ASSESSMENT OF THE DURABILITY OF FLOORING SLIP RESISTANCE

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ABSTRACT

At present, the anti-slip performance of ceramic floorings is evaluated on samples of the product as it leaves the factory, and therefore the only information available concerns its behaviour when newly installed. Earlier studies confirm that floorings can lose slip resistance as a result of wear caused by pedestrian traffic across the surface. That means that after a number of years in service, some floors are no longer suitable for the use for which they were designed.

The main objective of the study reported here is to develop an accelerated laboratory wear method that is capable of simulating changes in slip resistance caused by the actual wear that floorings undergo.

For that purpose, the first step was to conduct an examination and compilation of existing literature on currently available wear methods. One of the important points to consider is that a sufficiently large surface area of worn tile needs to be generated in order to measure slip resistance afterwards using the pendulum method.

At the same time, an *in situ* study was carried out to assess the real changes undergone by tiles as a result of wear due to pedestrian traffic. To that end, anti-slip tiles were installed as flooring in a self-service catering area in which the number of people walking across the surface under study could be monitored. An adhesive-free system was used to install the tiles so they could be easily removed and replaced in order to measure their slip resistance in the laboratory at regular intervals.

Based on the initial study of the literature, a laboratory wear tester was selected and the variables that might affect the wear process were assessed. Of particular importance were the type of abrasive material, displacement of that abrasive material over the surface of the tile, and the rate at which such displacement took place.

Finally, a comparative analysis was carried out of the preliminary results from the study under actual conditions of use and those obtained by the wear tester in the laboratory.

BACKGROUND

There are standard test methods [1-3] to measure the abrasion resistance of floorings but these methods are only useful for evaluating changes in appearance or gloss and do not allow the influence of wear on surface friction to be analysed, because the areas abraded by these procedures are too small and dissimilar to enable the coefficient of friction to be assessed with the methods currently employed (pendulum, ramp and tribometer).

Therefore, in order to be able to study, at laboratory scale, how changes in the surface of the flooring affect its anti-slip capabilities, first a method needs to be developed that enables worn surfaces to be generated in order to simulate the actual process, and which have a sufficiently large homogeneous area to be able to assess the flooring's slip resistance.

Currently, there are no standardised methods for assessing long-term slip resistance. However, mention can be made of the method for accelerating wear developed by C.J. Strautins [4-5], a method based on the use of a machine with which washability and wear tests are carried out in the paint industry (Gardco). The machine has a linear motion slider to which different abrasive materials (scouring pads) with different degrees of abrasion can be attached. Using that procedure, he obtained abraded specimens of sufficient size to be able to, subsequently, measure slip resistance using the pendulum method. Comparing the pendulum measurements carried out *in situ* in a restaurant with a large influx of people with the measurements taken on specimens abraded in the lab by this device, he concluded that 500 wear cycles (with a specific type of abrasive pad and under defined pressure conditions) could reproduce the same level of wear as seen in that restaurant after one year's service. However, as the abraded area was not big enough for ramp tests to be conducted, he used a floor polisher equipped with abrasive pads to reproduce approximately the same wear as with the Gardco machine, but over a larger area, enough to carry out the ramp test.

Subsequently, M. Engels [6-7] developed a wear procedure using a floor polisher with suitable abrasive discs, which he validated by comparing the topographies measured *in situ* with those obtained using the developed laboratory method. From this information, he reached the correlation that 20 abrasion cycles of his method reproduced 1.5 years' usage in a high-traffic area with abrasive dirt (hypermarket, shopping mall, train station passenger hall).

The Institute of Ceramic Technology (ITC) has been studying this problem for more than 15 years and several projects have been executed aimed at finding a suitable method of accelerating wear. A. Muñoz and G. Silva [8] developed a wear method using a semi-industrial polisher with a polishing head to which different abrasive items can be attached. Two *in situ* studies were carried out under real usage conditions in which slip resistance was measured after different periods of time in which the number of people who had walked across the surface of the tiles was known. Based on that information, the variables of the polishing device were studied and adjusted to reproduce the level of wear produced in real-life conditions.

Subsequently, A. Muñoz [9] completed the work by studying how other parameters, in addition to slip resistance, were altered by wear on 54 types of ceramic surfaces.

Although the device is able to simulate quite accurately conditions of actual wear caused by pedestrian traffic, once the different variables have been adjusted, it cannot be considered a "laboratory tester", but rather a pilot-plant or semi-industrial test device. For that reason, the aim of this work is to find a simpler test device that is equally capable of reproducing wear in real conditions.

DEVELOPMENT OF THE ACCELERATED WEAR METHOD

To perform the study, an Elcometer® abrasion tester with similar characteristics to the Gardco unit was used, which also enables the length of displacement of the abrasive element to be altered.

