FUNCTIONAL CLASSIFICATION OF CERAMIC FLOOR AND WALL TILES

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ABSTRACT

A functional classification system is proposed for ceramic floor and wall tiles; a tool that the branch in general lacks both at manufacturer and user levels.

Certain basic criteria are set for characterising tile applications (building domains), as well as methods for characterising the tiles, which are independent of the production process. Combining the applications and the products yields a basic "Functional Classification" table, which specifies the requisite technical levels to be met by the ceramic tiles for a specific application.

The study is accompanied by a coding proposal, as well as a selection of the applicable standards for product characterisation.

INTRODUCTION

The selection of ceramic floor and wall tiles by users is normally based on aesthetic reasons, product design being typically being the main factor in selection.

This selection method and the general lack of information regarding the possible uses of the materials are often a source of problems, since product durability in service not only depends on design but also on a set of technical characteristics related to service conditions.

The growth of ceramic tile applications, together with the great variety of models on the market and the absence of a system that allows minimum requirements to be

established for each case, are a source of considerable confusion for users as well as for the various links in the sales distribution chain, with regard to the true meaning of tile properties, and what the suitable values really are.

This ignorance often leads to selecting unsuitable products for a given application, producing customer dissatisfaction, and problems for the user, the manufacturer and for the ceramic floor and wall tile branch in general.

The aim of this study is to set out a method that allows classifying the different types of possible uses, as well as the most suitable test methods for assessing ceramic tile properties, indicating recommended values for each property in terms of each type of application.

As already mentioned, the choice of a ceramic product usually starts with an aesthetic evaluation, and it is only subsequently, in the most favourable of cases that any kind of technical assessment occurs regarding the product's suitability for a targeted application. Moreover, such evaluations are usually made by unqualified sales staff often incorrectly interpreting the various technical characteristics, owing to the considerable confusion reigning in the market as to the actual meaning of these technical characteristics.

It should also be noted that this lack of information acts as a constraint on ceramic tile use, since the inability to clearly assess tile characteristics and those of its service environment leads to other materials being used, which nonetheless often exhibit noticeable shortcomings.

A tool has been developed to try and remedy this situation, involving the selection of ceramic tiles in terms of use, set out in a clear and simple manner for ceramic floor and wall tile users.

METHODOLOGY

The functional tile classification system developed in the present work was designed to satisfy two basic needs:

- Providing a user-friendly tool that perfectly characterises the area to be tiled (Characterisation of the application)

- Establishing the properties of the ceramic materials that define the product's suitability for a given application (Product characterisation)

The approach adopted is presented in Figure 1. It details the methodology employed in the work to achieve a functional classification, and consists of the following stages:

1.- CHARACTERISATION OF THE APPLICATION (BUILDING DOMAINS)

1.1. *Selection of service parameters:* The fundamental concepts are defined to enable differentiating the various service conditions. Besides being easy to use, these concepts are designed to cover most arising situations.

1.2. *Characterisation of building domains:* The combination of the parameters defined above allows establishing service conditions, adequately characterising the building domain to be tiled.

2.- PRODUCT CHARACTERISATION

2.1. *Selection of the product's technical characteristics:* The product's basic technical characteristics are chosen, which, together with the parameters characterising building domains, will permit defining the ceramic product's suitability.

2.2. *Definition of test methods:* The most suitable test methods for determining these technical characteristics are selected from international standards.

3.- SUITABILITY OF THE PRODUCT FOR THE APPLICATION

3.1. *Coding:* The functional classification involves defining certain product codes to allow easily identifying whether a tile can be used in a given context, and which can be generally adopted as a standard nomenclature.

3.2. *Determination of recommended levels:* Recommended levels are set for the various characteristics of the selected product based on practical experience.

3.3. *Functional classification:* The combination of building domain parameters and product technical characteristics produces a functional classification, in which applications and recommended product levels for each application are established.

