ANALYSIS OF THE LIFE SPAN OF FLOORING SLIP RESISTANCE PERFORMANCE

A. Muñoz [(1)], G. Silva [(1)], R. Domínguez [(1)], J. Gilabert [(1)], M. López [(2)], M.C. Segura [(3)]

[(1)] Instituto de Tecnología Cerámica (ITC). Asociación de Investigación de las Industrias Cerámicas (AICE). Universitat Jaume I. Castellón. Spain

[(2)] Exagres, S.A. Betxí. Spain

[(3)] Vernís, S.A. Onda. Spain

ABSTRACT

At present, the slip resistance performance of ceramic floorings is evaluated on samples of the product at source, so that the evaluation only provides information on how the newly installed product will perform.

Various studies confirm that rapid changes develop in slip resistance owing to wear by pedestrian traffic across the floor surface. In previous papers, a laboratory methodology was proposed to abrade surfaces of sufficient size in order to be able to evaluate their slip resistance performance, although this method was not validated or correlated with the wear that occurred under actual conditions and consequently did not allow flooring life span to be predicted.

In the present study, a methodology has been developed that simulates the wear that occurs under real conditions by pedestrian traffic across the floor and allows sufficiently large surfaces to be generated to enable floor slip resistance to be evaluated using current standard test methods. In addition, different in situ studies were conducted with a view to adjusting the variables of the method to reproduce real conditions, as well as to correlate the different wear stages with the real life span of the product.

It may be noted that slip resistance is one of the characteristics derived from the essential requirements envisaged in the CE mark of ceramic tiles and must be declared when required by national regulations of the destination EU Member State. In Spain, these regulations are laid down in the Technical Building Code, DB SUA "Safety of Use and Accessibility", in which the requirements relative to the slipperiness of floors in buildings or publicly used areas are compiled. A key aspect to be taken into account is that these requirements need to be maintained throughout the service life of the flooring. The methodology developed enables the life span of tile slip resistance performance during its service life to be determined.

1. BACKGROUND

The laboratory test methods used to simulate the evolution of abrasion in floors subject to pedestrian traffic do not allow the influence of the surface friction wear process to be analysed because the test surfaces used are too small to allow the coefficient of friction to be evaluated with current methods (pendulum, ramp, and tribometer).

Consequently, in order to be able to study on a laboratory scale how changes in the floor surface affect its slip resistance performance, a method needs to be developed that allows worn surfaces to be generated that simulate the real process and that have a sufficiently large uniform area to be able to evaluate floor slip resistance.

At present, no recognised methods for evaluating long-term slip resistance are available. To be noted, however, is the accelerated wear method developed by C.J. Strautins [1]. That method is based on the machine used to test washability and wear in the paint sector. The machine has a slider with linear motion to which different abrasive materials (scouring pads) with different degrees of abrasion are fixed.

In the present work, to establish a representative reference of the wear evolution under the conditions associated with pedestrian traffic, the information obtained in previous ITC studies [2] was used, which led to the development of normative document UNE 138001:2008 IN [3] "Resistance to wear by pedestrian traffic of ceramic floorings. Recommendations for selection based on intended use".

To develop that method, various in situ studies were performed in which the evolution of the surface gloss of ceramic tiles, exposed to real conditions of pedestrian traffic, was analysed in indoor building areas and building areas with direct outdoor access.

The study confirmed that the evolution of wear differed noticeably, depending on the quantity and type of abrasive present, so that different types of abrasive are required to simulate different exposure conditions.

As slip resistance requirements are particularly significant in outdoor service conditions, it was decided to use the test conditions of building areas with direct outdoor access as comparative reference for the validation of the wear simulation method.

2. DEVELOPMENT OF THE WEAR SIMULATION METHODOLOGY

A semi-industrial polishing apparatus with a polishing head to which different abrasive elements could be fixed was selected to perform the abrasive wear.

This device is used to study the industrial polishing conditions of ceramic tiles on a pilot scale (Figure 1). The machine operates such that the test floor tile travels through it on a belt under the rotating polishing head. The head has 6 holders for grinding tools of the fickert type (Figure 2), in which different abrasive materials can be fixed.