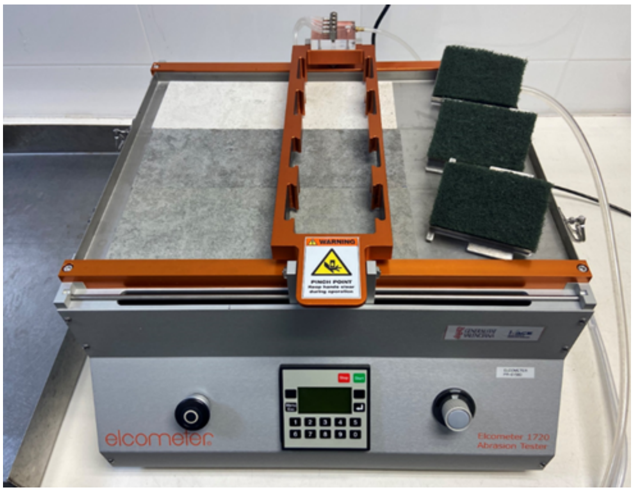


Figure 1. *Elcometer® tester*

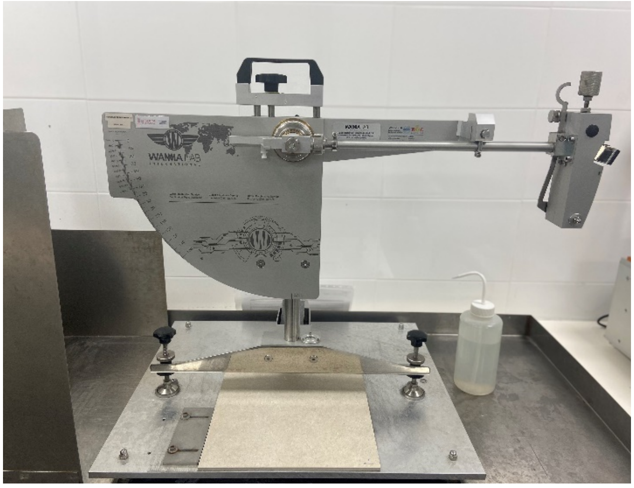


Figure 2. *Friction pendulum device*

To measure slip resistance, the method described in UNE-EN standard 16165 [12] "Determination of slip resistance of pedestrian surfaces. Evaluation methods" Annex C "Pendulum test" was implemented. The test was carried out under wet conditions, saturating the surface with water and using the two types of sliders indicated in the standard: Rubber 57 and Rubber 96.

Our research included a complete study of the variables that might affect the wear process, some of which had not been considered in previous studies. To do so, an anti-slip tile with a rough finish, whose slip resistance changed rapidly with wear according to information from earlier reports, was selected.

2.1 TYPE OF ABRASIVE MATERIAL

The first step was to study the effect that the abrasive material used might have. There are multiple types of abrasive pads on the market with varying degrees of coarseness, some of which have already been the objects of study [4-5]. Those papers chose finally to use 3M Scotchbrite heavy-duty scour pad No. 86. Our work focused on testing various types of scouring pads with a similar abrasive power to that one, which would make it easier for us to regulate the level of wear and then adjust the method to actual conditions of use.

To carry out the tests, the rest of the tester variables (pressure, length of displacement and speed of displacement of the abrasive pad) were adjusted to those prescribed in the Gardco method [4-5].

Figure 3 shows the evolution of slip resistance (measured as PTV_{57}) for each of the selected pads as a function of the metres of abrasive pad in contact with the surface of the tile throughout the wear process. Very slight differences were observed between the 3M No. 86 green, No. 96 green and Classic green scouring pads, while the 3M Brittex green scouring pad had a somewhat lower abrasive effect than the others.