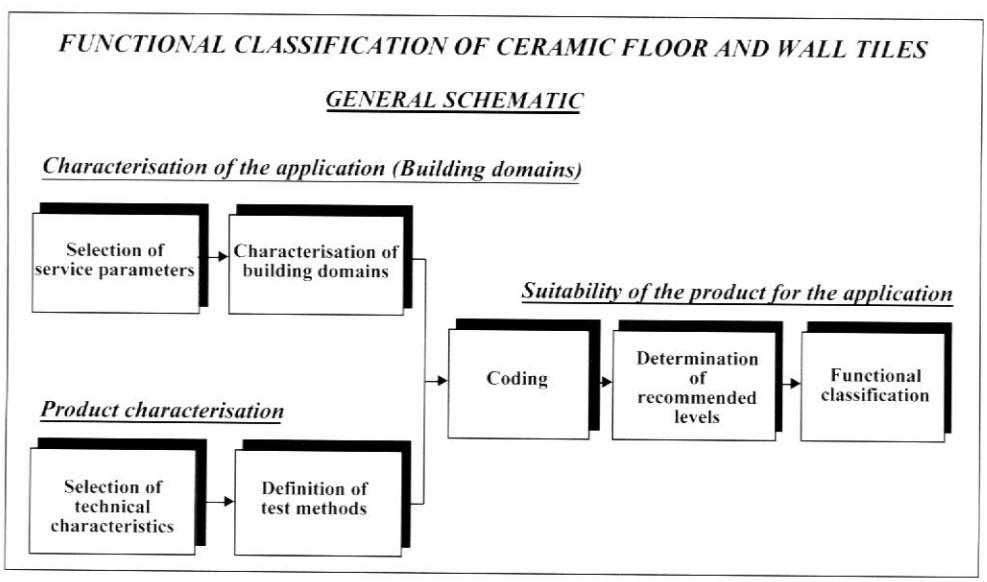


Figure 1. General schematic

1. CHARACTERISATION OF THE APPLICATION (BUILDING DOMAINS)

1.1. SELECTION OF SERVICE PARAMETERS

Basic parameters were chosen, which allow defining a selection criterion in terms of architectural applications.

These parameters need to be user-friendly for the non-professional, and relate to the physico-chemical characteristics that will determine the material's behaviour after the installation and throughout the tiling's useful life. The following were set as key parameters:

- PASSABLE OR NON-PASSABLE AREA: This defines the exposure of a material to potential traffic, whether pedestrian or otherwise, distinguishing it from uses without exposure to traffic. Flooring is thus conceived as a covering that will be exposed to traffic, while wall tiling will not.

- INTERIOR OR EXTERIOR: Parameter defining the insulation or absence of insulation of the area to be tiled from environmental agents, especially rain, and the presence of abrasive particles.

- RISK OF FROST: This parameter determines the possible location in climatically adverse conditions involving frost.

- FREQUENCY OF USE: Parameter related to two aspects, which together define different recommendable levels:
  - Amount of traffic (amount of expected pedestrian traffic).
  - Quality of the traffic (presence or absence of abrasive particles, associated with applications in exteriors or interiors with direct access from outside.)

- PRESENCE OF WATER: The customary presence of water in certain areas entails the recommendation, for preventive purposes, of a level of slip resistance. Areas exhibiting presence of water are defined as follows:
  - Exteriors as a result of rain or frequent use of water.
  - Interiors subject to frequent cleaning
  - Interiors subject to frequent contact with water or other fluids.

- PRESENCE OF CHEMICAL PRODUCTS: Parameter related to the possible use in the building domain of aggressive chemical products, including many common cleaning products.

- TYPE OF TILE INSTALLATION (OPEN OR BUTT JOINT): By tile joints is meant the physical separation between two adjacent ceramic tiles, arranged on installing the tiles. We will refer to open joints or tiling with joints when the spacing between the tiles (measured at the closest part of two adjacent edges) is equal to or larger than 3 mm. The expression butt joints or tiling without joints is used to refer to spacings of less 3 mm. (Joint spacings of less than 1,5 mm are not recommended).