The apparatus allows variables such as the following to be controlled:

- Head rotation speed.
- Belt speed.
- Number of swings.
- Pressure applied on the sample.
- Abrasive material.

Figure 1. Polishing facility.

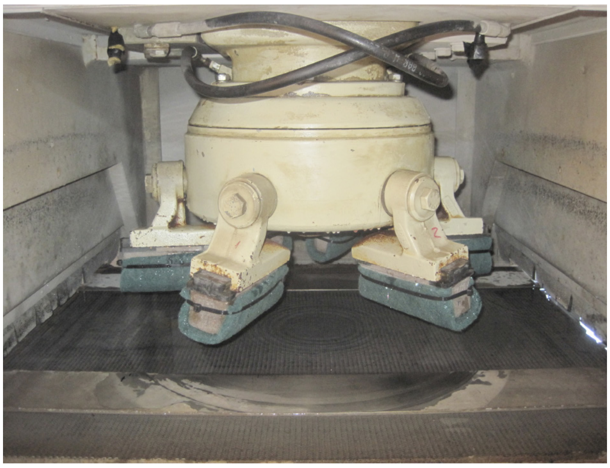

Figure 2. Polishing head.

2.1. STUDY OF ABRASIVE MATERIALS

As mentioned above, a key parameter in the wear process is the nature and size of the abrasive involved in the process.

Different abrasive materials were selected to simulate wear (Figure 3):

- Sanding brush.
- SiC brush.
- Commercial scouring pad.

Figure 3. Abrasive materials used: a) sanding brush, b) SiC brush, c) commercial scouring pad.

With a view to enhancing the precision of the wear measurement, gloss was chosen as the evaluation criterion because it varies markedly during the wear process.

The use of sanding brushes or SiC brushes did not exhibit sufficient progress in gloss loss to reach the expected reference values. In all cases, an initial drop in gloss was observed with the first passes, but the gloss did not decrease any further in subsequent wear stages.

In view of the results obtained, it was decided to work with a more abrasive material. A commercial scouring pad, whose composition consisted mainly of quartz with a particle size distribution (Figure 4) closely resembling that of the quartz used in the UNE 138001 IN wear method, generated a very similar wear evolution on the tiles to the gloss losses obtained by that method.

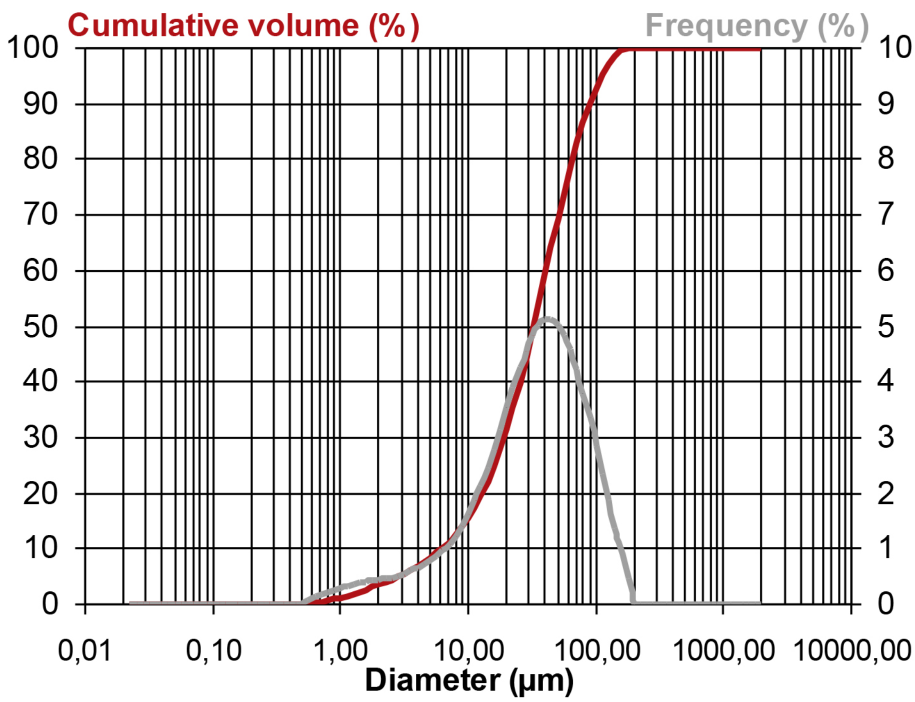

Figure 4. Particle size curve of the powder obtained on calcining the commercial scouring pad.