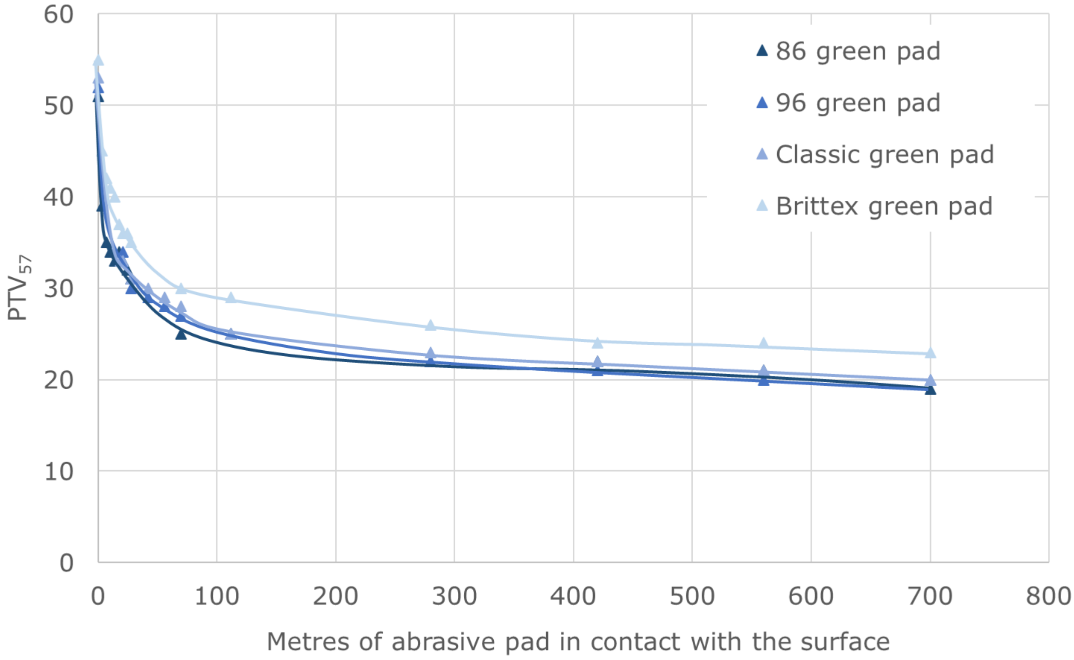


Figure 3. *Evolution of slip resistance with wear as a function of the type of pad used (Pressure: 11.49 g/cm², Displacement length: 30 cm, Linear speed: 50 cm/s).*

2.2 PRESSURE

The pressure exerted on the abrasive pads can significantly alter the effect they have on the surface of the tiles. For that reason, tests were carried out altering the weight placed on the abrasive pads. As can be seen in Figure 4, when the weight borne by the pad is reduced, the abrasive effect decreases slightly, although the drop is not significant until the pressure is reduced to 2.59 g/cm².

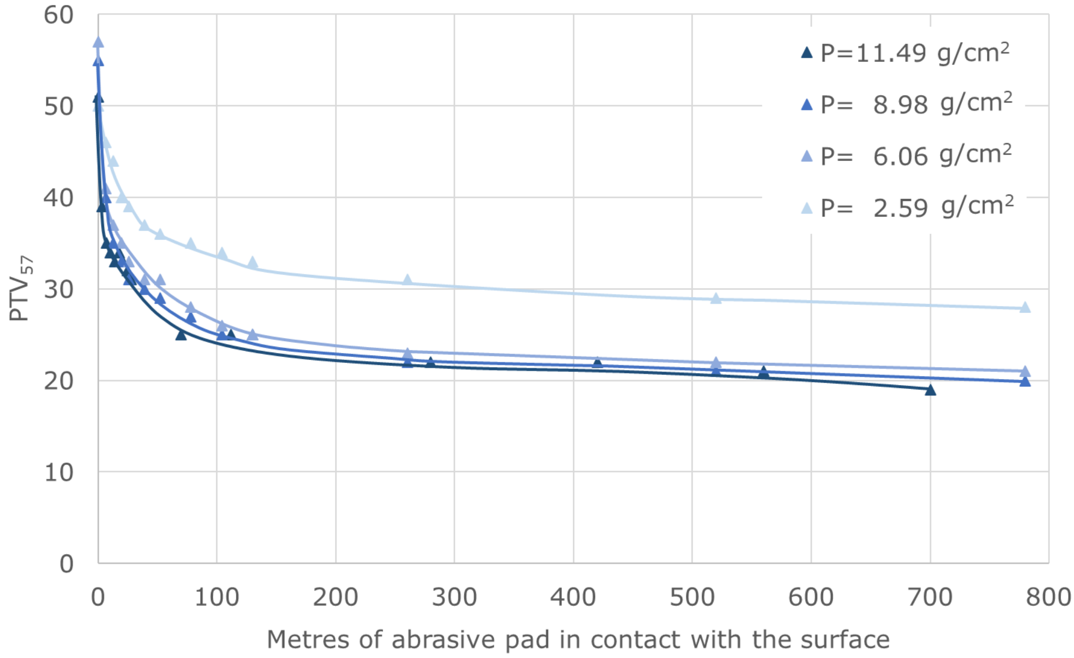


***Figure 4.** Evolution of slip resistance with wear as a function of pressure (Pad: 86 green pad, Displacement length: 30 cm, Line speed: 50 cm/s).*

2.3 ABRASIVE PAD DISPLACEMENT SPEED

The effect that abrasive pad displacement speed could have was also assessed, and it was observed that, in the studied range (between 4 and 50 cm/s), it did not significantly affect the wear process.

