COMPARATIVE STUDY OF SLIP RESISTANCE MEASUREMENT IN SPAIN, THE UNITED KINGDOM, AND THE USA

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1. INTRODUCTION

Though consensus has been reached on the measurement of most technical characteristics of ceramic tiles in order to have harmonised test methods on a European and international level, when it comes to determining slip resistance, there are currently a great number of standard measurement methods.

These test methods are based on the measurement of different parameters as a function of the apparatus used, the main ones being: the Dynamic Coefficient of Friction (DCOF or symbol μ_d), measured with a dynamic linear tribometer; the Critical Angle of

Slip (represented by the symbol α), determined by the ramp method; and the Pendulum Test Value (PTV), measured with the friction pendulum.

On the other hand, the slip resistance of a floor surface depends on several factors. These notably include the amount and nature of the contaminating agent (water, water+surfactant, oil, etc.), and the nature and geometry of the slider. The test conditions defined by each standard also differ, which makes correlating them difficult.

2. EXPERIMENTAL

This study compares the slip resistance values measured according to the Spanish standards (UNE-ENV 12633[1] and UNE 41901 EX[2]) and British standards (BS 7976-2[3]), in which the pendulum is used with sliders of different hardness, and the American standards ANSI A 137.1[4] (applicable to ceramic tiles) and ANSI A 326.3[5] (applicable to rigid floorings), in which a dynamic linear tribometer (BOT-3000E) is used as slipmeter.

2.1. FRICTION PENDULUM

The instrument consists of a pendulum with an arm length of 510 mm, which holds a rubber slider of about 76x25 mm (Figure 1a). Instrument height is adjusted such that the slider (rubber hardness IRHD 55±5 or 96±2), under a maximum load (F_{Nm}) of 22 N, maintains contact with the surface during a travel of 126 mm. The slider moves across the surface at an average angle of 26±3º, grazing it with one of its edges, which is 76 mm long and slightly bevelled.

2.2. BOT-3000E TESTER

The BOT-3000E tester consists of a self-propelled device that travels at constant speed (20 cm/s), across a flat horizontal surface (Figure 1b). In this case, a weight applying a normal force of 21.3 N is set on the slider, of hardness rubber SBR Shore A 95±3. The slider contains a device that allows continuous measurement of the force parallel to the surface, which is applied to move it (friction force). Starting with the normal force applied by the slider–load assembly (F_N) and the force required to move it (F_R), the value of the dynamic coefficient of friction (DCOF) is calculated.

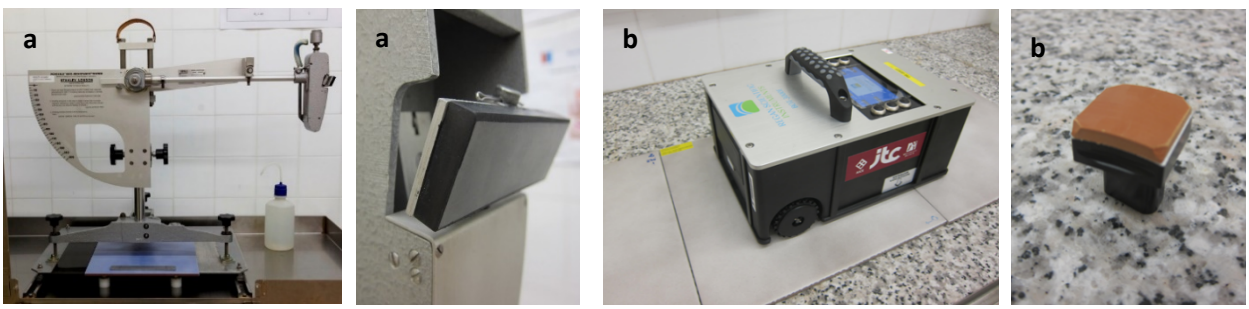

Figure 1. *(a) Friction pendulum and (b) BOT-3000E tester and detail of their respective sliders.*

Table 1 briefly details the nature of the slider and contaminating agent used in each standard method being compared, and the regulatory requirements or recommendations defined in each country.