It was therefore decided to use this abrasive element to define the test conditions. The following variables were studied: pressure on the surface, belt rate of advance, and life span of the scouring pad.

2.2. STUDY OF THE VARIABLES OF THE APPARATUS

The material selected for the study of the different variables was a ceramic tile that had a polished finish with a very high starting gloss. As noted above, gloss is a property that changes noticeably with wear, so that it is a very interesting characteristic for use in evaluating the arising wear.

2.2.1. Influence of pressure

The first variable to be studied, one of major importance in the wear process, was the pressure applied by the polishing head on the tile surface.

Trials were conducted at different working pressures, measuring the curves of gloss loss versus grinding tool–tile contact time in each trial (Figure 5).

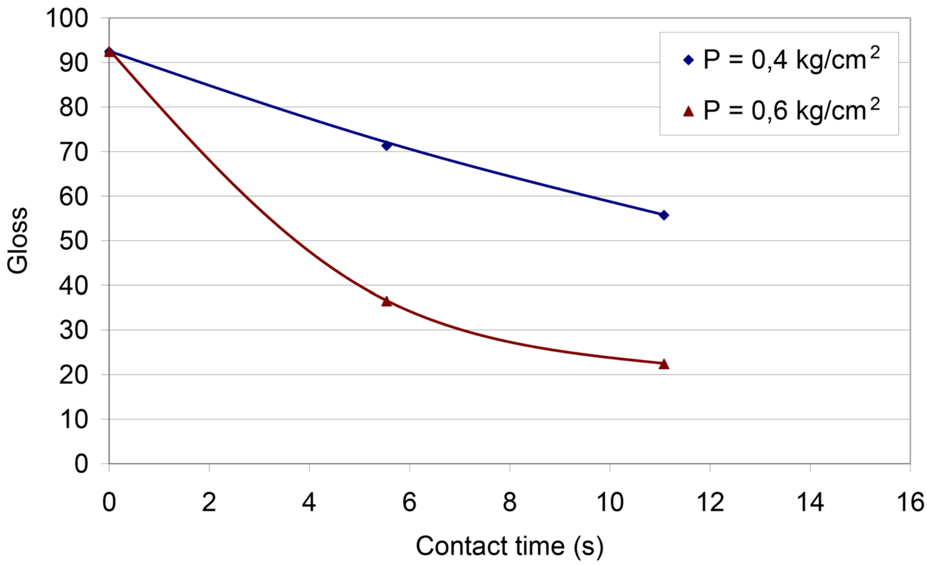

Figure 5. Surface gloss as a function of contact time at different pressures.

It may be observed that pressure significantly affected the gloss loss of the tile surface, as the slope increased when the pressure applied by the abrasive element rose.

2.2.2. Influence of the rate of advance

Another of the working parameters of the apparatus that could affect the arising wear was the rate of advance of the tile-conveying belt.

Trials were therefore conducted at three different speeds and the resulting gloss loss was plotted as a function of contact time (Figure 6). As the figure shows, the three speeds produced the same gloss loss.

It was thus established that the belt rate of advance did not influence wear, though it allowed the test to be accelerated by regulating the grinding tool–floor tile contact time.

