

COMPARISON OF FLOORING MATERIALS AND FITNESS FOR USE

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ABSTRACT

As a result of Directive 89/106/CEE on the free circulation of construction products in the European Union, there are an ever greater number of products subject to the CE mark, whose properties are declared according to harmonised standards, thus allowing materials and products throughout European to be compared and selected.

However, each product standard lays down a different series of tests, reference values, or specifications, generally relating to the characteristics of the material. As a result, the specifications declared in the CE mark in relation to a given use vary, depending on the material to be used: ceramics, stone, cement tiles, wood, synthetic materials, etc.

In addition, depending on the service requirements, more or less appropriate materials can be found which are, however, hard to compare owing to their different specifications.

The present paper presents an analysis of different product standards of internal and external flooring, in order to be able to establish a list of key properties for a material's intended use.

The ultimate aim of this study is to develop a chart of the suitability of different materials for the various flooring situations to be found in building construction and town development works.

1. INTRODUCTION

The present study is based on the comparison of flooring materials detailed in different product standards, as well as in the handbooks of manufacturers and associations, and in particular in the Quality Guides of the Autonomous Government of Valencia.

In addition, the section of the work focusing on the emotional perception of the different materials is based on users' impressions, collected by students of technical architecture in various studies comparing ceramic floorings with other, alternative materials.

The work has centred on the materials customarily used in building construction in Spain: stone, ceramics, concrete tiles, wood, and synthetic materials, without quantifying the use of each. However, the study has extended to the use of these same materials in exteriors, therefore including continuous materials applied *in situ*, such as concrete or asphalts, in order to include totally different manufacturing and installation technologies.

The study analyses the materials and products, users' emotional perception of each, and the standards that regulate them, in order thus to be able to compare their uses.

2. THE MATERIALS

2.1. Ceramics.

Ceramics are obtained by preparing, forming, drying, and firing clays. This process yields artificial products with multiple applications.

Ceramic tiles are impermeable materials generally consisting of a body of a clayey nature and variable porosity, which may be covered by a glassy coating that can provide it with enhanced surface technical performance and greater decorative possibilities.

The Ceramic Tile Guide defines the following types of ceramic tiles commonly found in Spain.

Type of tile	Forming	Body	Glaze	ISO 13006 UNE-EN 14411
Earthenware tile	Pressed	Porous	Yes	BIII
Glazed stoneware	Pressed	Non-porous	Yes	BIIb - BIIa
Porcelain tile	Pressed / Extruded	Non-porous	No - Yes	BIIa
Catalan tile	Extruded	Porous	No	AIIb - AIII
Rustic stoneware	Extruded	Non-porous	No - Yes	AI - AIIa
Fired clay	Extruded	Porous	No	AIIb 2 ^a - AIII

Table 1. Types of ceramic tiles.

2.2. Stone.

Natural stone is a material obtained directly from nature, which only requires dimensioning operations to obtain the appropriate form for use.

A commercial and technical classification can be drawn up to facilitate stone identification and use, based on its formation, origins, composition, and structure:

Technical-commercial designation	CHARACTERISTICS			
	Major composition	Major Mohs hardness	Polishability	Stratified
Slate	Siliceous	-	-	YES
Granite		>5	YES	NO
Sandstone and quartzite		>5	NO	NO
Marble	Calcareous	3-4	YES	NO
Limestone		3-4	NO	NO
Alabaster	Sulphates	<3	-	-

Table 2. Technical-commercial classification and key characteristics.

Once these natural stone materials have been dimensioned, they can be used as different construction products with a range of surface finishes, enabling them to respond appropriately to different service situations.

The European standards address the following natural stone products: flags, setts, kerbs, slabs, modular tiles, and slates.

On the other hand, the surface finishing processes can provide stone with various textures, for example by lapping, polishing, pumicing, sawing, ageing, flaming, grit blasting, sanding, bushhammering or dressing, etc., yielding different finishes and technical performances.

2.3. Concrete tiles (terrazzo, paving slabs, and paving flags).

According to current European standards, terrazzo tiles are prefabricated concrete products of uniform shape and thickness, which are suitably compacted and made by compression and/or vibration.