- SPECIAL CHARACTERISTICS: In some cases it is necessary to know whether the tiling needs to exhibit certain special characteristics. The most common are as follows:
  - Electrical conductivity
  - Special non-slip characteristics
  - Chemical resistance to specific products
  - Requirements regarding controlled gloss
  - Extreme temperature changes
  - Special mechanical performance.

1.2. CHARACTERISATION OF BUILDING DOMAINS

The scheme set out in the form of a hierarchical tree, which logically combines the parameters, perfectly characterises most tiling domains. These domains have been arranged in 25 basic groups.

HIERARCHICAL ARRANGEMENT OF BUILDING DOMAINS						
PASSABLE OR NON-PASSABLE	**EXTERIOR O INTERIOR**	**PRESENCE OF WATER AND RISK OF FROST**	**AMOUNT OF TRAFFIC**	**QUALITY OF TRAFFIC (PRESENCE OF ABRASIVES)**	**TRAFFIC GROUP**	**PRESENCE OF CHEMICAL PRODUCTS**
PASSABLE AREA (FLOORING)	EXTERIOR	PRESENCE OF WATER AND RISK OF FROST	HIGH	RISK	HEAVY	YES
			MEDIUM	RISK	INTENSE	YES
				NO RISK	HIGH	YES
			LOW	RISK	MEDIUM	YES
				NO RISK	LOW	YES
		PRESENCE OF WATER WITHOUT RISK OF FROST	HIGH	RISK	HEAVY	YES
			MEDIUM	RISK	INTENSE	YES
				NO RISK	HIGH	YES
			LOW	RISK	MEDIUM	YES
				NO RISK	LOW	YES
	INTERIOR	PRESENCE OF WATER	HIGH	RISK	HEAVY	YES
			MEDIUM	RISK	INTENSE	YES
				NO RISK	HIGH	YES
			LOW	RISK	MEDIUM	YES
				NO RISK	LOW	YES
		ABSENCE OF WATER	HIGH	RISK	HEAVY	YES
			MEDIUM	RISK	INTENSE	YES
				NO RISK	HIGH	YES
			LOW	RISK	MEDIUM	YES
						NO
				NO RISK	LOW	NO
NON-PASSABLE AREA (WALL TILING)	EXTERIOR	FROST	NO TRAFFIC	NO RISK	NO TRAFFIC	YES
		NO FROST				YES
	INTERIOR	NO FROST	NO TRAFFIC	NO RISK	NO TRAFFIC	YES
						NO

The special uses that are defined by specific, non-basic parameters are treated as SPECIAL AREAS.

The selection of the parameters is independent of the nature, aesthetic characteristics and manufacturing processes of ceramic tiles, and can therefore not be linked to technical-commercial attributes, so often shielded as sales arguments in choosing a product. For example:

- Colour of the tile body (red or whiteware).
- Manufacturing process (twice fire, single fire, dust pressing, extrusion, etc)
- Nature and characteristics of the surface

Generally, none of these attributes have any relationship to tile quality or function.

The following step in the functional classification of ceramic tiles is linking the foregoing parameters to the tile's physico-chemical characteristics, and these to the test methods that allow evaluating the product.

2. PRODUCT CHARACTERISATION

After characterising the applications, the materials now need to be characterised. This involves defining the product's technical characteristics, which are directly or indirectly related to service parameters, as well as to the selection of the measuring methods that serve to determine them.

2.1. SELECTION OF THE PRODUCT'S TECHNICAL CHARACTERISTICS

Each basic parameter used in defining the building domain will be related to one or more technical characteristics. This relationship allows establishing the relevant technical requirements of the ceramic material, which ensure suitable performance of the selected material both on installing it and in subsequent use.

Six basic characteristics were selected:

- Dimensional characteristics
- Mechanical strength
- Frost resistance
- Wear resistance
- Chemical resistance
- Slip resistance

To these can further be added the possible special technical characteristics related to a specific building domain requirement, which will correspond directly to an associated physical magnitude.

2.2. DEFINITION OF TEST METHODS

The level of a given product for each of the technical characteristics described is determined by one or more standard test methods:

DIMENSIONAL CHARACTERISTICS

These parameters perfectly describe the geometry of the tile as well as its deviation from standard geometrical shapes.