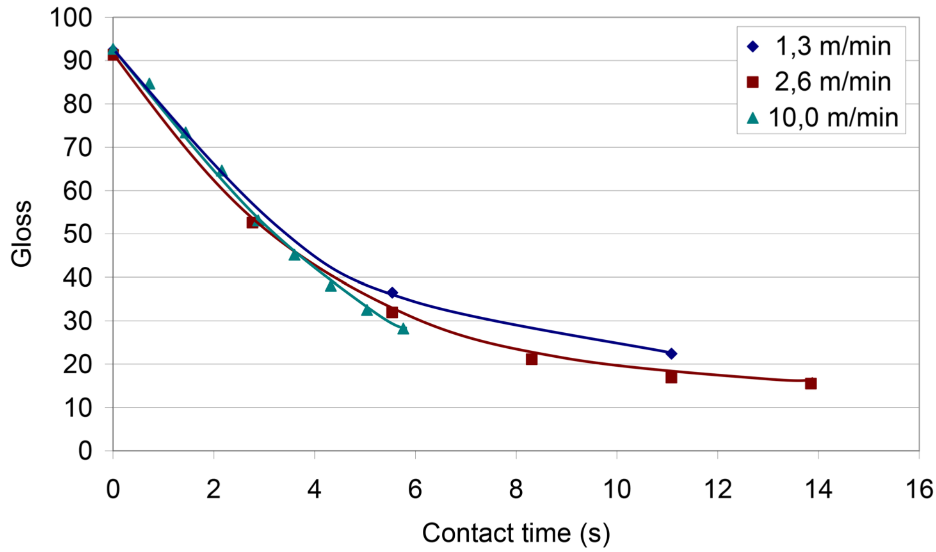

Figure 6. Surface gloss as a function of contact time at different belt rates of advance.

2.2.3. Study of scouring pad life span

With a view to studying scouring pad life span, trials were conducted either changing the scouring pad after each wear stage or reusing the same pad throughout the wear process (Figure 7).

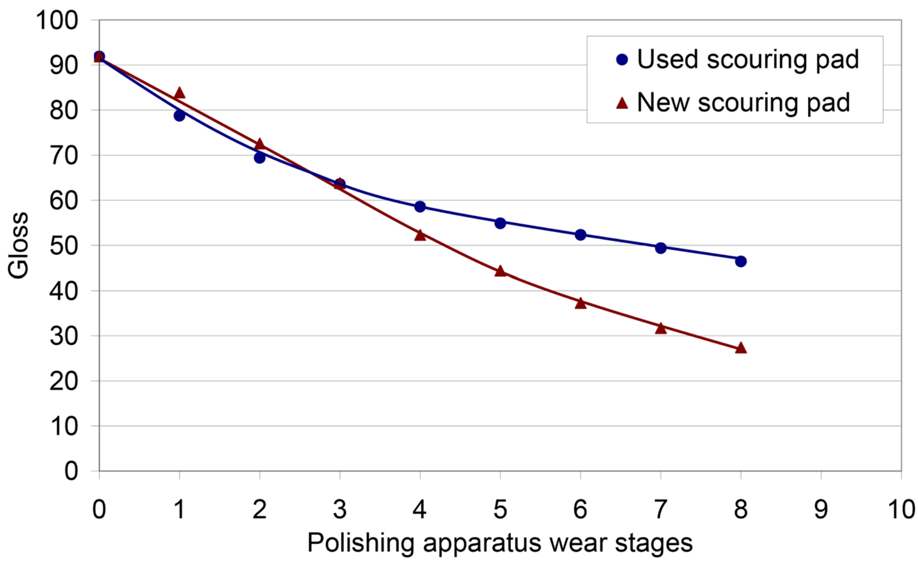

Figure 7. Surface gloss as a function of the wear stage either reusing the scouring pad or changing it after each wear stage.

The results confirmed that the abrasive element deteriorated progressively during the wear process, reducing its wear capacity on the tile surface. This limited the maximum time that the scouring pad could be used and highlighted the need to replace it.

2.3. TEST CONDITIONS

After analysing the influence of each variable, the variables were adjusted, thus enabling real wear conditions to be reproduced.

As mentioned, the selected abrasive element was a commercial scouring pad whose composition consisted mainly of quartz. After studying the degradation that it underwent during the test, a wear stage was defined that assured its abrasive performance was maintained throughout the process.

The main working parameters used are summed up in Table 1.

Effective pressure	0,4 kg/cm^2
Head rotation speed	226 rpm
Belt speed	18,5 m/min
Grinding tool length	145 mm
Composition of the abrasive	85% quartz
Average particle size of the abrasive	45 mm

Table 1. Selected working parameters.

3. VALIDATION OF THE TEST METHOD

3.1. WEAR METHOD UNE 138001 IN

The developed test method was validated with regard to wear simulation method UNE 138001 IN developed at ITC and validated under actual service conditions indoors and with direct outdoor access.