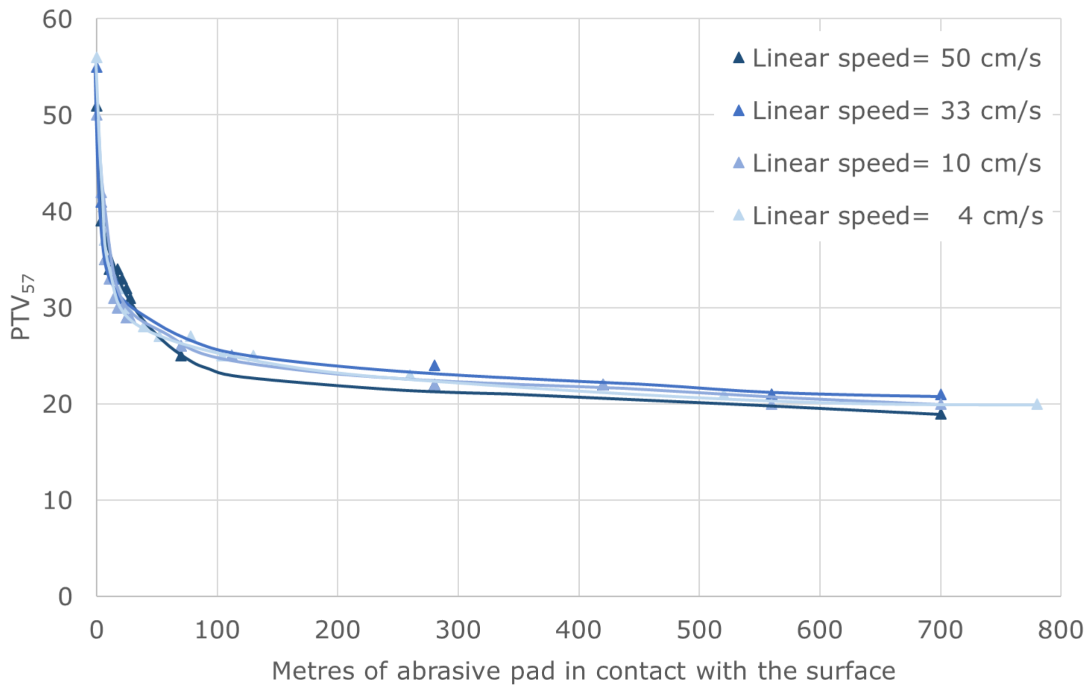


***Figure 5.** Evolution of slip resistance with wear as a function of displacement speed (Pad: 86 green pad, Pressure: 11.49 g/cm^2, Displacement length: 30 cm).*

2.4 ABRASIVE PAD DISPLACEMENT LENGTH

The influence of the length over which the abrasive pad travels during the wear process was also studied. To do so, displacement lengths of 30 cm, 5 cm and 2 cm were compared. Less wear was observed when displacement length decreased, the 5-cm and 2-cm displacement length curves of the abrasive pad being practically equivalent.