This same definition also covers concrete tiles, paving slabs, and paving flags, which only differ from terrazzo in that, in general, the aggregate is not visible at the surface.

The market also contains products produced by moulding large blocks or slabs of mineral aggregates agglomerated with cement, which are subsequently cut to the appropriate sizes.

Thus, concrete products for floorings in modular formats can be classified as follows:

Classification of concrete files

Products for interiors	Terrazzo for interiors
Products for exteriors	Terrazzo for exteriors
	Concrete paving flags
	Concrete paving slabs

These products all allow their final finish to be made on site or in the workshop, it being usual to prepare the finish on site for products for interiors and to have a factory finish for outdoor products, with a great variety of textures.

2.4. Wood.

Wood is a natural material obtained by cutting down trees which, after drying, cutting, and the application of protective treatments, yield natural products with a wide range of applications.

The market offers a broad spectrum of flooring solutions, consisting of wooden items for interiors and exteriors, with different sizes.

Classification in terms of product make-up and shape

Wood floors:	Boarding
	Raised floors
	Lamparquet
	Multilayer parquet (floating raised floor)
	Panels
	Block flooring
	Veneered board flooring (these are not parquet
Laminate floors	

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2.5. Synthetic floorings (textiles and resilient flooring materials).

Synthetic floorings may be considered to be floor coverings made with artificial materials, generally derived from oil, which may be combined or not with natural materials. They are usually defined commercially and in the standards as textiles and resilient flooring materials.

Synthetic floorings

Textiles	Carpeting
Resilient flooring materials	Rubber
	Linoleum
	Vinyl
	Laminates

3. TECHNIQUES

All the floorings studied here are characterised as modular prefabricated elements, except for some continuous materials, which may be arranged on site as follows:

Flooring installation techniques

Direct floorings	Adhered (glues, cementitious adhesives, mortars) Nailed or screwed (directly / on battens) Fitted (directly / on battens) Arranged by gravity
Technical floorings	On pedestals / on substructures

4. SERVICE SITUATIONS

The classification of a flooring material is a complex issue, given the great many situations or aggressions to which it may be exposed, and the widely differing behaviour of different materials.

Schematically, the following service situations may be defined:

Service situations

General situations	Interiors	Moderate, normal, or heavy use.
	Exteriors	Moderate or heavy pedestrian use. Moderate, medium, or heavy rolling traffic. Lightweight or heavy-weight rolling traffic.
Other situations	Hygienic / readily cleanable. Non-slip. Outdoor durability / Frost resistant.	

One of the classifications that can be used as a reference is the **UPEC** classification of the CSTB (Centre Scientifique et Technique du Bâtiment) based on product quality levels, which match the common directives of the UEAtc for the selection of materials according to their suitability for intended use.

This classification uses four groups of properties, which then link the materials to internal building areas: (<http://www.cstb.fr/evaluations/autres-evaluations/upec.html>)

Identifier	Description	Levels
U (use)	wear resistance.	1 to 4
P (piercing)	resistance to pressure of furniture.	1 to 3
E (water)	resistente to water.	0 to 3
C (chemicals)	sensitivity to chemicals.	0 to 3

Table 3. UPEC classification.

5. EMOTIONAL PERCEPTION

In order to analyse users' perception of different floorings, the image that each material projects may be identified by means of quotes from popular culture, advertisements, and surveys.

5.1. Quotes.

Some popular quotes, in addition to various other specific quotes relating to the materials, may provide some idea of characteristics of these materials:

- *"Ceramics are a structural covering subject to fashion"* Fernando Diago, (Former President of ASCER).
- *"Quotes to be sculpted in marble"* Anonymous.
- *"The sculptor thinks of marble"* Oscar Wilde.
- *"The architecture of the Gods, in stone, and the architecture of humankind, in clay"* Juan Manuel Valiente.
- *"Old wood for burning, old wine for drinking, old friends in whom to trust, and old authors for reading"* Francis Bacon,
- *"Wood: symbol of the mother"* Dictionary of symbols, Juan-Eduardo Cirlot.
- *"It has more hairs than the werewolf's rug"* Anonymous.

