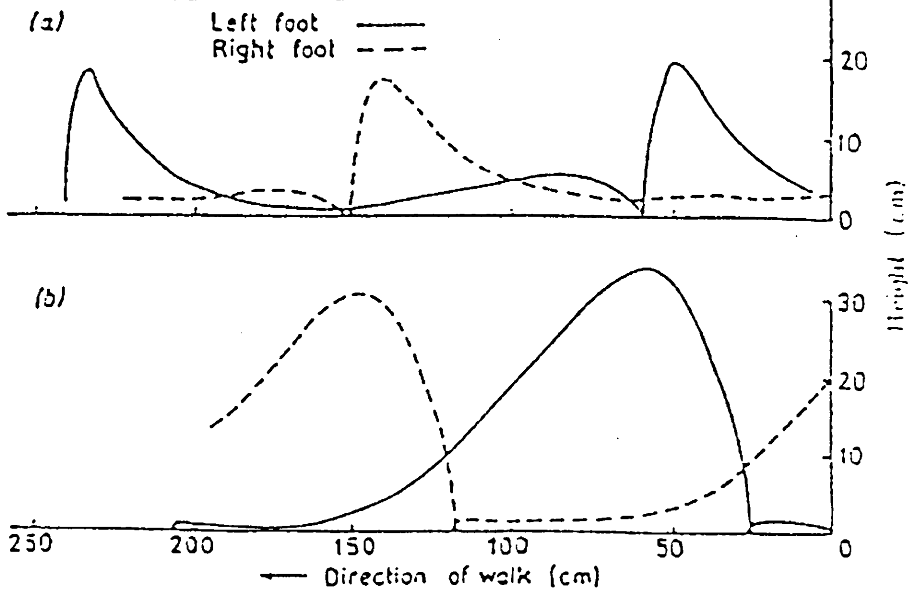
4 NORMAL STRAIGHT LINE WALKING

5 INITIAL HEEL CONTACT

These parameters were deliberately chosen to represent the simplest basic conditions pertinent to walking on ceramic floors. It seemed to us to be beyond our scope to accommodate all the extreme variations that may exist beyond these parameters. For instance, our measurements would not encompass people running, jumping, or turning suddenly. Furthermore, in the first instance, measurements would be limited to ceramic tiles only and laid on a flat surface.

Discussions with various bodies who had experience of slipping accidents showed that the critical factor was when the heel of the shoe made initial contact with the floor. To establish the features we were looking for, the mechanism of walking was studied. A large number of people were filmed while walking on a tiled floor past an illuminated screen with vertical and horizontal grid lines. The cine camera was set at ground level and, knowing the filming rate (frames/second) a total analysis of the mechanism of walking was possible.

The next figure shows a typical example of one of the results.



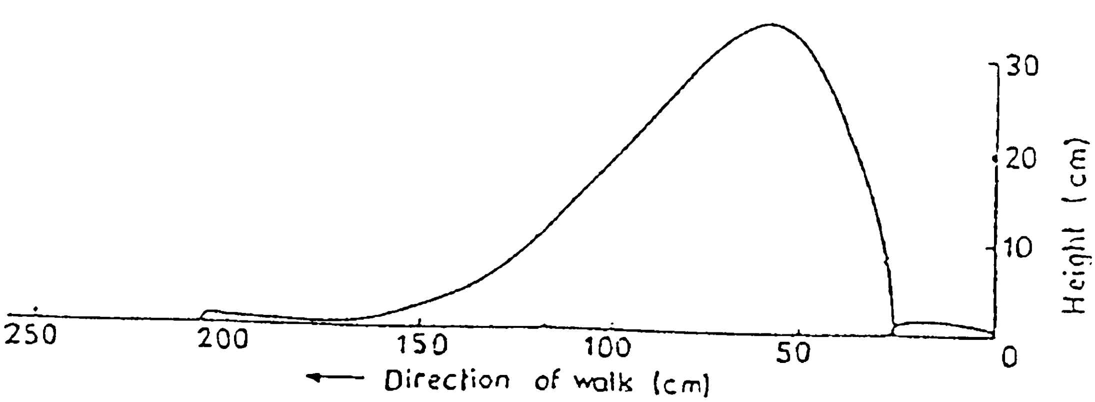
(a) Toe and (b) heel movements during walking