A glossy floor tile was selected for this purpose with a view to measuring the gloss loss with wear curve. Different wear stages were carried out using method UNE 138001 IN with the proposed method (polishing apparatus), adjusting the different variables studied in the previous section to the parameters defined in Table 1. The results obtained (Figure 8) confirmed that the proposed method displayed a high correlation with UNE 138001 IN.

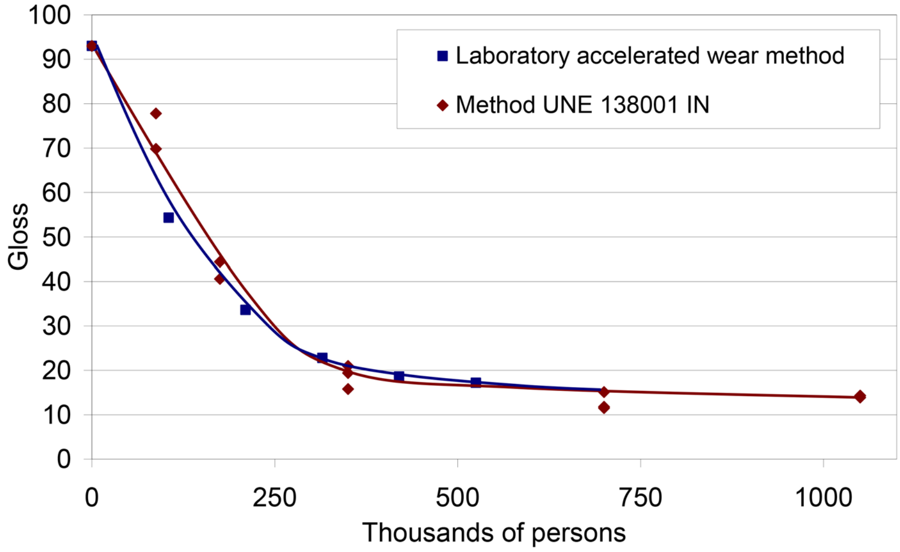

Figure 8. Correlation of the accelerated wear method with method UNE 138001 IN.

3.2. IN SITU STUDY IN OUTDOOR CONDITIONS

Since the previously described method is only applicable to surfaces with high or medium gloss, and wear cannot be simulated on matt flooring or flooring with pronounced reliefs, it was decided to perform a parallel real study on these types of floorings in outdoor conditions, using the friction measurement with the pendulum method as variable, according to the method described in standard UNE-ENV 12633 Annex A [4].

Two of the entrances to the Instituto de Tecnología Cerámica premises were used for this purpose, on which information was available on the actual pedestrian traffic by an employee clocking system that provided correlated data for evaluating surface evolution.

The slip resistance of the existing flooring (which had been installed in October 2005) was measured first. In September 2010, one of the tiles at each entrance was replaced with new tiles of the same material and these were regularly monitored, their slip resistance being determined by the pendulum method.

During the first year, in which a high number of measurements were made, a very pronounced drop in slip resistance was observed (Figure 10), which subsequently tended asymptotically towards a practically constant value after more than 5 years' exposure (corresponding to the values obtained for the originally installed tiles).

Figure 9. Door with clock access controller and monitoring tile.

The developed accelerated wear method was applied on tiles of the same material as those installed at the ITC entrances, and different wear stages were performed until steady slip resistance values were obtained.

Floor tile performance was very similar to that observed in actual conditions, there being a quite pronounced drop in the first wear stages, which then smoothed out as contact time with the abrasive element increased until practically constant values were reached.

The values obtained by the developed method are shown, for comparative purposes, together with the values measured in real conditions in Figure 10.