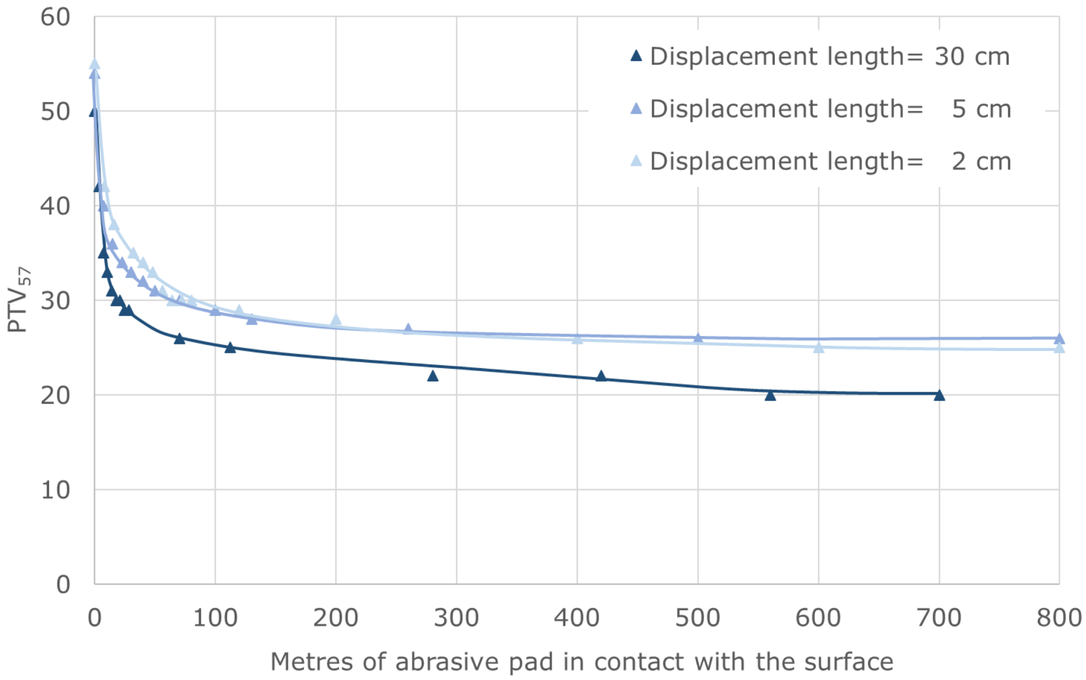


Figure 6. *Evolution of slip resistance with wear as a function of (Pad: 86 green pad, Pressure: 11.49 g/cm^2, Linear speed: 10 cm/s).*

3. *IN SITU* STUDY UNDER REAL CONDITIONS OF USE

A study was carried out under real-life conditions of high indoor pedestrian traffic to determine the changes produced on the different types of surfaces. To do so, an adhesive-free installation system was used to enable the tiles to be removed and replaced in order to assess what changes had occurred. At the same time, the number of people who walked across the surface was recorded using optical counters in order to correlate the changes noted with actual traffic volumes.

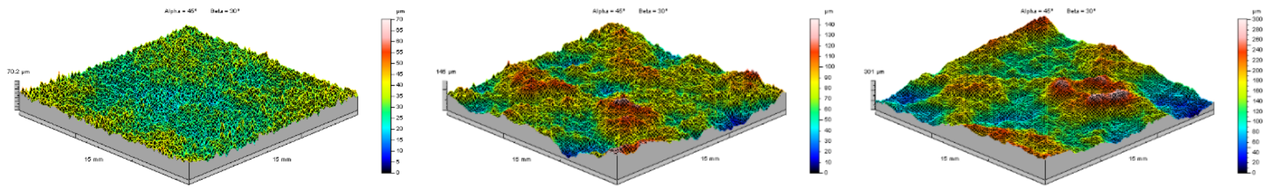
To study flooring wear under real-life conditions of use, samples of different types of anti-slip ceramic floor tiles were selected.

In the selected samples, slip resistance was measured with the pendulum method using Rubber 57 and Rubber 96 with a view to determining their starting characteristics.

Sample	Description	Wet PTV_{57}	Wet PTV_{96}
1	Glazed floor tile w/ textured surface	55	60
2	Glazed floor tile w/ textured surface	43	51
3	Glazed floor tile w/ profiled surface	32	45
4	Glazed floor tile w/ textured surface	49	53
5	Glazed floor tile w/ profiled surface	48	55
6	Glazed floor tile w/ textured surface	51	34
7	Glazed floor tile w/ smooth rough surface	43	51
8	Glazed floor tile w/ textured surface	55	59

Table 1. *Initial PTV slip resistance measurements.*

By way of example, Figure 7 shows the topography of a sample corresponding to each type of surface finish.



Sample 7
Smooth rough surface

Sample 2
Textured surface

Sample 5
Profiled surface

Figure 7 *Topographic maps of samples with different surface finishes*

To carry out this study, the selected tiles were installed on the floor of the self-service passageway in one of the canteens at Universitat Jaume I (indoor premises with direct entrance from outdoors without any dirt retention system). As it is a one-way passage area bordered by railings, an optical meter was placed at the exit next to the cash register to count the number of people who walked over the tiles in the study, installed in the middle area of the passageway (Figure 8).

Although most of the samples have now been installed for more than a year and a half, the level of daily pedestrian traffic has been much lower than expected, so no very long-term information on the level of wear that might be reached is yet available.

Figure 8. *Sample installation area*

The results obtained so far are shown in Figures 9 and 10. As can be seen, all samples show a progressive loss of slip resistance in the initial stages of use and this loss is more noticeable when measurements are made with Rubber 96.