Subject, height 6 ft 1 in,

stride 2.94 ft, walking speed 4.2 mph,

maximum speed of toe 16.4 mph, of heel 14.9 mph

As you can see the mechanism of walking is very complex. However, the important factor to emerge from these experiments is the part of the graph where the heel first makes contact. The next figure shows the heel movements.



Heel movements during walking

It can be seen from this graph that there is only a very small horizontal component of movement as the heel contacts the floor. Calculations from the results showed that the horizontal component of velocity is invariably < 10 mm/s and is frequently zero.

3 DEVELOPMENT OF THE TORTUS

From this work the following parameters were chosen to be incorporated in the slip resistance measuring apparatus.

PARAMETERS ADOPTED

1 VERTICAL LOAD

200 g.

2 SLIDER DIAMETER

9 mm.

3 SPEED OF TRAVERSE

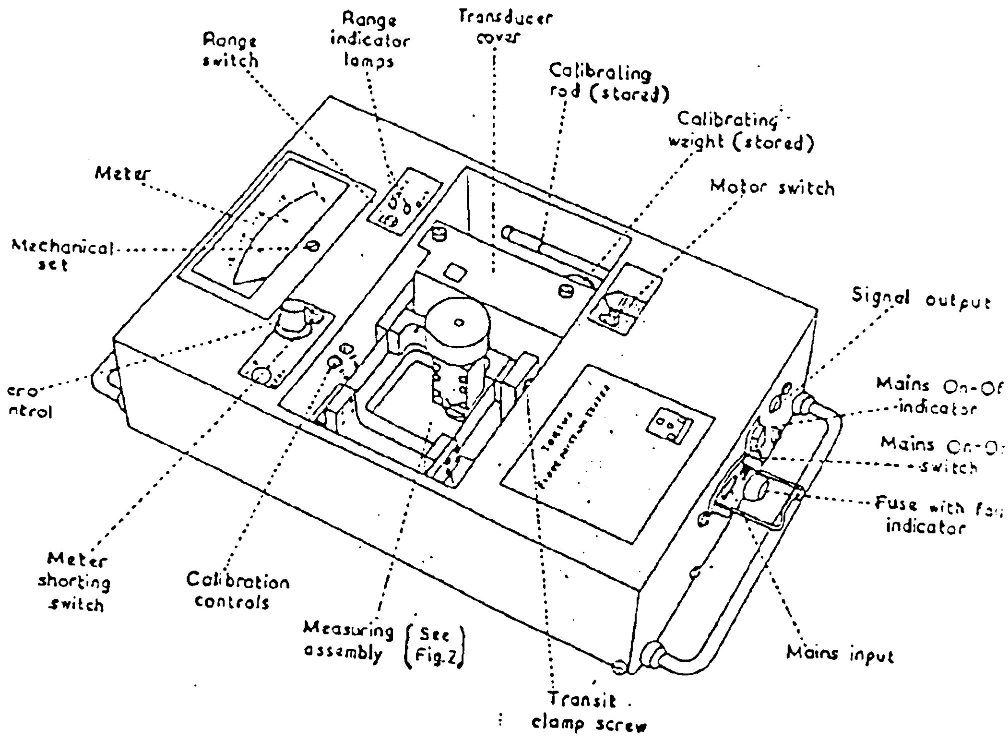
17 mm/s.

