PROPOSAL OF A STANDARD METHOD FOR DETERMINING THE DURABILITY OF FLOORING EXPOSED TO PEDESTRIAN TRAFFIC

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ABSTRACT

Current tendencies in standardisation activities and the application criteria of the requirements deriving from the European Directives, particularly relative to construction products (89/106/EEC), both focus on establishing methods for evaluating product performance which are equally applicable to all types of materials, via the development of standards through horizontal committees (for example, CEN/TC 339 Slip resistance of pedestrian surfaces – Method of evaluation). Curiously enough, this approach has not yet been applied to the wear resistance of flooring, the only characteristic regarding which, after the latest revision of the standards applicable to ceramic tiles, two different methods persist, for evaluating glazed and unglazed floor tiles, respectively.

Previous studies have confirmed the reliability of a new test method for reproducing the wear associated with pedestrian traffic under different service conditions. By its very definition (dry test, three-body tribosystem, use of real abrasives) the method is applicable to all types of flooring, regardless of their nature and/or surface finish, so that it could be used to evaluate comparatively the durability of any type of material used for flooring.

The present paper describes the study conducted to define the test variables and evaluation conditions that will assure the method's accuracy and validity for classifying floorings based on their wear resistance, as a preliminary step to submission of the method to the relevant national and international standardisation committees, as a proposed new standard test method to replace the present standards (ISO 10545-6 /ISO 10545-7).

1. BACKGROUND

The reliability of a criterion for estimating the durability of floorings subject to pedestrian traffic will depend as much on the correct definition of the expected service conditions as on the availability of means to reproduce product performance under these conditions.

Previous studies to evaluate materials performance conducted in actual service conditions[1] and the use of a prototype for simulating human walking (Tribopod)[2] have confirmed the inadequacy of present test methods for this purpose, and have also allowed defining a test method that simulates different service conditions of floorings[3].

As premises for its design the need was considered, first, of defining a simple and robust method that could be adopted as a reference in the international standards, as well as facilitating its generalised implementation in the ceramic sector at the lowest possible cost, without distorting the market. This has led us to modify the method described in standard UNE-EN ISO 10545-7[4], eliminating the deficiencies relative both to the method's inability to reproduce actual wear mechanisms (rigid counterbody and excessively hard abrasive) and to the evaluation criteria (absence of an evaluation of changes in gloss and surface texture).

The main changes have consisted in replacing the abrasive charge of steel balls with a cylindrical abrasion device (Figure 1) that has three support points of 4S rubber (Standard Shoe Simulation Sole) arranged symmetrically at angles of 120°, and the use of abrasives of a hardness similar to that of particles present in real situations, thus allowing reproduction of different flooring service conditions. Moreover, the measurement of surface gloss has been incorporated as an evaluation criterion, which is the characteristic that most varies during the abrasion process, as demonstrated in studies conducted under actual service conditions.

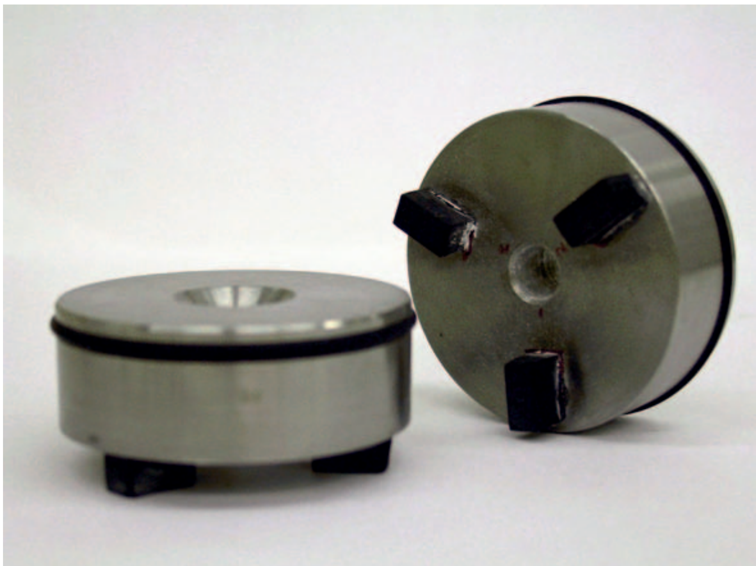

Figure 1. Abrasion device

After studying the influence of the test variables on the obtained results, it was confirmed that the characteristics of the abrasive used (chemical composition, particle size and proportioning) were the main factor to be evaluated, in order to modify the intensity of the wear generated and therefore, to limit the conditions for simulating different service environments. The present study defines a test and evaluation method for estimating the durability of any type of flooring subjected to pedestrian traffic, under reference service conditions. The conclusions have been submitted to the AEN/CTN 138 committee as a working basis for drafting a test method to replace the present standards.