5.2. Advertising slogans.

Similarly, the way in which manufacturers advertise their products provides some idea of a product's best emotional qualities:

- *"A woman's Ceramics".*
- *"New spaces, new solutions"* [ceramics].
- *"The innovative and creative potential of ceramics".*
- *"Marble, work and myth "*.
- *"The new fashion in raised floors. Wood adapts to everything..."*.

5.3. Users' perception.

The users' perception was measured by means of a survey in which university first-year students were asked to describe each of the materials with a word that expressed their emotional perception.

The responses signalled the following positive aspects:

- **Ceramics and synthetic materials:** innovative, modern, original, hygienic, cold.
- **Ceramics and wood:** cosy, warm, comfortable, homely, hygienic, clean.
- **Stone and wood:** rustic, ecological, natural, amplitude, freedom, economical.
- **Stone and concrete tiles:** strong, austerity, sobriety.
- **Concrete tiles and synthetic materials:** glossy, strong, functional, practical.
- **Ceramics:** art, design, comfortable, variety, functional, adaptable, luminous.
- **Stone:** compact, unpolished, nostalgic, culture.
- **Concrete tiles:** colourful, suitable.
- **Wood:** quality, delicate, warm, hotel and catering trade, perfect, sensual, tranquillity.

And the following negative aspects:

- **Natural stone:** rough.
- **Stone, terrazzo, and ceramics:** common, normal, typical, vulgar, plain, slippery.
- **Wood:** damp.
- **Synthetic materials:** artificial, industrial, false, dirty.
- **Terrazzo:** ugly, stress.

6. STANDARDS AND USE

Construction regulations lay down the requirements that materials intended for use as flooring shall conform to.

On the other hand, product standards and quality guides detail the best performance features of these materials, which make it interesting to analyse these standards.

With regard to the compulsory regulations for floorings in Spain, to be noted is the requirement defined in the Technical Building Code (TBC) in relation to

Flooring Slipperiness, TBC DB SU8, which establishes the following constraints on flooring uses.

CLASS	USE	Resistance to slipperiness ⁽¹⁾
0	Without requirements / vertical claddings and floorings in apartment buildings.	$R_d \leq 15$
1	Use in floors dry interiors with slope $< 6\%$.	$15 < R_d \leq 35$
2	Use in dry interiors with slope $\geq 6\%$ and stairs Use in wet interior floors with slope $< 6\%$.	$35 < R_d \leq 45$
3	Use in wet interior floors with slope $> 6\%$ and stairs. Use in interior floors with grease, lubricants, etc. Use in outdoor floors and swimming pools.	$R_d > 45$

⁽¹⁾ Test conducted according to UNE-ENV 12633:2003.

Table 4. Resistance to slipperiness.

6.1. Ceramics.

Ceramic materials for claddings are classified by the ISO 13006 UNE-EN 14411 standards in terms of water absorption, forming system, and the presence or absence of a surface glaze.

To obtain a classification that relates the materials to their use, however, it is necessary to resort to guides like the Ceramic Tile Guide.

This guide classifies ceramic tiles according to their intended use by means of the following three identifiers: mechanical characteristics, slip resistance, and additional characteristics.

TYPE	Use
Type 1	Use in facings.
Type 2	Use in floors light pedestrian traffic.
Type 3	Use in floors moderate pedestrian traffic.
Type 4	Use in floors medium pedestrian traffic.
Type 5	Use in floors heavy pedestrian traffic.
Type 6	Use in floors very heavy pedestrian traffic.
Type 7	Use in floors with rolling traffic.

Table 5. Types of use in terms of mechanical characteristics. (Ceramic Tile Guide).

TYPE	Breaking load	Glazed tiles			Unglazed tiles
		Abrasion resistance		Mohs hardness	Resistance to deep abrasion
		Visible change and stain esistance	Gloss loss at 600 rev.		
Type 1	> 450N				
Type 2	> 900N	≥ 600 rev.			< 2356mm ³
Type 3				Mín. 4	< 1419mm ³
Type 4		≥ 1500 rev.	< 15		< 649mm ³
Type 5		≥ 2100 rev.		< 393mm ³	
Type 6		≥ 6000 rev.		Mín. 6	< 175mm ³
Type 7	> 2000N				

Table 6. Mechanical requirements for each type of use. (Ceramic Tile Guide).