4 SLIDER MATERIAL

4S RUBBER

A vertical load of 200 g on a 9 mm diameter slider (~ 0.64 cm2) the equivalent of 68 kg on an area of ~ 220 cm2 hopefully, an average person. Of course, it is appreciated that subsequent to heel contact the vertical load will vary but for ease of operation a constant load was chosen. The slider made of 4S rubber is representative of about 90% of footwear. However, it is no problem to use sliders of any material and, as a routine, we always include sliders of leather and soft rubber.

The next figure shows a general view of the Tortus as it looks today after considerable refinements.



General View of instrument

Essentially the apparatus consists of a slider of the appropriate material with a constant vertical load that is dragged across the test specimen. It is attached to a steel spring assembly which bends according to the horizontal force opposing movement. The apparatus is so calibrated that the coefficient of friction is indicated:

(a) On the meter

(b) On a recorder, producing a permanent record

There are a number of advantages to be obtained by the use of the Tortus:

(i) The instrument is portable and so can be used on-site and in the laboratory.

(ii) Sliders of any material and varying geometry can be used.

(iii) A continuous record of friction is obtained and small areas of low friction are easily identifiable.

4 DRAFT STANDARD, ISO/DIS 10545-17

In the draft standard for measurement of friction, besides the dynamic method just described, there are two other methods, the German Ramp and the American Static Method.

The two methods are briefly described in the standard as follows:

4.1 Method B: Static Slider

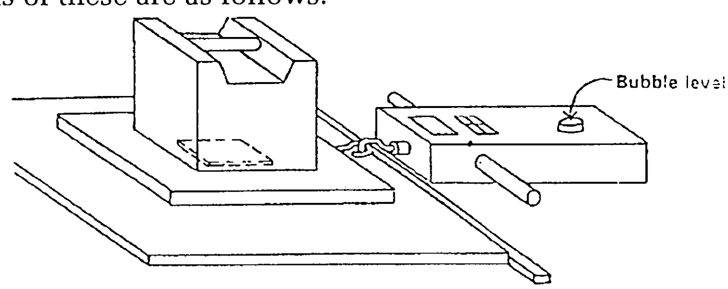
This method uses a slider assembly shod with 4S rubber as the contact surface. A suitable system is used to determine the maximum horizontal force necessary to initiate movement between the slider and the tile face under both wet and dry conditions. See Annex B for a detailed description of one example of this type of method and procedures.

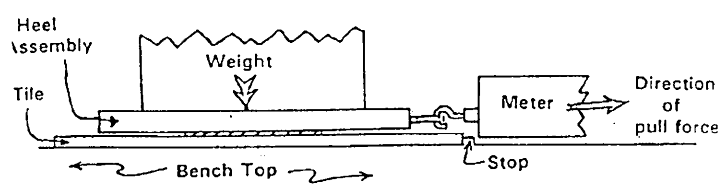
Note: This method may be used for laboratory measurements or on floors in service.