2. DESCRIPTION OF THE PROPOSED TEST METHOD

2.1. REFERENCE CONDITIONS OF USE

Previous studies have demonstrated that the evolution of the surface characteristics of a given product can vary significantly as a function of its service conditions. Figure 2 displays the changes in gloss found when a polished floor tile was tested using the three types of abrasive charges adopted to simulate conditions of residential use, interior public use, and public use with direct outdoor access, respectively.

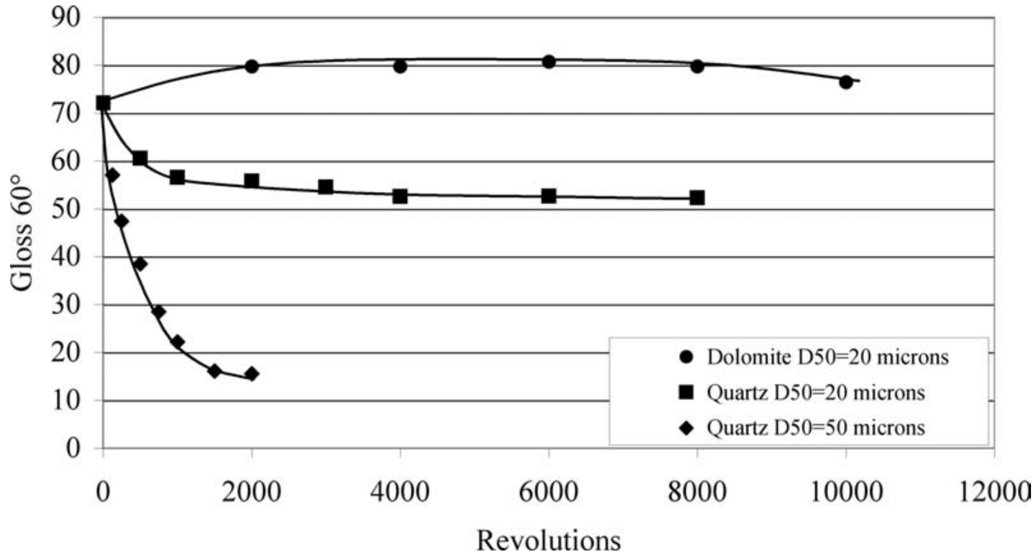

Figure 2. Comparison of different conditions of use

Given this high variability, associated mainly with the size and amount of abrasive present, in order to obtain a valid estimation of durability in each possible intended service condition, different test parameters would need to be used. However, from a standardisation standpoint it would be unfeasible to define test methods with optional variables of execution, since this would be detrimental to test reliability and repeatability.

For this reason, with a view to establishing a scale for evaluating comparatively how different types of flooring perform, it is necessary to define certain reference test conditions, although the results obtained with these test variables can only be associated with the service conditions that are simulated. Among a wide variety of possible levels of use, it has been decided to compare the materials in the most severe test conditions (public use with direct outdoor access), in order to favour differentiating between product performances without excessively prolonging test duration.

In order to define the test variables that enable simulating these service conditions, data obtained in a previous study on the evolution of gloss in polished ceramic tiles, conducted at food stores in the Valencia Region, have been used. The abrasive used was quartz with a particle size below 200 µm, which allowed simulation of the progressive loss of gloss observed in these actual service conditions (Figure 3), with an approximate equivalence of 1000 revolutions per 700,000 persons entering the premises.