Test methods: ISO 10545-2

The test methods established in the current standards are used since these perfectly describe the geometry as well as the possible deviations of the product.

BENDING STRENGTH

This is a ceramic tile's degree of resistance to breaking by bending.

Test methods: Measurement of breaking load ISO 10545-4 (on whole tiles)

The physical magnitude chosen is the most representative one of the product's real behaviour, since it indicates the real peak load that the tile is capable of withstanding.

FROST RESISTANCE

This is the capacity of a ceramic tile to remain unaltered after successive frost-thaw cycles.

Test methods: ISO 10.545-12

This method was chosen as being the only available standard method that was widely used.

WEAR RESISTANCE

This is the capacity of a ceramic tile surface to maintain an unchanged surface quality or appearance in service on ageing. A combination of several methods was chosen to measure this property. Although the methods individually exhibit serious shortcomings, combining them yields an excellent characterisation of the material.

Test methods:

- Surface abrasion (Glazed tiles) ISO 10.545-7
- Deep abrasion (Unglazed tiles) ISO 10.545-6
- Stain resistance after abrading ISO 10 545-14
- Mohs hardness UNE-67-11-92
- Gloss loss (Measurement with a reflectometer ISO 2813)

The test methods for surface and deep abrasion were chosen as being the internationally most widely used procedures by both manufacturers and users. It has been attempted to get round the shortcomings of these two methods, which do not provide a real view of the tile's practical behaviour, by also jointly considering three other technical characteristics that are closely related to the actual behaviour of the material:

- Stain resistance: the method shows the irreversible stain retention capacity of the abraded product.
- Mohs hardness: this is the most widely used method for determining the scratch hardness of a ceramic surface.
- Gloss loss. This supplementary measurement serves to highlight a practical factor in wear, not accounted for in the other methods.

CHEMICAL RESISTANCE

This is the capacity of a ceramic tile surface to maintain an unaltered surface quality on habitual exposure to common chemical products.

Test methods: ISO 10.545-13

This method was chosen as it determines a degree of resistance to a whole range of common chemical cleaning agents and household cleaning products.

SLIP RESISTANCE

This is the slip resistant capacity of a ceramic tile surface.

Test methods: ISO 10.545-17 dynamic method

This method has been chosen as it offers the greatest guarantees of reproducibility for dry and wet surfaces.

SPECIAL CHARACTERISTICS

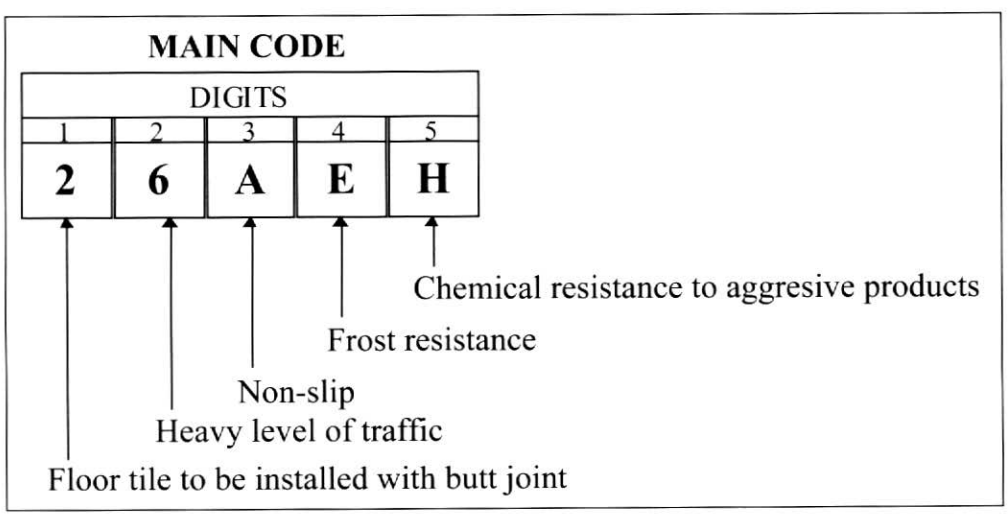
These are a product's physico-chemical characteristics that meet the requirements of a special application. Given the great variety of special applications, as well as the diversity of possibly applicable standards, the selection of a given method for a particular use should be defined by mutual agreement between the manufacturer and the user requiring a special specific property.

