PART 2

WHICH

CERAMIC TILES

Introduction

In Part 1, we traced the reflections that led the Homeowner and the Specifier to focus their attention on ceramic tile as a material for floor and wall covering.

In Part 2, we will follow the Homeowner and the Specifier in their explorations aimed at identifying, among all ceramic tiles available on the market, those best suited to their respective aesthetic and technical needs. As the diagram on page 81 indicates, this goal can only be achieved with an adequate knowledge of ceramic tiles,

which qualifies the buyer to evaluate the tiles being considered for acquisition.

We begin with a complete and thorough overview of the products from which a selection may be made, classifying and describing, also in terms of aesthetic alternatives, the various types of ceramic tiles (§ 2.1). We will suggest the variety of aesthetic solutions possible…specify the regulations (the norms) according to which the producer, the vendor and the user of ceramic tiles may communicate and agree upon product quality and performance (§ 2.2)…and analyze the various technical properties (§ 2.3) which different types of tiles may possess to various degrees. Subsequently we will introduce the technical specifications of tiles (§ 2.4) as an indispensable instrument with which to assess a tile's quality, evaluate its performance level, and generally pass judgment on every product that is a candidate for pre-selection.

The results will confirm and document what we have found to be a signal strength of ceramic tiles compared to competing materials: the almost limitless range of products, both aesthetically and in terms of technical properties and performance level.

The overview presented suggests two important conclusions:

1. The range of products is so vast as to guarantee there will be tiles for all tastes, all needs and all environments. The Homeowner and the Specifier can

rest assured that their search (as to which tile to select) will end in success.

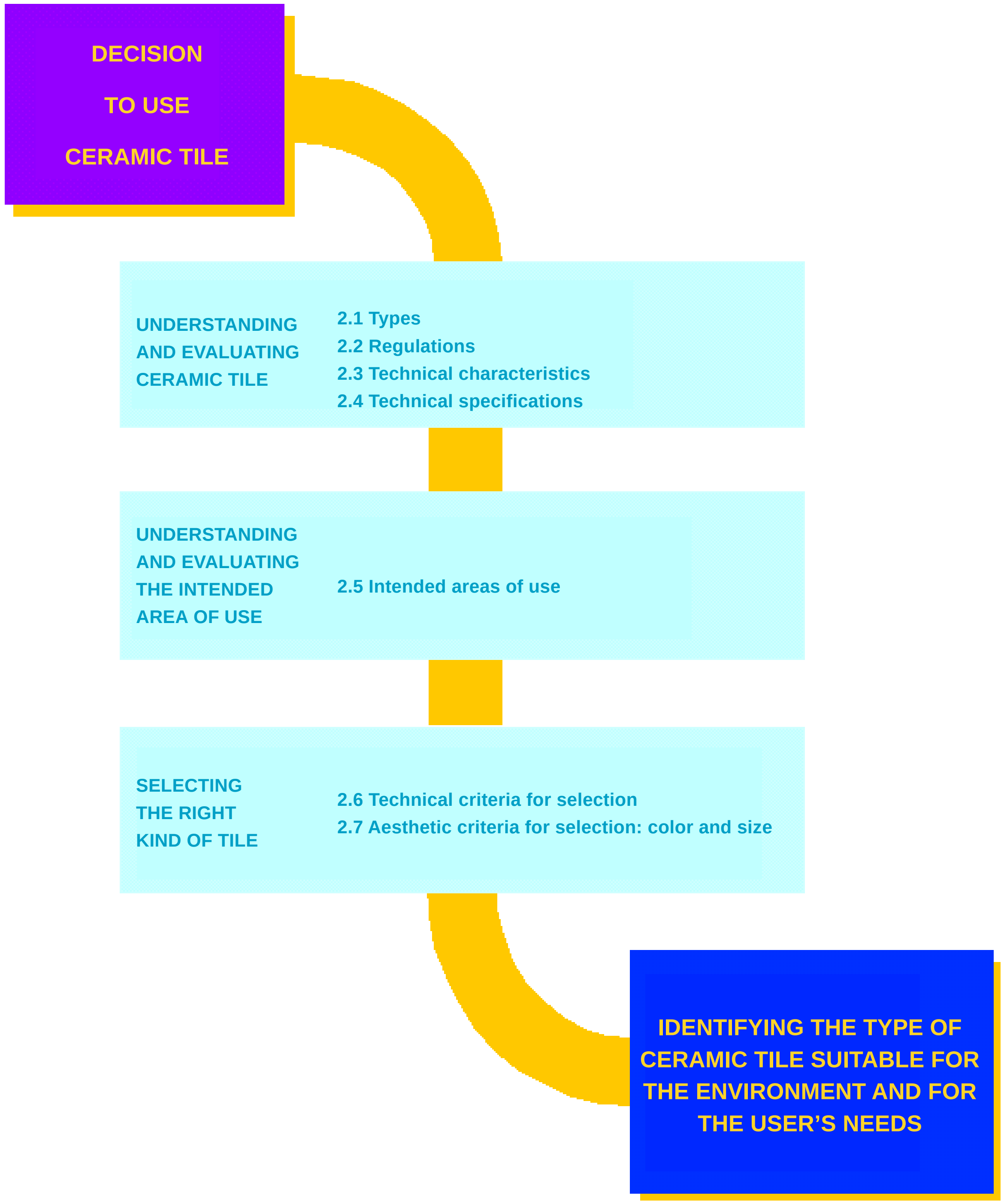
2. In general, no single type of tile or single product can be considered suitable for all uses and environments. Therefore the choice cannot be random, but must be made consciously and responsibly. The Homeowner and the Specifier are thus advised that their selection will be satisfactory only if conducted with the proper care.