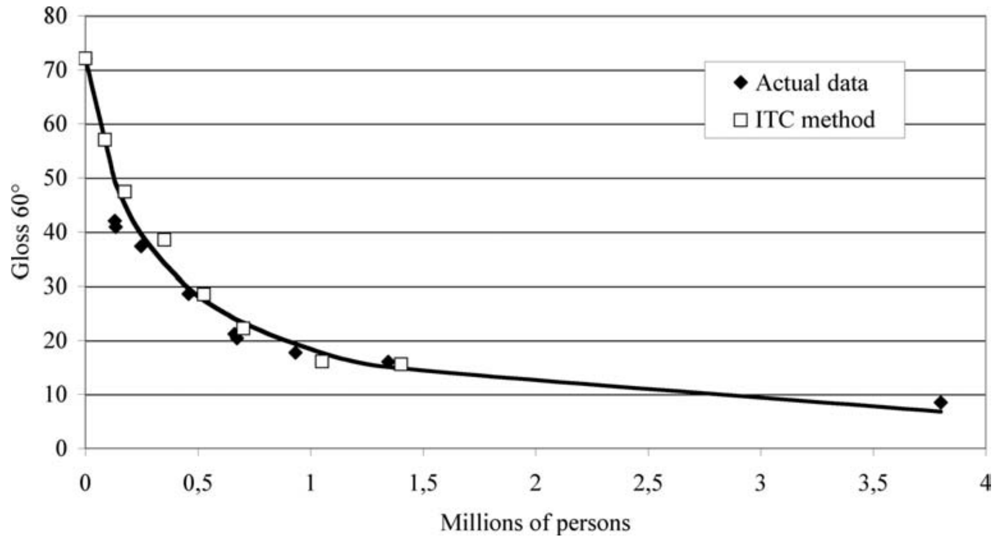

Figure 3. Conditions of commercial use with direct outdoor access

2.2. ABRASIVE PROPORTIONING AND TEST SEQUENCE

Although the hardness of the abrasive particles was slightly superior to that of the tested floor tile surface, during the abrasion process both materials underwent progressive deterioration. It was verified that when a high number of revolutions were performed with small amounts of abrasive, the resulting gloss loss was smaller than when the same abrasive proportioning took place in stages with a lower number of revolutions. This phenomenon is probably associated with the progressive fragmentation and/or rounding of the abrasive particles, which, in an advanced state of deterioration, reduces abrasive penetration capability and limits their effect to the top part of the relief, causing roughness to decrease and producing a partial recovery of the initial surface gloss.

It was verified that the minimum ratio required to carry out the wear process without any significant change in the behaviour of the abrasive was 0.1 g per 100 revolutions. This meant that different proportioning needed to be used for each test stage (e.g. 0.5g/500rev, 1.0g/1000rev, etc.).

In order to validate the defined proportioning criterion, we verified the equivalence between the results obtained by direct stages with different levels of abrasion (e.g. 500rev-0.5g) as opposed to the corresponding ones in cumulative stages until reaching the same value (e.g. 250+250rev - 0.25g in each stage). Figure 4 shows that the same levels of abrasion are reached when performing both direct and cumulative stages on two types of glazed surfaces. The maximum proportioning used has been 2.5 g for 2500 revolutions, since at higher amounts of abrasive, problems of abrasive adhesion to the inner wall of the test housing were observed. Therefore, to reach abrasion levels exceeding 2500 revolutions, cumulative stages need to be carried out on previously abraded test specimens.