3. SUITABILITY OF THE PRODUCT FOR THE APPLICATION

The definition of a product's applications and characterisation has been brought together in a single coding system with a definition of levels.

3.1. CODING

The classification of building domains and selection of tiling joints lead to a ceramic tile code, whose objective is to synthesize basic tile characteristics in a simple way, with a nomenclature that can be adopted in the market. It also specifies the special characteristics to be met if necessary. The code is made up of the following digits:



Digit 1: This corresponds to the joint descriptor. The figures are: 1 on installing tile with an open joint on floors and walls; 2 on installing tile with a butt joint on floors; and 3 on installing tile with a butt joint on walls.

Digit 2: This corresponds to the descriptor for resistance to loss of surface

quality. Levels range from 1 to 7. Level 7 corresponds to trafficked flooring not exclusively transited by pedestrians, and involves tiles with special mechanical strength (exhibiting breaking loads exceeding 2000 N), and other specific requirements (resistance to rolling, to light or heavy impact, size, thickness, etc.).

Digit 3: This corresponds to the slip resistance descriptor (A)

Digit 4: This corresponds to the frost resistance descriptor (E)

Digit 5: This corresponds to the chemical resistance descriptor (H)

3.2. DEFINITION OF RECOMMENDED LEVELS

The association of the parameters relating to building domains with the product's technical characteristics allows determining the set of physico-chemical properties to be exhibited by the material for a specific service application.

BUILDING DOMAIN CHARACTERISTIC (PARAMETER)	ASSOCIATED PRODUCT CHARACTERISTIC
PASSABLE/NON-PASSABLE	WEAR RESISTANCE MECHANICAL STRENGTH SLIP RESISTANCE
INTERIOR / EXTERIOR	WEAR RESISTANCE CHEMICAL RESISTANCE SLIP RESISTANCE
PRESENCE OF WATER	SLIP RESISTANCE
RISK OF FROST	FROST RESISTANCE
AMOUNT AND QUALITY OF TRAFFIC	WEAR RESISTANCE CHEMICAL RESISTANCE
PRESENCE OF CHEMICAL PRODUCTS	CHEMICAL RESISTANCE
TYPE OF TILE INSTALLATION	DIMENSIONAL CHARACTERISTICS
SPECIAL REQUIREMENTS	SPECIAL CHARACTERISTICS

The values of the product's requisite physico-chemical characteristics are set out below for each digit value of the code. The values have been defined by taking into account the following points:

- Existence of an international standard (ISO) applicable to ceramic floor and wall tiles, with certain set minimum levels.
- Market demands for levels that are often considerably stricter than those set in the standards, with which the industry usually works.
- Experience in the sector.

The ultimately recommended levels are intended to be not only consistent with those set in the standards, but to correspond to those most widely used in the branch, and which, on being logically ordered, establish a set of requisite values with which a ceramic tile is to comply in order to assure its suitability for the targeted application.