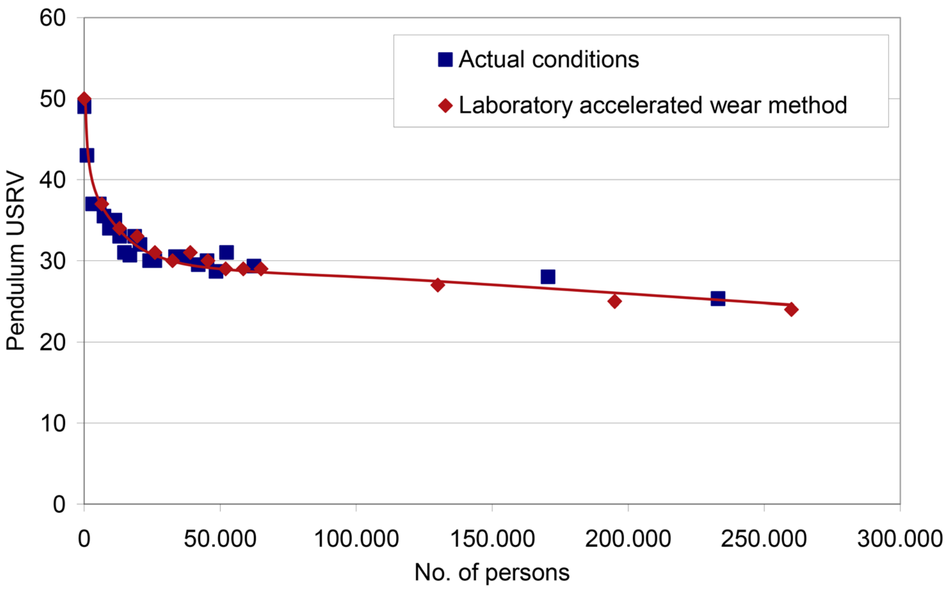

Figure 10. Correlation of the polishing apparatus wear method with actual conditions for the outdoor flooring.

3.3. IN SITU STUDY IN THE INDOOR BUILDING AREA WITH DIRECT OUTDOOR ACCESS

A similar study was performed in service conditions of an indoor building area with direct outdoor access, in which ceramic tiles were installed in the flooring of the passages of one of the self-service dining facilities at Universitat Jaume I. As this was a one-way place of passage, set off by railings, optical counters were installed at the exit next to the cash registers to quantify the number of persons that crossed the tiles being studied, which were located in the centre area of the section (Figure 11).

A tile installation system without adhesives was used to allow the tiles to be withdrawn and replaced in order periodically to measure their slip resistance in the laboratory. To perform the study, 12 representative samples of different types of flooring were selected, in addition to tiles with high slip resistance that are customarily not used indoors, with a view to being able to measure changes of greater magnitude in the slip resistance properties.

Just as occurred in the previous study, the most slip-resistant tiles exhibited a quite high drop in slip resistance during the initial service stages. This drop then became more gradual until relatively steady values were reached (Figure 12).

Figure 11. In situ study in the university self-service dining facility.

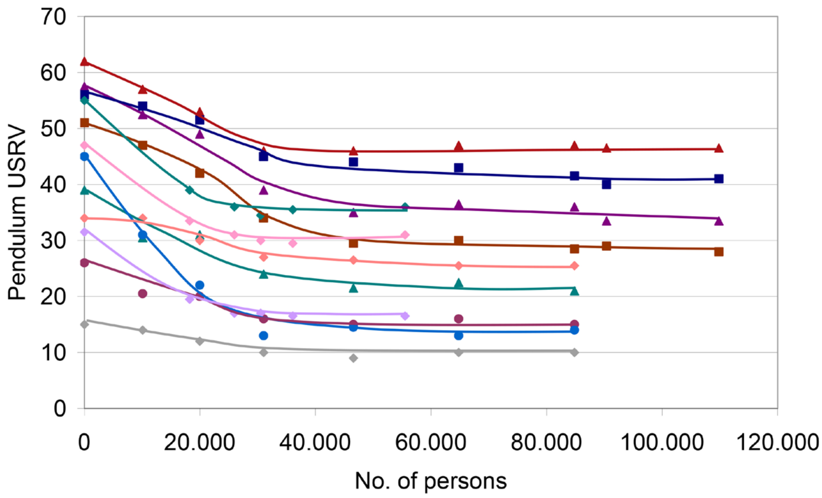

Figure 12. Evolution of slip resistance of the flooring installed in the university cafeteria.

Four samples with different types of surface finish and, therefore, with different initial slip resistance were selected from the different materials being evaluated under actual conditions. These samples were subjected to the laboratory accelerated wear process.

The slip resistance values obtained in each wear stage, together with the slip resistance measured in the tiles installed in the university self-service cafeteria, are plotted in Figure 13.