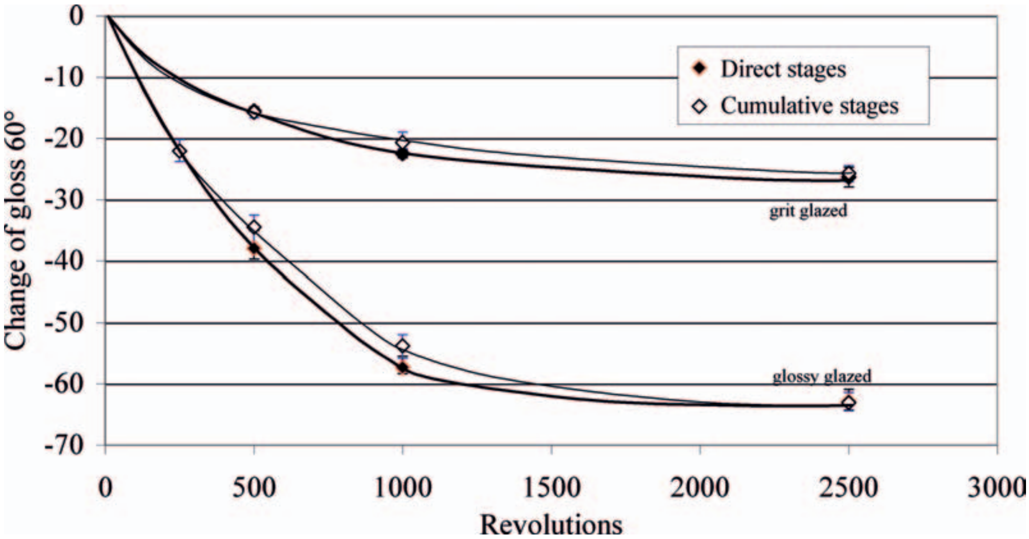

Figure 4. Equivalence between direct and accumulative stages

To evaluate wear resistance, we took seven square test specimens with 90 mm side length, representative of the sample, selected such that their centre zone exhibited the maximum gloss and/or colour homogeneity, to conduct the stages described in Table 1.

NO. OF REVOLUTIONS	125	250	500	1000	2500	5000	7500	10000
SEQUENCE	Direct					Foregoing + 2500 rev.		
PROPORTIONING (g)	0.12	0.25	0.50	1.00	2.50	2.50 each stage		

Table 1. Test sequence

Before carrying out each abrasion stage, each test specimen was cleaned with 96% alcohol and its mean gloss was determined with a standard reflectometer at 60° angle, averaging three measurements in the centre position and at a distance of 1.5 cm from the two sides. The stages from 125 to 2500 revolutions were performed without interruption, according to the proportioning indicated in Table 1. After each stage had ended, the test specimens were cleaned again, and final gloss was determined as the average of the measurements made in the three positions indicated above.

Subsequently, before carrying out the visual evaluation, each test specimen was stained with a suspension of active carbon in water (0.5g/ml) rubbing this manually with cotton wool, followed by cleaning under a stream of water with a chamois cloth. This staining process is intended to simulate the dirt retention that takes place simultaneously with the wear process; its efficiency had previously been verified by comparison with the results obtained in actual service conditions. When the test specimens had been dried, they were classified visually to determine if any change in colour and/or surface design in the centre zone of the test specimens could be observed.

If any alterations of the surface were observed in any of the direct stages, this stage and the immediately preceding stage were repeated to verify the classification. When no surface alterations were observed, the 2500 revolutions stage was repeated on a second test specimen, followed by a further 2500 revolutions, thus totalling 5000 revolutions. The gloss measurements were then made again on these test specimens, with the staining process and evaluation of change in appearance, assigning as gloss change the mean value of the two test specimens and confirming the classification by the change in appearance produced in the second test specimen. This cumulative process was continued until a significant change was evidenced in an abrasion stage, or until reaching a maximum of 10,000 revolutions.

2.3. CRITERION FOR DURABILITY EVALUATION

The studies conducted in real conditions confirmed that wear was evidenced in most materials by a change in surface gloss. In flooring with a matt surface, which displays no significant alterations of surface gloss, appreciable changes in surface colour or design may be evidenced in advanced stages of the wear process, and incidentally in certain floor tiles a light change in shade was detected, associated with stain retention.

As indicated previously, to establish materials performance at different levels or stages of abrasion, change in surface gloss was measured instrumentally, while colour changes were visually evaluated. Although the test method reproduces the surface changes observed in actual service conditions, it does so on a different scale, which is why the capacity to appreciate the changes in the entire surface of a floor tile cannot be immediately correlated with the results of evaluating test specimens with a 9 cm side length.