TYPE OF TILE INSTALLATION

	1st DIGIT VALUES					
Tile destination	**1 Floor or wall tiling**		**2 Flooring**		**3 Wall tiling**	
Type of tile installation	**Open joint (Width >= 3 mm)**		**Butt joint Width (1,5 - 3 mm)**		**Butt joint Width (1.5 - 3 mm)**	
Tile size (Max. edge L)	**L<200 mm**	**L>=200mm**	**L<200 mm**	**L>=200 mm**	**L<200 mm**	**L>=200 mm**
Length and Width						
Deviation with regard to work size	± 3.0 mm	± 1.5 % (<4.5 mm)	± 1.0 mm	± 0.6 % (<1.8 mm)	± 1.0 mm	± 0.5 % (<1.5 mm)
Deviation with regard to the measurement of 10 tiles	± 1.5 mm	± 1% (<3.0 mm)	± 0.5 mm	± 0.5 % (<1.0 mm)	± 0.5 mm	± 0.3 % (<0.75 mm)
Thickness						
Deviation with regard to work thickness	± 5 %	± 5 %	± 5 %	± 5 %	± 5 %	± 5 %
Straightness of edge						
Deviation with regard to work size	± 1.5 mm	± 1% (<3.0 mm)	± 0.5 mm	± 0.5 % (<1.0 mm)	± 0.5 mm	± 0.3 % (<0.75 mm)
Rectangularity						
Deviation with regard to work size	± 2.5 mm	± 1.5% (<4.5 mm)	± 1.0 mm	± 0.6 % (<2.0 mm)	± 1.0 mm	± 0.5 % (<1.5 mm)
Surface flatness						
Centre curvature	± 2.5 mm	± 1.5% (<4.5 mm)	+ 1.5 mm - 0.75 mm	± 0.5 % (+2.0/-1.0mm)	+ 1.5 mm - 0.75 mm	+0.5/-0.3 % (+2.0/-1.0mm)
Edge curvature	± 2.5 mm	± 1.5% (<4.5 mm)	+ 1.0 mm - 0.5 mm	± 0.5 % (+1.5/-1.0mm)	+ 1.0 mm - 0.5 mm	+0.5/-0.3 % (+1.5/-1.0mm)
Warping	± 2.5 mm	± 1.5% (<4.5 mm)	+ 1.0 mm - 0.5 mm	± 0.5 % (+1.5/-1.0mm)	+ 1.0 mm - 0.5 mm	±0.5 % (+1.5/-1.0mm)

WEAR RESISTANCE (GLAZED TILES)

Test	2nd DIGIT VALUES					
	1	**2**	**3**	**4**	**5**	**6**
Surface abrasion resistance class according to ISO-10545-7 (Class and visible stage>=)	-	II 600 rev	II 600 rev	III 1500 rev	IV 2100 rev	IV 6000 rev
Stain resistance class after abrading (visible stage) according to ISO-10545-14 * For wall tile the test is performed without abrading.	3	3	3	3	3	3
Mohs scratch hardness class (UNE-67-11-92)	-	-	4	4	6	6
Mean gloss difference at 60° before and after abrading at 600 rev.	-	-	-	<15	<15	<15

ABRASION RESISTANCE (UNGLAZED TILES)

Test	2nd DIGIT VALUES					
	1	2	3	4	5	6
Max. value for volume removed (at mm3) in deep abrasion, according to ISO-10545-6	-	<2365	<1419	<649	<393	<175
Stain resistance class after subjecting the tiles to surface abrasion test ISO-10545-14 a 600 rev.	-	3	3	3	3	3
Stain resistance class according to ISO 10545-14.	3	-	-	-	-	-

SLIP RESISTANCE

Test	3rd DIGIT VALUE	
	Letter A	No letter
Dry coefficient of friction. Dynamic method ISO 10545-17	>=0.4	>= 0,4
Wet coefficient of friction. Dynamic method ISO 10545-17	>=0.4	-

FROST RESISTANCE

Test	4th DIGIT VALUE	
	Letter E	No letter
Frost resistance according to ISO 10545-12	Pass	-

CHEMICAL RESISTANCE

Test	5th DIGIT VALUE	
	Letter H	No letter
Household chemical cleaning products ISO 10545-13 (3.1)	A	A
Swimming pool salts ISO 10545-13 (3.2)	A	A
Low concentrations of acids and alkalis ISO 10545-13 (3.3.1)	LA	LB
High concentrations of acids and alkalis ISO 10545-13 (3.3.2)	HB	-

MECHANICAL STRENGTH

Test	2nd DIGIT VALUES					
	1	2	3	4	5	6
Measurement of breaking load on whole tiles according to ISO-10545-4	>=450 N	>=900 N	>=900 N	>=900 N	>=900 N	>=900 N

3.3. FUNCTIONAL CLASSIFICATION OF CERAMIC FLOOR AND WALL TILES

The combination of requisite technical characteristics together with the arrangement of logical combinations of building domain parameters leads to the following chart, which sets out the 25 performance levels associated with the 25 groups of building domains in terms of the selected parameters, thus ultimately establishing the functional classification.