Tester	Standard	Slider	Contaminating agent	Specification
Friction pendulum	UNE-ENV 12633	Rubber 59 IRHD 59±4	Water	***CTE DB SUA***[6]***:*** Wet indoor areas: class 2: PTV>35 Outdoor areas and swimming pools: class 3: PTV>45
	UNE 41901 EX	Rubber 57 IRHD 55-61	Water	
	BS 7976-2	Rubber TRL IRHD 55±5 Rubber 4S IRHD 96±2	Water	***UKSRG***[7]***:*** Low slip risk: PTV>35
BOT-3000E tribometer	ANSI A137.1 ANSI A326.3	Rubber SBR Shore A 95±3	Water + surfactant	***ANSI A137.1/ANSI A326.3:*** DCOF≥0.42

Table 1. *Summary of the characteristics, test conditions, and specifications of each described measurement method.*

The study was performed on 120 types of ceramic floor tiles, seeking to encompass the widest possible range of surface textures on both a macroscopic level (profile, relief, uniformity) and microscopic level (roughness).

3. RESULTS AND DISCUSSION

In order to be able to compare the results obtained by the friction pendulum (PTV) with those obtained by means of the dynamic linear tribometer (DCOF), these values were converted to friction coefficient, dividing this magnitude by 100 (PTV/100).

The results obtained by the pendulum method, using the Spanish standard (rubber 57) and the British standard (rubber 96), were compared first.

Figure 2 shows plots of the PTV57/100 values of the different test samples, referenced in ascending order of this value, together with the limits specified in Spanish regulations for class 2 (PTV57>35) and class 3 (PTV57>45). They ones corresponding to PTV96/100 and their recommended limit (PTV96>35) have been included in blue. It may be observed that, in general, using the hard rubber (96) yielded higher values than the soft rubber (57), particularly for samples with coefficients of friction between 0.2 and 0.5 (Figure 3).

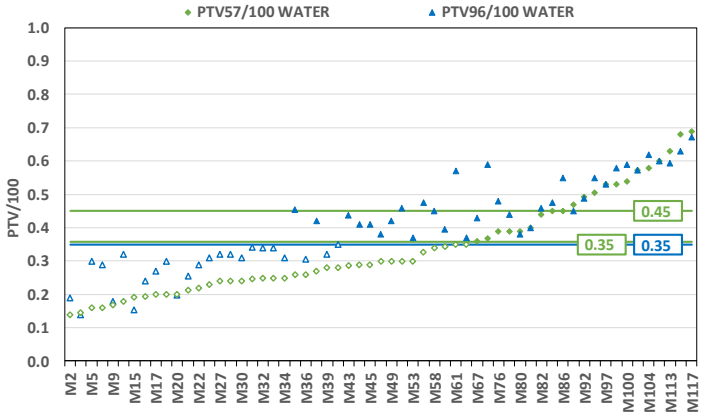

Figure 2. *PTV/100 values with rubber 57 (Spanish standard) and rubber 96 (British standard).*

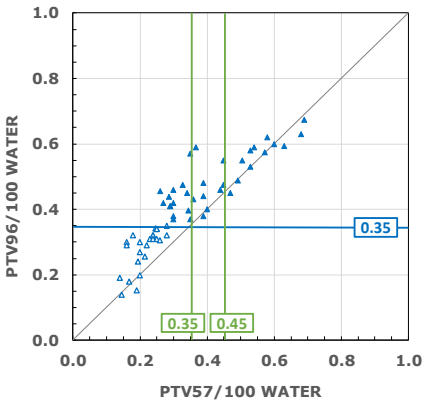

Figure 3. *PTV96/100 versus PTV57/100 values.*

The results obtained by the BOT-3000E dynamic linear tribometer (American standard) and by the pendulum with rubber of hardness 57 (Spanish standard) were then compared.