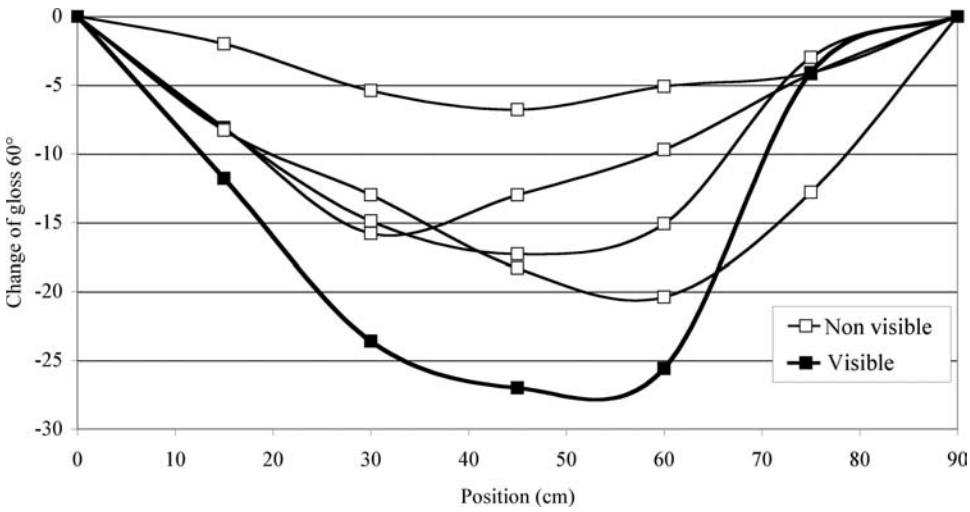

Figure 5. Gloss profile in inside accesses

With regard to the ability to appreciate gloss changes, although the human eye is extremely sensitive in discerning small variations of gloss when comparing two contiguous surfaces of different texture, when there is a progressive variation of gloss in the surface of the flooring, differences below 15-20 gloss points are not detected. In order to establish an acceptance criterion for changes in gloss produced by wear, the relation between visual appreciation and the changes in gloss present in a glossy polished floor tile installed in real conditions has been studied. Figure 5 plots the specular gloss profile at 60° of the surface in different doorways with inside access (width 80 cm) of the studied premises.

It can be observed that there is a progressive variation of gloss between the non-trafficked side areas and the central area of the access doors, in certain cases with a certain displacement of the maximum wear area towards the sides, related to the preferential direction of the traffic in each access. Although these changes do not become noticeable until reaching maximum losses exceeding 20 points in some cases, progressive lateral extension of the worn area favours the appreciation of the deterioration, probably because of the greater contrast compared with the non-trafficked area in which the original gloss is maintained. For this reason, instead of using the maximum value as a reference, the acceptance criterion has been defined in relation to the mean value of gloss loss in the centre area of the test specimen, establishing a mean gloss loss of 17 units as the limit of appreciable change.

With relation to colour change, during the study a diffuse reflectance spectrophotometer has been used to verify the relation between the quantitative values of colour change, evaluated as ΔE, and the capacity of visual appreciation. Although it has been found that in plain surfaces changes become noticeable from values of $\Delta E \approx 2$-3 units, according to the literature, in multicolour surfaces or surfaces with a heterogeneous design, values can be reached that may be 2-3 times higher, without any changes being detected in visual appraisal. This means that it is not possible to establish a single limit value as an acceptance criterion, since this depends on the design of the surface being evaluated. Therefore, the method of visual classification has been chosen to evaluate the colour changes. For this, an improved version of the visual classification method described in UNE-EN ISO 10545-7 has been used, increasing the intensity of the illumination to a minimum of 1000 lux and observing the test specimens at a distance of 50 cm. Furthermore, the requirement of evaluation by three qualified technicians has been kept, in order to reduce the subjectivity of the classification.

2.4. STUDY OF METHOD REPEATABILITY

In addition to the important influence on the result of the type of abrasive charge used, the geometric finish of the abrasion device was found to alter significantly the intensity and distribution of the wear in the surface of the test specimen. The surfaces of the rubber studs, initially flat and parallel to each other, display progressive wear with use, which reduces the contact of their outer face with the surface of the test specimen, in turn diminishing the level of wear generated.

For this reason, in order to assure the repeatability of the results, both the abrasive charges and the devices must be checked prior to use; in addition, the devices must be regularly checked or when a lack of parallelism is detected between the stud faces. For this, a calibration method has been defined, using float glass as a reference material. The method consists of carrying out 300 revolutions with an abrasive charge of 0.1 g and determining the gloss loss in the centre zone of the glass. The gloss measurements on the glass are made as set out in section 2.2 on a black matt surface, and the resulting loss shall be 50±10% on float glass with an initial gloss exceeding 120 gloss units 60°.

Using devices checked at the ends of this range, repetition tests were conducted on different types of surfaces and it was verified that the obtained maximum differences were below ±3 gloss points. Figure 6 shows the range of variations obtained at different levels of abrasion.