FUNCTIONAL CLASSIFICATION OF CERAMIC TILES

Floor or wall tile	Location	Environmental conditions	Amount of traffic	Risk of abrasion	Level of traffic	Chem. Resist. to aggress. prod.	Type of joint	RPA	RD	RH	RQ
FLOORING	EXTERIOR	PRESENCE OF WATER AND RISK OF FROST (E)	HIGH	RISK	HEAVY (6)	RESISTANT	1 - 2	6	A	E	H
			MEDIUM	RISK	INTENSE (5)	RESISTANT	1 - 2	5	A	E	H
				NO RISK	HIGH (4)	RESISTANT	1 - 2	4	A	E	H
			LOW	RISK	MEDIUM (3)	RESISTANT	1 - 2	3	A	E	H
				NO RISK	LOW (2)	RESISTANT	1 - 2	2	A	E	H
		PRESENCE OF WATER WITHOUT RISK OF FROST	HIGH	RISK	HEAVY (6)	RESISTANT	1 - 2	6	A		H
			MEDIUM	RISK	INTENSE (5)	RESISTANT	1 - 2	5	A		H
				NO RISK	HIGH (4)	RESISTANT	1 - 2	4	A		H
			LOW	RISK	MEDIUM (3)	RESISTANT	1 - 2	3	A		H
				NO RISK	LOW (2)	RESISTANT	1 - 2	2	A		H
	INTERIOR	PRESENCE OF WATER	HIGH	RISK	HEAVY (6)	RESISTANT	1 - 2	6	A		H
			MEDIUM	RISK	INTENSE (5)	RESISTANT	1 - 2	5	A		H
				NO RISK	HIGH (4)	RESISTANT	1 - 2	4	A		H
			LOW	RISK	MEDIUM (3)	RESISTANT	1 - 2	3	A		H
				NO RISK	LOW (2)	RESISTANT	1 - 2	2	A		H
		ABSENCE OF WATER	HIGH	RISK	HEAVY (6)	RESISTANT	1 - 2	6			H
			MEDIUM	RISK	INTENSE (5)	RESISTANT	1 - 2	5			H
				NO RISK	HIGH (4)	RESISTANT	1 - 2	4			H
			LOW	RISK	MEDIUM (3)	RESISTANT	1 - 2	3			H
						NORMAL	1 - 2	3			
				NO RISK	LOW (2)	NORMAL	1 - 2	2			
WALL TILING	EXTERIOR	FROST	NO TRAFFIC	NO RISK	NO TRAFFIC (1)	RESISTANT	1 - 3	1		E	H
		NO FROST				RESISTANT	1 - 3	1			H
	INTERIOR	NO FROST	NO TRAFFIC	NO RISK	NO TRAFFIC (1)	RESISTANT	1 - 3	1			H
						RESISTANT	1 - 3	1			

RPA = Resistance to loss of surface quality RD = Slip resistance

RH = Frost resistance RQ = Chemical resistance

CONCLUSIONS

The present study allowed drawing the following conclusions:

- Classification of possible ceramic tile applications, reducing use typology to 25 functional groups.

- Selection of the physico-chemical characteristics to be considered for each type of product, to thus allow assessing the product's suitability for its targeted application.

- Determination of the test methods to be used and minimum recommended values for each characteristic.

- Assigning a code in terms of product characteristics to allow harmonising the selection criteria to be applied by the user to any ceramic tile, regardless of its nature, manufacturing method, producer, etc.

The above has been set out in terms of a functional classification of ceramic floor and wall tiles, which in itself constitutes a user-friendly tool for manufacturers, specifiers, tile fixers and users of ceramic floor and wall tiles.