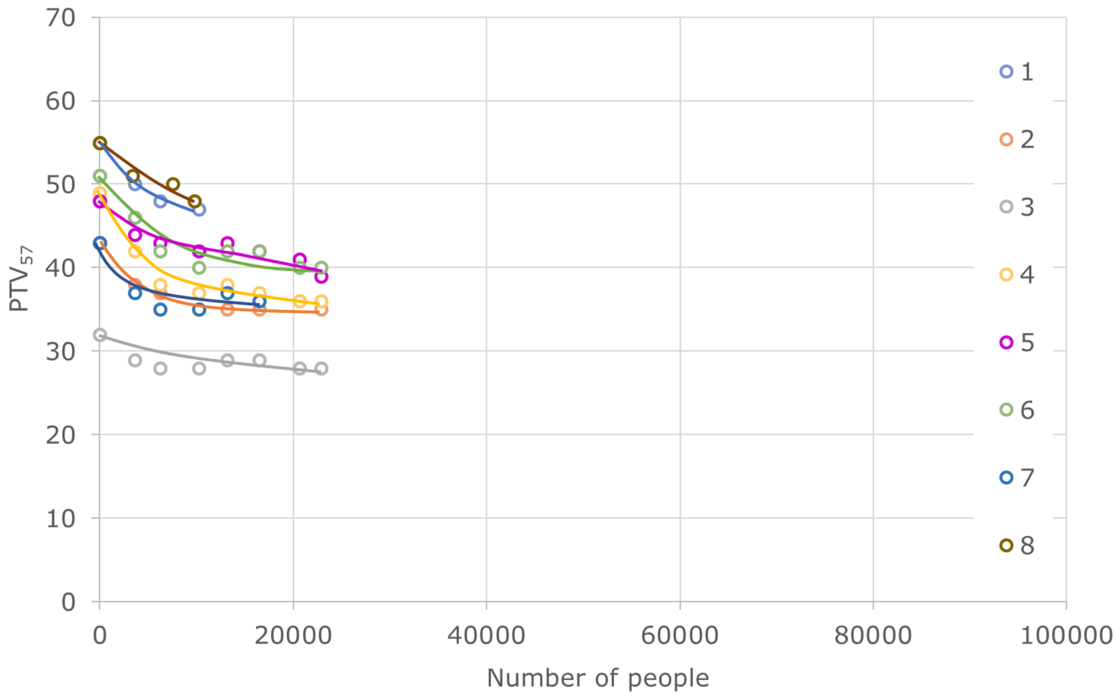


Figure 9. *Evolution of PTV_{57} slip resistance of the samples in the study under real-life conditions of use.*

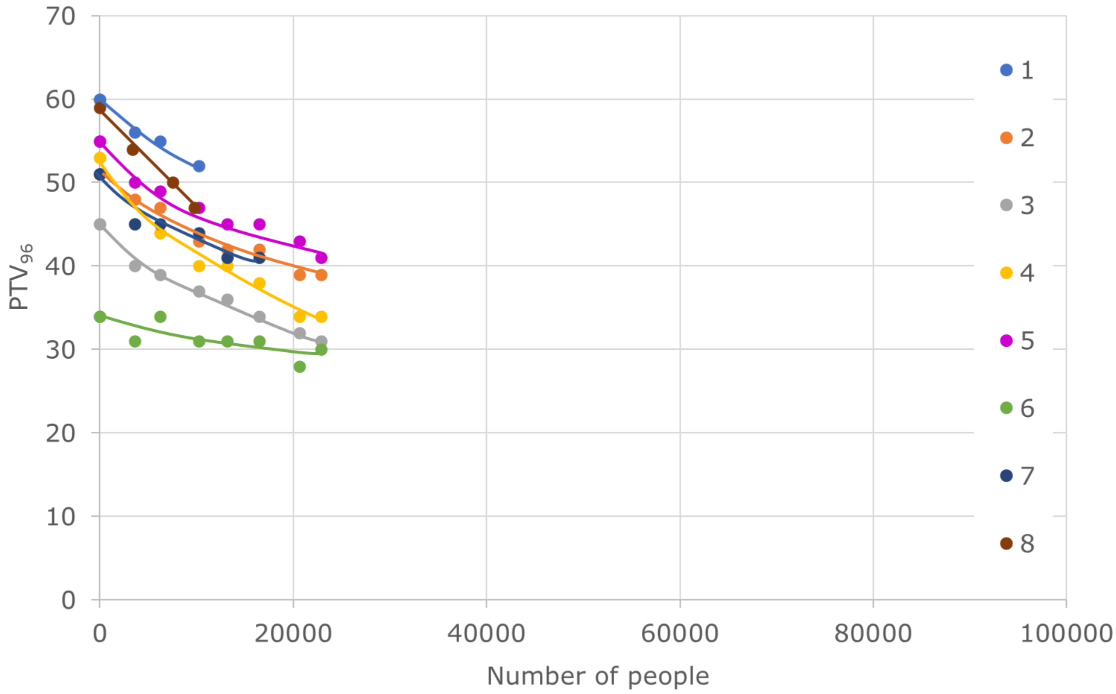


Figure 10. *Evolution of PTV_{96} slip resistance of the samples in the study under real-life conditions of use.*

4. PRELIMINARY ANALYSIS OF RESULTS

Based on the results to be obtained over the next few months in the study under real conditions of use, the variables that we have seen in the earlier part of the work will be adjusted in order to reproduce as faithfully as possible the changes that are observed in these real-life conditions.

With the initial data that are currently available from the *in situ* study, a comparison has been made with respect to the data from wear in the laboratory using the Elcometer® tester. For that purpose, the different variables were maintained at the levels defined by Strautins [4-5] using the Gardco device (type of abrasive material, pressure, speed and length of displacement).