Type	Characteristic	Requirements
H	Hygienic	According to UNE-EN ISO 10545-13 Minimum: In low concentration Class LA – In high concentration Class HB (Unglazed tiles: contact time and classification according to glazed tile test).
E	Exterior	Frost resistance: water absorption below 3% and passes the test defined in UNE-EN ISO 10545-12.

Table 7. Additional characteristics of ceramic tiles. (Ceramic Tile Guide).

6.2. Stone.

To study the material itself, it is interesting to use the ASTM standards as a reference, since they establish limit values for the physical-mechanical characteristics, which allow the materials to be classified and characterised, as set out in the table 6.

Directive 89/106/CEE on the free trade of products is applicable to natural stone products, the following harmonised standards being applicable to these products:

Standard	Product
UNE-EN 1341:2003	Slabs of natural stone for external paving . Requirements and test methods.
UNE-EN 12057:2004(1)	Natural stone products. Modular tiles . Requirements.
UNE-EN 12058:2004(1)	Natural stone products. Slabs for floors and stairs . Requirements.

Furthermore, in the Valencia Region, there is a draft Natural Stone Guide, of voluntary application, but which it is hoped will become a document recognised by the Administration, in which the uses and specifications of stone products are typified.

The stone guide classifies natural stone products according to their use by means of the following three identifiers: mechanical characteristics, slip resistance, and additional characteristics.

Type	Use
PR	Cladding on facings.
P1	Internal flooring and areas for exclusively pedestrian use. (Class 1 according to standard UNE 1341).
P2	Pedestrian and cycling areas. Gardens and rows of balconies. (Class 2 according to standard UNE 1341).
P3	Occasional entryways for cars, light vehicles, and motorcycles. Garage entrances. (Class 3 according to standard UNE 1341).
P4	Pavements, commercial areas, with occasionally passing emergency or transport vehicles. (Class 4 according to standard UNE 1341).
P5	Pedestrian areas, frequently used by heavy vehicles. (Class 5 according to standard UNE 1341).
P6	Roads, streets, petrol stations. (Class 6 according to standard UNE 1341).

Table 8. Levels of mechanical characteristics. (Natural Stone Guide).

Type	Calculated load for tiles (kN) ⁽¹⁾	Impact resistance (J)	Resistance to wear by friction ⁽²⁾	Uniformity ⁽³⁾
PR	0,45	according to use	--	LOW
P1	0,75	>3	<24mm	
P2	3,5	>5	<22mm	
P3	6	>5	<22mm	
P4	9	>7	<20mm	
P5	14	>7	<20mm	HIGH
P6	25	>10	<18mm	

⁽¹⁾ **Minimum breaking load of the finished product** according to specifications UNE-EN 1341 and UNE-EN 1343. The **determination** is according to annex B of standard UNE EN 1341, applying a reduction factor of 1,6

⁽²⁾ **Resistance to wear by friction** according to UNE-EN 1341.
Estimated values obtained from materials in real applications.

⁽³⁾ **Uniformity:** attribute indicating the consistency of product strength independently of the direction in which the test piece is cut.

Table 9. Minimum physical-mechanical specifications for each level.

This Natural Stone Guide also includes a series of further product characteristics that entail compliance with additional specifications:

Identifier / Characteristics	
E0	Warm climate areas (A and B).
E1	Mild climate areas (C) without flux salts.
E2	Cold climate areas (D) without flux salts.
E3	Very cold climate areas (E) or subject to the action of flux salts.
H y L	hygienic conditions with special asepsis and cleanness.
M	additional mechanical requirements.

Table 10. Additional characteristics and requirements.

Climate areas defined by the Technical Building Code in the Document on Limitation of the energy demand TBC DB HE1.