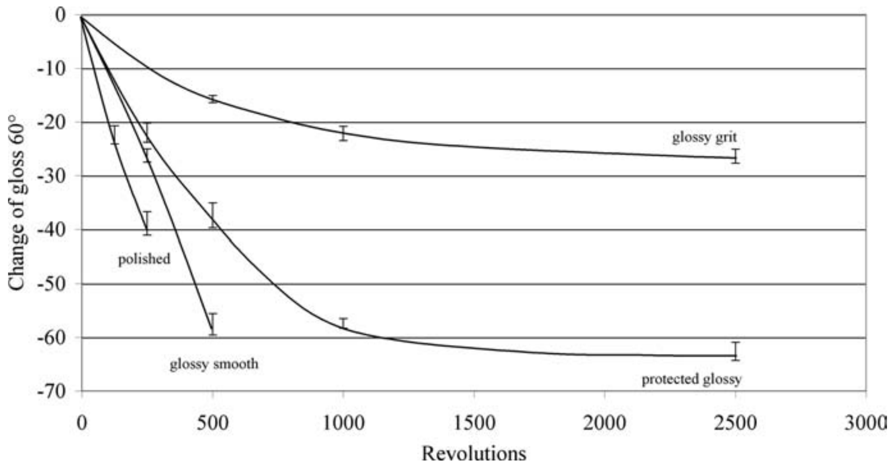

Figure 6. Evaluation of test method repeatability

Since the test method establishes that each abrasion stage must be evaluated by averaging the results and/or visual evaluation of two different test specimens, a sufficient level of repeatability can be assured. In the case of materials with a heterogeneous surface or highly variable design, there may be differences stemming from non-representative sampling. For this reason, when differences exceeding 3 points in gloss loss or discrepancies in visual evaluation between two test specimens at a same stage are observed, the number of test specimens will need to be increased to confirm the result.

3. DEFINITION OF THE CLASSIFICATION SCALE

In order to define the scale and group levels needed to evaluate comparatively the performances of different types of floorings, tests have been conducted with the proposed method on a wide range of product types available in the market, grouped in the categories set out below:

GROUP	MEAN GLOSS	TYPE OF SURFACE
A	80-100	Polished and crystalline glazes
B	70-90	Glossy smooth GL
C	60-80	Polished porcelain tile
D	50-70	Protected/wavy glossy GL
E	30-50	Glossy grits and reliefs
F	20-30	Matt grits and reliefs
G	<20	Matt plain colours
H	<20	Matt multicolour
I	<20	Extruded stoneware UGL

Table 2. Product types

Based on the evaluation criteria described above, and on the stage after which appreciable wear is evidenced, each model has been assigned a corresponding classification, detailed in Table 3:

CLASS	L1	L2	L3	H4	H5	H6
Gloss loss >17 or visible change (revolutions)	125	250	500 1000	2500 5000	7500 10000	>10000

Table 3. Classification criterion–ITC method

The assignment of levels in two categories for light traffic (Light) and intense traffic (Heavy) has been established to favour adequate interpretation of the levels by the specifications writer and/or user, who is generally unfamiliar with usual product performances. Furthermore, a 6-level scale matching the proposed scheme in Annex P of standard EN 14411: 2003 has been established. This annex defines five classes of abrasion resistance for use in floorings (Class 1 to Class 5), plus an unclassified higher level, associated with extremely heavy traffic and a great amount of dirt, for which the use of unglazed tiles of Group I is suggested, and which in the proposed classification is associated with level H6.

The application of these classification criteria to the results obtained in the tests conducted on the different groups described in Table 2 yields the distribution detailed in Figure 7.