First, for sample 2, the PTV_{96} slip resistance values measured *in situ* were adjusted to the values obtained in the laboratory (Figure 11). This same correlation was applied to Samples 4 (Figure 12) and 5 (Figure 13). As can be seen, in Sample 4, the slip resistance obtained under real conditions of use and the measurements taken in the lab using the accelerated wear procedure match reasonably well. However, the slip resistance of Sample 5 decreases more rapidly in the laboratory test than under real-life conditions. That could be due to the fact that the sample has reliefs which protect certain areas of the tile in the case of wear from pedestrian traffic, as they prevent the sole of the shoe from coming into contact with its entire surface. However, in lab wear, the abrasive pads are much less rigid than shoe soles and able to abrade the entire surface.

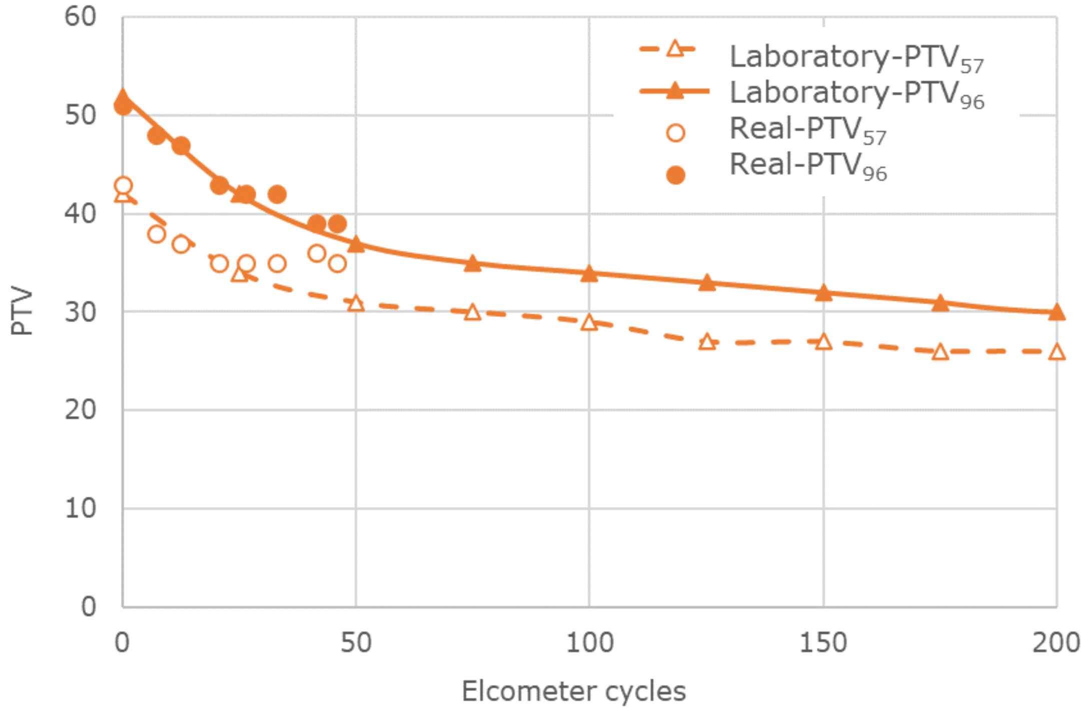


Figure 11*. Comparison of the evolution of slip resistance in Sample 2 when abraded in the laboratory and under real conditions of use.*