6.3. Concrete tiles (terrazzo, paving slabs, and paving flags).

Concrete tiles are subject to the CE mark and are defined by the following harmonised standards:

Standard	Product
UNE-EN 13748-1	Terrazzo tiles for internal use.
UNE-EN 13748-2	Terrazzo tiles for external use.
UNE-EN 1339	Prefabricated concrete tiles , paving slabs and paving flags.

In these standards, classifications are established based on use, with the ensuing requirements:

USE	Description	Breaking load (kN) ⁽¹⁾		Resistance to abrasive wear ⁽²⁾
Normal	light pedestrian traffic.	≥ 2.5	≥ 3.0	< 25mm
Heavy	heavy pedestrian traffic, occasional lightweight vehicular traffic.	≥ 3.0	≥ 3.9	< 23mm
Industrial	occasional traffic of vehicles with a medium load.	≥ 3.6	≥ 4.7	< 21mm

⁽¹⁾ The two breaking load values indicated correspond respectively to tile surface areas smaller than 1100cm² and larger than this surface area.

⁽²⁾ Individual values of resistance to wear by friction.

Table 11. Classification of terrazzo tiles for internal use UNE-EN 13748-1.

In the case of terrazzo tiles for external use and cement tiles, use is not defined, but the classification is based on breaking load and wear resistance.

MARKING		Examples of application	Breaking load ⁽³⁾	
(1)	(2)		Characteristic value	Individual value
3T	3	Dwellings and private buildings; Public buildings and services.	≥ 3,0 kN	≥ 2.4 kN
4T	4		≥ 4.5 kN	≥ 3,6 kN
7T	7	Public thoroughfares; Industrial areas, Transport centres; Sports centres.	≥ 7.0 kN	≥ 5.6 kN
11T	11	Other uses subject to loads of 11 or 14 kN.	≥ 11,0 kN	≥ 8.8 kN
14T	14		≥ 14,0 kN	≥ 11.2 kN
25T	25	Other uses subject to loads of 25 or 30 kN.	≥ 25,0 kN	≥ 20,0 kN
30T	30		≥ 30,0 kN	≥ 24.0 kN

⁽¹⁾ Marking of terrazzo tiles for exteriors. ⁽²⁾ Marking of concrete tiles.

Table 12. Classification and mechanical requirements of terrazzo tiles for external use UNE-EN 13748-2 and concrete tiles UNE-EN 1339.

MARKING		Individual value (mm)
G	Low	≤ 26
H	High	≤ 23
I	Very high	≤ 23

Table 13. Classes of resistance to wear by friction in terrazzo tiles for external use UNE-EN 13748-2 and concrete tiles UNE-EN 1339.

6.4. Wood.

Wood floors are regulated by great number of UNE-EN standards, which establish general definitions as well as some product specifications.

Particularly to be noted is standard EN 1991-1-1 *Eurocode 1 Actions on structures*, which establishes the load categories applicable to wood floors.

Category	Description	
Category A: Areas of domestic and residential activities.		
Category B: Office areas.		
Category C: Meeting areas.		
	C1	Areas with tables.
	C2	Areas with fixed seats.
	C3	Areas without obstacles for moving people.
	C4	Areas with possible physical activities.
	C5	Areas liable to overloading.
Category D: Commercial areas.		
	D1	Retail commercial areas.
	D2	Large store areas.

Table 14. **Load categories** Standard EN 1991-1-1.

Standard UNE EN 13810-1:2003 **Wood-based panels: Floating floors** relates these categories to mechanical requirements in relation to uniformly distributed load, concentrated load, and live and alternate load, as defined in the following table:

Load category: EN 1991-1-1	A	B	C1 to C3 and C5	C4	D1	D2
Concentrated load: EN 1991-1-1 kN contact area of 50x50mm	2	2	4	7	4	7
Concentrated load kN contact area of 25mm	1.3	1.3	2.6	4.5	2.6	4.5
Deformation limit in mm for concentrated load. x ₁₋₄ below the device. x ₅₋₈ above the device. Δx _c difference (between the top and bottom of the device).				3.0	2.5	2.5

Table 15. Concentrated load. Load and deformation requirements.