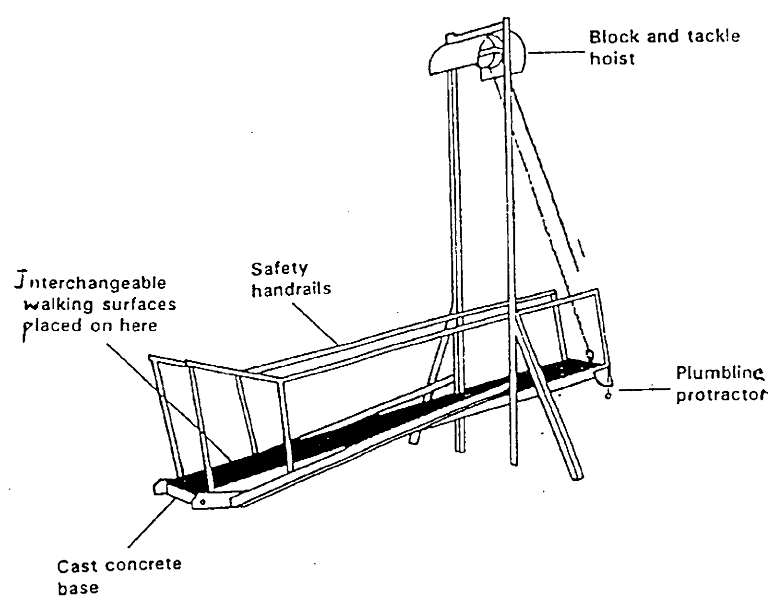
4.2 Method C: Inclined Platform

A person in an upright position moves forward and backward on a ceramic tile test panel (1000 x 500 mm). The inclination of this test area is increased at a constant rate from horizontal to an angle at which the testing person shows signs of insecurity in his movement. The test is performed with oil on the test area. The angle of inclination of the ceramic tile test panel is determined. See Annex C for a detailed description of one example of this type of method and procedures.

Diagrams of these are as follows.







5 DRAFT ISO/DIS 13006

This is the requirements standard for ceramic tiles and there has been considerable criticism of the friction classifications in Annex E.Tiles are classified as follows on the basis of average values:

Class	< 0.4 dynamic CoF tested in accordance with ISO 10545-17 Section 4.1
	< 0.5 static CoF tested in accordance with ISO 10545-17 Section 4.3
Class 2	≥0.4 dynamic CoF tested in accordance with ISO 10545-17 Section 4.1
	≥0.5 static CoF tested in accordance with ISO 10545-17 Section 4.3

Products in Class 1 are satisfactory for normal installations. Where enhanced slip resistance is required, the use of tiles in Class 2 is recommended.

The main objection to this is the implication that tiles of zero friction (say) would be suitable for normal installations. To correct this anomaly the following extended classification has been proposed.

Class 1

< 0.2 CoF. Tiles will mostly be smooth glazed tiles which will record this low value when wet. These tiles should only be used in dry situations and should be excluded from wet environments.

≥ 0.2 - < 0.4 CoF. Tiles will usually be glazed tiles which show these lower values only when wet, although there may also be a small number of unglazed tiles in this category. Besides domestic bathrooms, where the use of a slip-resistant bathmat is essential, they ma be considered for other domestic areas such as kitchens, and other areas which are dry.

Class 2

≥ 0.4 < 0.7 CoF: Tiles will include some glazed tile and most unglazed tiles. If a tile has this CoF as a minimum, dry and wet, it may be regarded as safe for installations including bathrooms, kitchens, porches, halls, cloakrooms and living rooms. They may also be used for public areas such as large cloakrooms, lavatories, communal showers, swimming pool surrounds and larger areas such as shopping centres, airport concourses, hotel foyers, public walkways, etc.

≥ 0.7 CoF: Where more enhanced slip resistance is required such as in commercial kitchens, abattoirs, garage floors and certain industrial environments, the use of tiles, plain or textured surface, with CoF ≥ 0.7 is advised.

This type of classification is based on a "suitable for purpose" concept and, apart from extending the classification, provides a guide to the tile user.

6 SLIPPERY FLOORS, IN-SERVICE DEFINITION

Finally, some words about what we understand by a "slippery floor" from on-site experience. The extremes are easy. If everyone slips over then the floor is slippery. If no one slips then the floor can be said to be slip-resistant. However, we are looking for a definition somewhere between these two extremes. At what level do we differentiate between safe and unsafe.

If one person in 100,000 slips, is this a slippery floor? Or should it be one person in 10,000?

Possibly the definition should be in terms of x slips in the number of steps across the floor (106 say)

Maybe we are seeking a definition impossible to achieve because:

(i) People walk differently

(ii) There exists a wide variety of footwear

(iii) People have varying agility in correcting potential slipping

(iv) Across a floor area there may different contaminants

The achievement of a definition in user terms seems a long way off but, in the meantime, we who measure friction characteristic continue to do our best to resolve this dilemma.