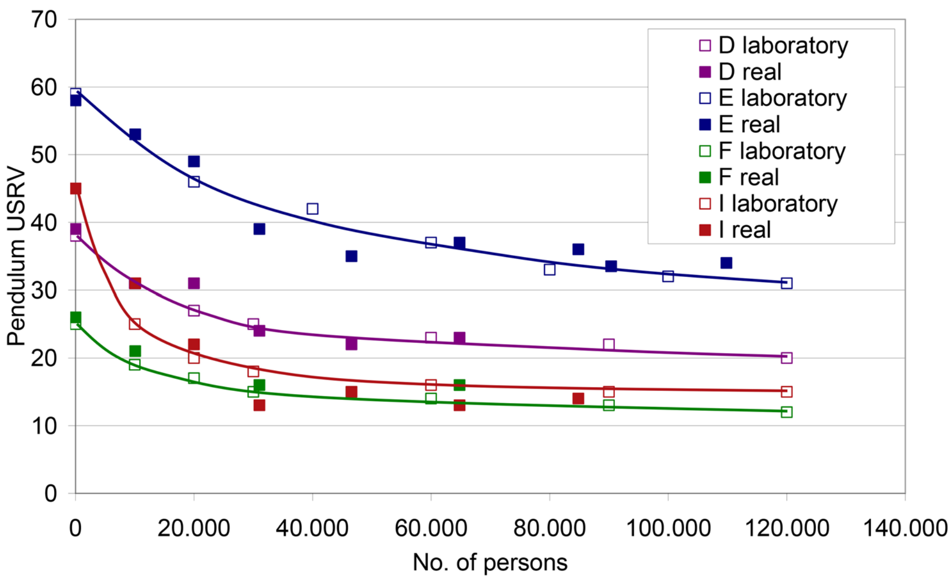

Figure 13. Correlation of the polishing apparatus wear method with the in situ study in the indoor building area with direct outdoor access.

The real wear curves, in which slip resistance had been measured as a function of the number of persons that crossed the flooring, were used to obtain the relationship between the wear stages of the polishing apparatus and the corresponding number of pedestrians: that relationship was about 10.000 persons/wear stage.

4. FLOORING PERFORMANCE WITH RELATION TO WEAR

The developed wear method was applied to a wide range of products customarily used as flooring for indoor and outdoor use. Floor tiles with different surface finishes were selected, taking into account parameters such as relief, texture, and surface roughness.

Both the slip resistance performance of the tiles at source and their variability with wear depended on the combination of the different surface parameters mentioned previously.

The slip resistance of different types of ceramic tiles after successive wear stages has been plotted in Figure 14, with a view to displaying their foreseeable evolution when subjected to pedestrian traffic under real conditions.

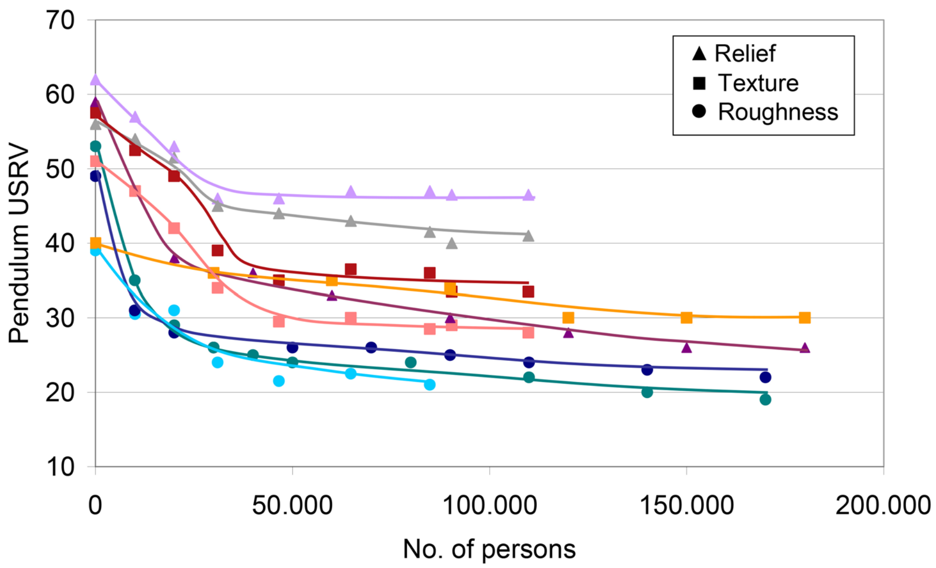

Figure 14. Life span of the slip-resistance performance of different types of ceramic tiles.