In the case of **wood veneer floor coverings**, standard UNE-EN 14354 divides these into different classes, as a function of the specified requirements.

Class	21	22	23	31	32	33
Symbol						
Level of use	Domestic			Commercial		
	Moderate	General	High	Moderate	General	High
Resistance to piercing	≥ 10 N/mm ²	≥ 20 N/mm ²		≥ 30 N/mm ²	≥ 40 N/mm ²	

Table 16. Classification of wood veneer floors UNE EN 14354.

6.5. Synthetic materials.

Much of the synthetic flooring is regulated by European standards that lay down general definitions and some product specifications:

Standard	Product
UNE-EN 14041:2005:	Resilient, textile and laminate floor coverings. Essential requirements.
UNE-EN 548:2005:	Resilient floor coverings. Specification for plain and decorative linoleum.
UNE-EN 686:1997:	Resilient floor coverings. Specifications for plain and decorative linoleum on a foam backing.

- UNE-EN 687:1997: Resilient floor coverings.
Specifications for plain and decorative linoleum on a corkment backing.
- UNE-EN 688:1997: Resilient floor coverings.
Specifications for corklinoleum.

Standard UNE-EN 15468:2008 **Laminate floor coverings** divides these into the same classes as above, but with different requirements:

Class	21	22	23	31	32	33
Level of use	Domestic			Commercial		
	Moderate	General	High	Moderate	General	High

In other cases, it will be necessary to resort to the criteria for use established by manufacturers' associations or research institutes. Thus, selection criteria as a function of performance can be found, such as the following: technical floors, anti-static floors, wheelchair-proof floors, floors with chemical resistance, burn-resistant floors, floors that are electric conductors or provide impact sound insulation,... www.armstrong.es.

In the case of **carpeting**, one can resort to several classifications such as the ICCO or UPEC classifications, reaction to fire or treatments against dirt.

ICCO (International Carpet Classification Organization) uses the classification T followed by a letter or a figure.

Identifier	Description
TL	Artistic carpet and luxury decorative carpet.
TD	Decorative carpet
T2	For moderate use.
T3	For regular use (living room, bedroom).
T4	For heavy use (corridor)

Table 17. Identification of pile carpets according to the ICCO.

In criteria for use, as indicated in (www.textil.org) in relation to the UPEC classification, carpets can generally attain levels of use and piercing up to level 3; however, all carpets with a 100% synthetic composition are rated E1, and only the carpeting capable of withstanding stagnant water are included in the E2 rating.

With respect to their chemical resistance, all carpets are rated C0.

7. COMPARATIVE ANALYSIS

Given the disparity in the classifications of the studied materials, in order to be able to compare them, a partial analysis follows of their mechanical characteristics, resistance to slipperiness, and additional characteristics, which includes all the parameters considered in the different product classifications, as well as compliance with basic building construction requirements.

Basic requirements

Safety	Structural	Mechanical strength
	Fire	Reaction to fire
	Use	Slipperiness
Habitability	Health	Hygiene
Functionality	Durability	Wear resistance
	Use	Cleaning /maintenance

7.1. Mechanical characteristics.

Ceramics		Stone		Internal terrazzo		External terrazzo and concrete tiles		Wood: Floating floors		Synthetic materials				
Type	kN	Class	kN	Class	kN	Class		Class	kN	Class				
1	0.45	PR	0.45	Vertical claddings										
2	0.9	P1	0.75	Norm.	≥ 2.5			A, B	2 /1.3	21, 22				
3		P2	3.5			3T	3							
4				Heavy	≥ 3.0	4T	4	C1-C3, D1	4 /2.6	23, 31				
5		P3	6			7T	7	C5,	4 /2.6	32, 33				
6								C4, D2	7.1 /4.5					
7	2	P4	9	Indust.	≥ 3.6									
											P5	14	11T	11
											P6	25	14T	14
													25T	25
													30T	30

Table 18. Comparison of mechanical classes and bending load.

This table has been drawn up based on the recommendations for use of each type or class, seeking out their coinciding features.