In this case, the same situation as noted above was observed, albeit in a more exaggerated form. Figures 4 and 5 show that the DCOF values obtained by the American tribometer were much higher than those measured by the pendulum with rubber 57 for almost all test samples.

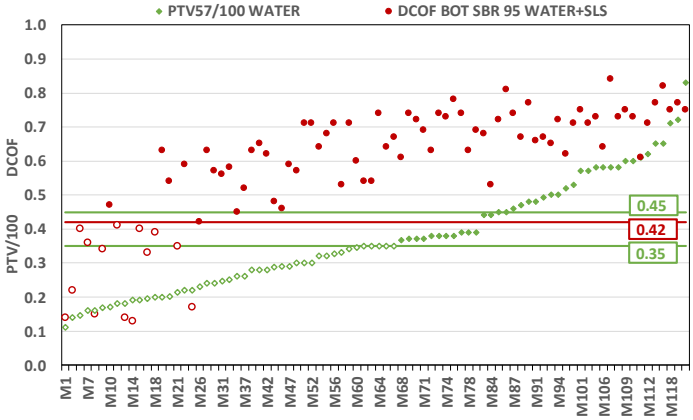

Figure 4. *PTV/100 values with rubber 57 (Spanish standard) and BOT DCOF values (American standard).*

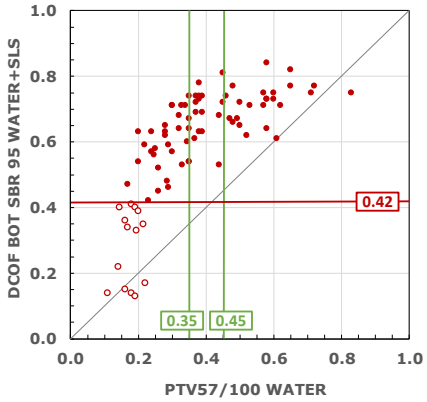

Figure 5. *BOT DCOF versus PTV57/100 values.*

In the above graphs, the samples that would exceed the specified and/or recommended limits in the different countries are plotted in solid symbols, those that would be below these limits being plotted in empty symbols. It may be observed that a large number of samples could obtain different classifications depending on the measurement method and the country's own specifications, it being possible to deem the samples acceptable or unacceptable, depending on the standards used for evaluation.

4. CONCLUSIONS

- The values obtained for the coefficient of friction depended both on the tester and on the test conditions, and particularly on the nature and hardness of the slider.
- On analysing the different standards examined in this study, the pendulum method using rubber 57 (Spanish standard) yielded the lowest coefficient of friction values, followed by the British pendulum. Finally, the BOT-3000E tribometer yielded considerably higher results, i.e. it was the most permissive of all the studied methods.
- The limits established in the different countries are not harmonised to provide a consistent classification. At present, a large number of samples could be deemed suitable or unsuitable, depending on the measurement method and on the national specification applied.

5. REFERENCES

[1] UNE-ENV 12633: 2003. Método de la determinación del valor de la resistencia al deslizamiento/resbalamiento de los pavimentos pulidos y sin pulir.

[2] UNE 41901 EX: 2017. Superficies para tránsito peatonal. Determinación de la resistencia al deslizamiento por el método del péndulo de fricción. Ensayo en húmedo.

[3] BS 7976-2:2001+A1:2013. Pendulum testers. Part 2. Method of operation.

[4] ANSI A137.1:2017 Clause 9.6. American National Specification for Ceramic Tile. Procedure for Dynamic Coefficient of Friction (DCOF) Testing.

[5] ANSI A326.3:2017. American National Standard Test Method for Measuring Dynamic Coefficient of Friction of Hard Flooring Surface Materials.

[6] Código Técnico de la Edificación. DB SUA: Documento Básico SUA. Seguridad de Utilización y Accesibilidad. Ministerio de Fomento. Secretaría de Estado de Infraestructuras, Transporte y Vivienda. Dirección General de Arquitectura, Vivienda y Suelo.

[7] UKSRG Guidelines (2011). The Assessment of Floor Slip Resistance. United Kingdom Slip Resistance Group.