A proper selection must begin with an understanding and assessment of the intended area of use, and of the conditions to which the tiles — or more precisely, the tiled surface — are likely to be exposed. In section § 2.5, the Homeowner and the Specifier are guided through a simple but careful analysis of the area of intended use, in order to predict, identify and evaluate (at least qualitatively) the major kinds of stress to which the tiled surface will be exposed based on the activities conducted there, or the prevailing conditions.

The two final sections will employ a range of examples to analyze the proper criteria for identifying and selecting the type of ceramic tile most suitable for various environments and user needs.

Section § 2.6 presents the criteria to be adopted in the selection of tiles that will be technically satisfactory, specifically in terms of the durability of a tiled surface. Remember that durability was established in Part 1 as one of the principal strengths of ceramic tiles compared to competing materials for floor and wall covering.

Finally, section § 2.7 offers some suggestions on how to select tiles to suit aesthetic and decorating needs. Some basic guidelines will be presented, especially as regards the effective use of color and size.


DECISION
TO USE
CERAMIC TILE
UNDERSTANDING AND EVALUATING CERAMIC TILE
2.1 Types
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UNDERSTANDING AND EVALUATING THE INTENDED AREA OF USE
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SELECTING THE RIGHT KIND OF TILE
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IDENTIFYING THE TYPE OF CERAMIC TILE SUITABLE FOR THE ENVIRONMENT AND FOR THE USER'S NEEDS

2.1 - Types

In Part 1 we compared ceramic tiles to other floor and wall covering materials, and in so doing may have seemed to suggest that the class of ceramic tiles was relatively homogeneous: that is, that all ceramic tiles on the market are if not identical (since they come in different colors and sizes) at least interchangeable.

The truth instead is that there are different types of ceramic tile, differing substantially from each other both aesthetically and technically. Furthermore, each type includes a range of products that is virtually limitless, again in both aesthetic and technical terms. In brief, the range of ceramic tiles is extremely broad, at least as broad as the range of fabrics for apparel.

In this section we will explore the various types of tiles in order to identify and recognize them. We begin by listing and briefly commenting on the distinctive aspects of ceramic tiles, and will then proceed to detail the types of tiles, identified according to the technical-commercial terminology now in use.