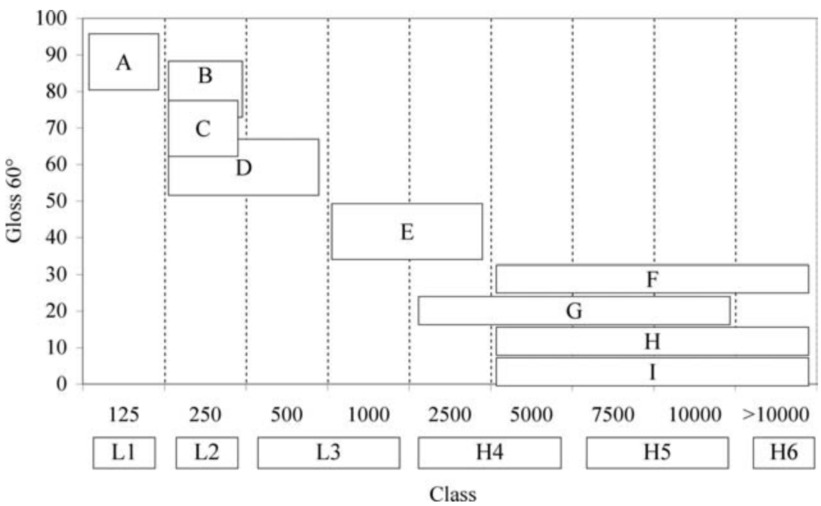

Figure 7. Classification according to types of models

As may be observed, by using the test method and the proposed evaluation criterion, the different types of models scale in agreement with the selection criteria normally used in the ceramic tile sector, based on the experience of the manufacturers consulted. Models with a smooth glossy surface tend to display the effects of wear more rapidly, whereas tile models with relief or a rough surface display no significant alterations as a result of gloss changes.

As far as the influence of surface colour is concerned, and counter to the results obtained with the method set out in standard ISO 10545-7, it has been verified that the colour of the surface has a less pronounced influence on wear resistance, although it has been verified that multicolour surfaces or surfaces with a heterogeneous design tend to reduce the capacity to perceive wear, in contrast to plain surfaces.

4. PROPOSAL FOR SELECTION ACCORDING TO USE

The definition of a classification criterion that allows scaling the materials according to their performance affords the advantage of reducing the possibility of error in the selection of the flooring. However, this improvement is incomplete if no equivalence between product performance and foreseen service conditions is established which enables assuring product durability.

As the proposed test method has been defined to reproduce certain conditions of use (food stores with direct outdoor access), it is not possible to extrapolate directly the performance to other types of premises or traffic conditions, since the cleaning frequency and/or use of abrasive retention systems at the accesses can significantly modify flooring performance.

Nevertheless, given the importance of having an appropriate criterion for flooring selection, a relation is proposed below between the classification obtained and the different types of use (Table 4). This classification has been defined from a conservative standpoint, to avoid misleading evaluations by users and/or specifications writers, with a view to reducing the risk of claims and fostering the use of ceramic tiles in all types of environments.

Obviously, this proposal represents a first orientational approach, and only seeks to serve as a starting point for subsequent discussion on a sectoral level, which, on the basis of product knowledge and experience in regard to product behaviour in different actual service conditions, will enable establishing a selection criterion agreed by consensus in accordance with the interests and needs of the Ceramic Sector.

CLASS	REVOLUTIONS	TYPE OF USE
L1	125	Light traffic without abrasive (e.g. home bathrooms)
L2	250	Light traffic without direct outdoor access (e.g. dwellings in buildings, common elements)
L3	500, 1000	Light traffic with direct outdoor access* (e.g. shops and retail trade)
H4	2500, 5000	Medium traffic with direct outdoor access* (e.g. shops and premises with medium public traffic)
H5	7500, 10000	Heavy traffic with direct outdoor access* (e.g. building areas of public use, sales areas of shopping centres)
H6	>10000	Continuous heavy traffic with constant presence of dirt (e.g. non-covered building areas and pedestrian zones with urban furniture)

**In order to maintain and to assure flooring durability, the premises with direct outdoor access will need to be suitably protected against the accumulation of dirt from outside by means of abrasives retaining systems at the entrances.*

Table 4. Proposed selection according to use

5. CONCLUSIONS

- A test procedure has been defined that allows comparative evaluation of different types of surfaces, and simulates the wear generated in commercial premises with direct outdoor access.
- The method is applicable to both glazed and unglazed tiles, as well as to any other type of rigid material used as floor covering, which will enable establishing comparative references with non-ceramic products.
- Unlike the present standard methods, by using a tribosystem that simulates the action of pedestrian traffic, the incorporation of the assessment of change in gloss as an evaluation criterion, and the combination with a progressive staining test, a classification scale has been established that matches experience in actual use of different types of materials.
- Test variables have been delimited and verification criteria defined to assure the repeatability of the results, which will allow using the test as a standard method and/or its adoption as a standard test method.
- The conclusions of this study have been submitted to the AEN/CTN 138 Committee for Standardisation as a starting point for drafting a standard test method, and for evaluation as a possible national and/or international standard for ceramic tiles.

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