Thus, it may be observed that the mechanical requirements do not coincide in all cases, because they are not always the most noteworthy service requirements of the material while, in addition, a different test method is used in each case.

Wear resistance cannot be compared, because the methods are quite different: in some cases mass loss is measured while, in others, wear resistance is assessed in terms of impaired appearance or surface damage.

7.2. Slip resistance.

With the wide variety of available materials and surface finishes, an approximate assessment can be made of the compliance with this requirement as regulated in the Technical Building Code TBC DB SU-1.

Class	Ceramics	Stone	Terrazzo	Wood	Synthetic materials
0	Polished Glossy Smooth non-profiled Smooth with a satin finish	Polished, lapped or waxed	Polished, lapped or waxed	Glossy wood Normal laminates	Smooth glossy
1	Smooth matt rough porcelain natural smooth profiled	Polished without waxing Pumiced	Polished without waxing	Wood without gloss Non-slip laminates	Smooth
2	Smooth matt very rough; smooth with non-slip application	Sawed Aged		Natural wood	Rubber and rough finishes
3	Non-slip profile	Grit-blast Sanded Flamed Dressed	Washed Bas-reliefs Textured Grit-blasted Composite		Carpets and ergonomic floorings

Table 19. Slipperiness class of the flooring materials.

As the table shows, practically all the materials can attain the different slipperiness resistance classes. However, for the artificial materials and especially ceramics, this is easier because this characteristic can be included in the manufacturing process without a subsequent texturising treatment as occurs with other natural materials.

7.3. Additional characteristics.

The additional characteristics that may be required of each flooring material, as well as the particular characteristic that distinguish it from its competitors, may also be compared.

Characteristic	Ceramics	Stone	Terrazzo	Wood	Synthetic materials
Hygienic cleanness	MA	MA, A	PA	PA	MA/NA
Suitable for exteriors	MA	MA, A	MA	A	A
Technical floors	MA	A	PA	MA	PA
Durability	MA	MA	MA	A	A
Reaction to fire	A1_{FL}	A1_{FL}	A1_{FL}	A2 _{FL} , B _{FL}	B _{FL} C _{FL}
Surface hardness	Very high	Very high	Very high	Low	Low
Brittleness	High	High	High	Low	Low
Maintenance	Zero	Low	Moderate	Moderate	Zero
Weight	Low	High	High	Very low	Very low
Price ⁽¹⁾	1	1.75-6.6	0.76-0.85	1.3-2.2	0.69-1.6

MA = Highly suitable, A = Suitable, PA = Not very suitable, NA = Quite unsuitable.

⁽¹⁾ Estimation of costs performed with values obtained of construction price bases for housing uses.

Table 20. Additional and particular characteristics of the studied flooring materials.

8. CONCLUSIONS

The analysis performed allows the following conclusions to be drawn in relation to ceramic materials:

- Ceramic materials **have sufficient mechanical capability** to cover a broad range of service situations, only being surpassed by natural stone and concrete tiles in which greater thickness does not lead to a significant increase in production cost.
- Ceramic materials **perform well in use** (in relation to wear) compared with their competitors, the only constraint being that in certain cases the loss of appearance is noticeable in early stages of damage.
- Ceramic materials can achieve the different levels of slip resistance more easily than their competitors, because the necessary profiles or materials can be included in the ceramics manufacturing process itself.
- Ceramic materials generally display good **hygienic qualities** (chemical and stain resistance) and cleanability, which provide ceramics with high durability while they require hardly any maintenance.
- Ceramic materials, together with stone and concrete tiles, display good **reaction to fire** and high surface hardness.

- The **low weight** in relation to other materials makes it easier to export ceramics.
- The **cost** of terrazzo, concrete tiles, and some synthetic materials is lower. However, the mechanical performance and durability of those materials are far inferior.

As new horizons for ceramics in floorings, we propose the following:

- For **floorings with few requirements** the use of laminates with a ceramic finish would entail a reduction in cost and weight.
- For **the most demanding floorings**, increased thickness with a reduction in size would allow the loading capability to be enhanced. In addition, the combination of materials using prefabricated systems could entail a reduction in costs.

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