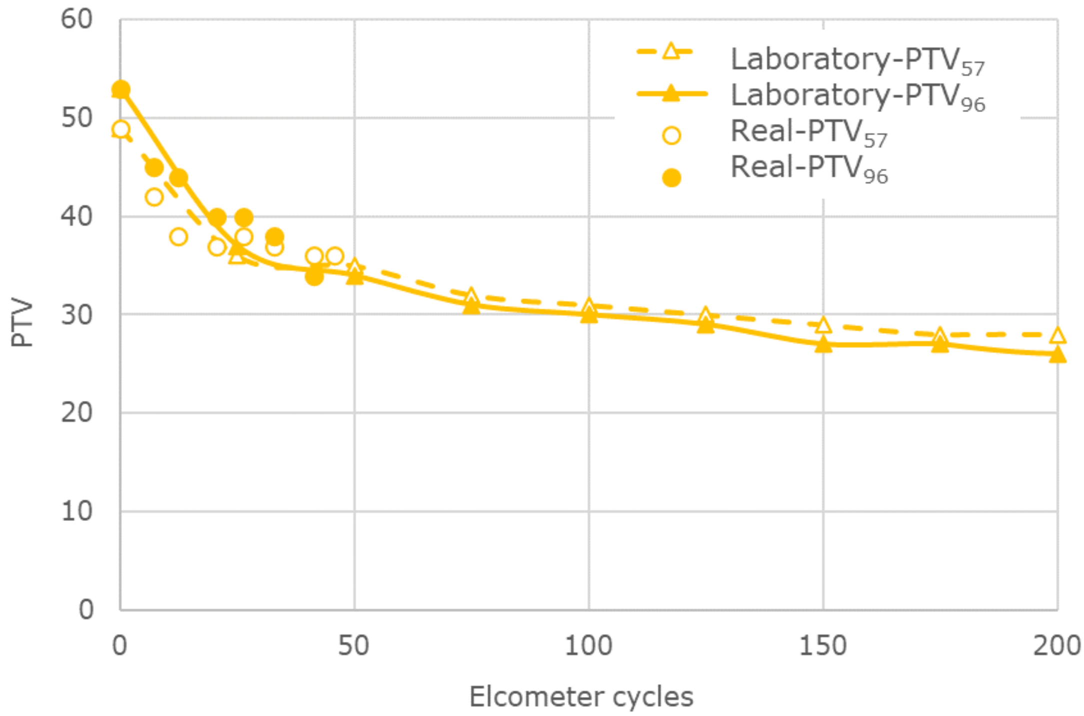


Figure 12. *Comparison of the evolution of slip resistance in Sample 4 after wear in the laboratory and under real conditions of use.*

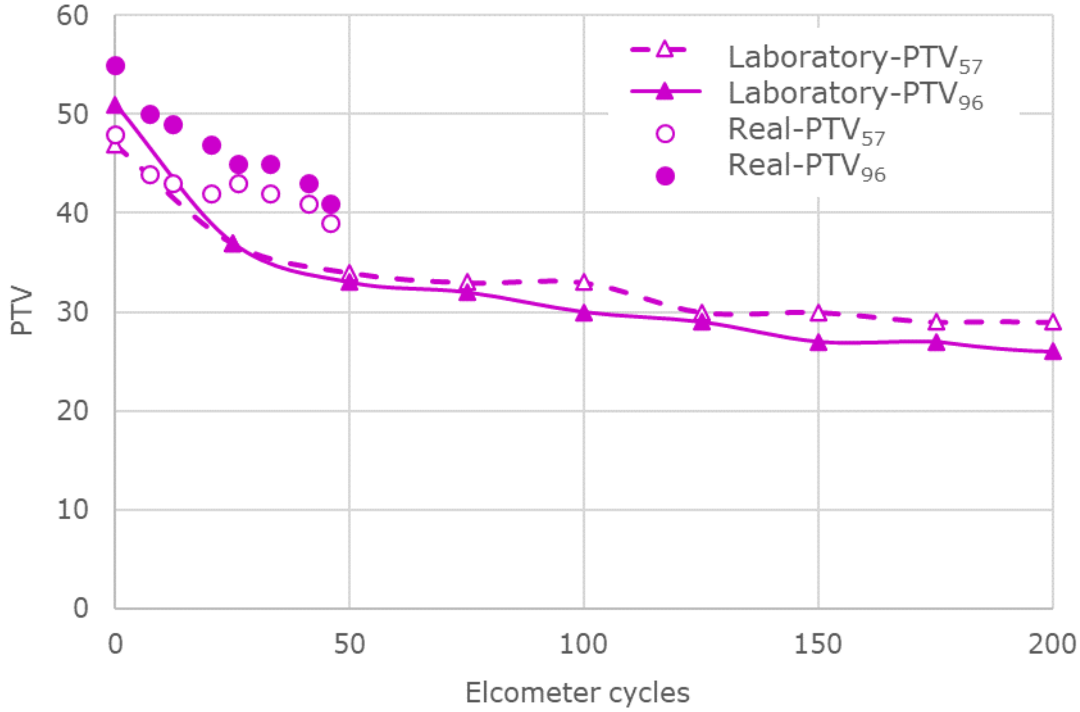


Figure 13. *Comparison of the evolution of slip resistance in Sample 5 after wear in the laboratory and under real conditions of use.*

5. CONCLUSIONS

- The method developed generates surfaces with homogeneous wear of a sufficient size to enable slip resistance measurements to be performed with the pendulum method.
- The influence of the test variables was studied in order to alter the intensity of wear simulation in the accelerated laboratory method and adjust it to the wear observed in real-life conditions.
- From the measurements taken from the *in situ* study, it is observed that slip resistance on some types of surfaces can significantly alter during the first year of use.
- With the aid of the laboratory procedure currently under development, the goal is to be able to predict the anti-slip behaviour that floorings will have throughout their service life and therefore estimate their durability.

6. ACKNOWLEDGEMENTS

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