In the foregoing graph, the materials have been divided into three large groups: smooth tiles that display surface roughness, textured tiles, and embossed tiles or tiles with relief that could also have a certain surface roughness.

By way of example, Figure 15 shows a photograph of a sample of each described type of tile.

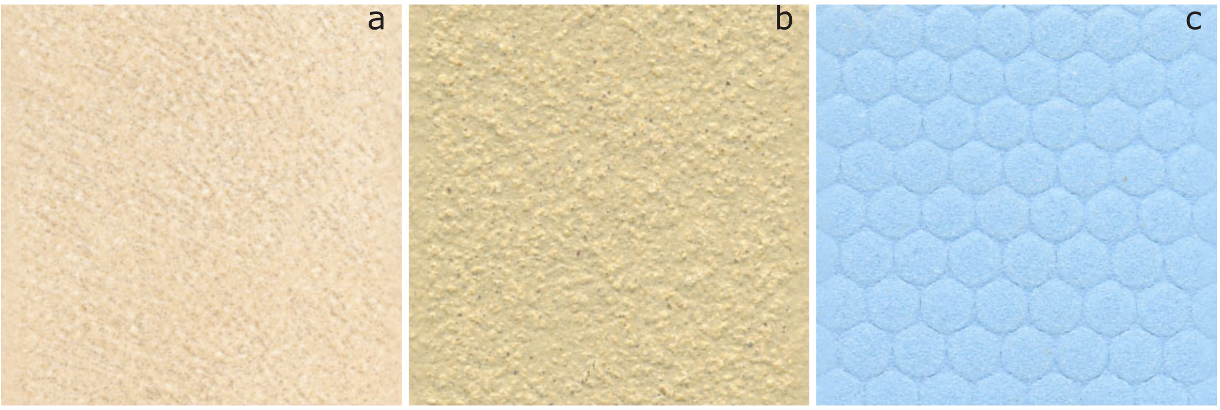

Figure 15. Tested ceramic tiles: a) smooth with roughness, b) textured, c) embossed.

The smooth tiles obtained a relatively high degree of initial slip resistance as a function of the surface roughness of the glaze. In general, this roughness changed markedly in the first wear stages, leading to an important decrease in the tile coefficient of friction. Slip resistance then diminished more gently, stabilising after successive wear stages at similar values. The value to which the curves corresponding to the smooth models tended asymptotically depended especially on the particle size of the abrasive that produced the surface wear.

The ceramic tiles with surface texture generally exhibited curves with a gentler drop in the first stages, followed by a relatively sharp drop and a stabilisation at higher values than in the smooth surfaces. In this case, the stabilisation value depended on tile starting topography.

The embossed tiles or tiles with relief performed similarly to those in the foregoing case. Most of these tiles also had a surface coating with a certain roughness. The coefficient of friction depended both on the topography and on the surface roughness. In the first wear stages, the curves exhibited a quite pronounced slope owing to the modification of this surface roughness (as occurred in the smooth samples). Slip resistance then decreased much more gently, probably owing to the slight change in topography of the relief. In this case, the stabilisation value varied significantly, depending on the type of relief (geometry, shape, height, spacing between reliefs, etc.).

5. CONCLUSIONS

- The developed method generates large enough surfaces with uniform wear to be able to make slip resistance measurements with the standard pendulum method.
- Wear conditions have been defined that allow simulation of the changes produced by pedestrian traffic under actual service conditions with outdoor access; these were validated by comparison with the results obtained in in situ studies.
- The slip resistance performance of certain types of surfaces can change markedly during the first year of service.
- The developed procedure enables flooring slip resistance performance throughout the flooring service life to be predicted and, therefore, the flooring slip resistance life span to be estimated.
- The use of this laboratory accelerated simulation tool will allow the appropriate slip-resistant type of tile to be selected as a function of expected traffic.
- The information obtained in this study allows surfaces with a long slip-resistance life span to be designed and developed for flooring used in areas with heavy traffic.

6. ACKNOWLEDGEMENTS

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