Tiles may be:

❑ glazed or unglazed

Glazed tiles have a surface that is covered with a layer of colored glass, giving it characteristics that are unique both aesthetically (color, brightness, decor, nuance, etc.) and technically (hardness, impermeability, etc.). All these characteristics depend on the

Technical-commercial classification of ceramic tiles

Technical-commercial Classification	Surface		Body Structure			Shaping Method	
	Glazed	Unglazed	Porous	Vitrified	W.A. %	Press.	Extrus.
Majolica tiles	●		●		15÷25	●	
Cottoforte tiles	●		●		7÷15	●	
Earthenware - white body tiles	●		●		10÷20	●	
Red single-fired tiles	●			●	2÷10	●	
Whitish single-fired tiles	●			●	2÷7	●	
Porous single-fired tiles (monoporosa, red and whitish)	●		●		> 10	●	
Pressosmaltatura	●			●	< 3	●	
Clinker tiles	●	●		●	2÷6	(1)	●
Terracotta tiles	●	●	●		3÷15		●
Red stoneware tiles		●		●	1÷4	●	
Porcelain stoneware tiles	●	●		●	0÷0.5	●	

(1) Although there are products called “pressed clinker” tiles on the market, clinker tile is principally an extruded product.

Technical-commercial Classification	Body Color[2]		Main sizes (cm x cm)	Main Intended Use				EN ISO Group [3]
	White	Other		Flr.	Wall	Int.	Ext.	
Majolica tiles		●	15x15 15x20 20x20		●	●		BIII
Cottoforte tiles		●	15x25 20x20 20x30	●	●	●		BIIb-BIII
Earthenware - white body tiles	●		15x15		●	●		BIII
Red single-fired tiles		●	10x20 20x20 30x30 40x40	●		●	●	BI-BII
Whitish single-fired tiles	●		30x30 40x40	●		●	●	BI-BII
Porous single-fired tiles (monoporosa, red and whitish)	●	●	20x20		●	●		BIII
Pressosmaltatura	●	●		●		●	●	BI
Clinker tiles	●	●	12x24 20x20 30x30	●	●	●	●	AI-AIIa
Terracotta tiles		●	25x25 20x40 30x30 40x60	●		●	●	AII-AIII
Red stoneware tiles		●	7.5 x15	●		●	●	BI-BIIa
Porcelain stoneware tiles	●		20x20 30x30 40x40	●	●	●	●	BIa

(2) The color of the body depends on the properties of the raw materials, and on their quality requirements with regard to color. The types of product classified as “white” are those for which the color of the support (even when not exactly white) is a basic specification of the product itself. Such products are generally obtained from specially selected raw materials, often of foreign origin.
(3) EN ISO Group: see Sec. 2.2

type of glaze and can vary broadly. The range of colors and decors, in particular, is almost limitless. Unglazed tiles are uniform throughout, with no difference between surface and body, and normally have no decor or design (although some unglazed porcelain products, to be discussed later, are decorated).

Technical-commercial classification of ceramic tiles

The table on the preceding pages (p. 84-85) presents an overview of the various types of tiles. Besides summarizing and quantifying the aspects discussed in Section 2.1, the table highlights some important factors to be considered when selecting tiles suitable for specific needs.

1. Certain types of tiles are clearly distinguishable and relatively homogeneous products, while others feature a range of products that is highly diversified, especially in technical terms. An example of the "homogeneous" and clearly distinguishable type of tile is majolica tile: all majolica tiles are glazed with a porous and colored body, obtained through pressing, mainly used for interior walls and included in Group BIII of the EN ISO classification. An example of a heterogeneous type of tile is single-fired (monocottura).

2. The main areas of intended use for some types of products, such as single-fired tiles, include both floors and walls, interior and exterior. It should be clarified that this does not imply that any tile – for example, any single-fired tile — is equally applicable to all of these areas. It means only that some single-fired tiles are suitable for exterior areas, and others are suitable only for interiors. Suitability depends on the technical properties of each single product (as will be discussed in sections 2.3 and 2.4).

3. A tile type with a given technical-commercial denomination may include tiles belonging to various EN ISO classifications. As documented in Section 2.2 and in Appendix 2, every group has distinct technical specifications, as detailed in the specific norms for that product. This observation is related to the observation in point #2 above. Example: red single-fired tiles.Tiles of group BI, BIIa and BIIb may belong to this type.

4. A single EN ISO group may include tiles of various types according to the technical-commercial classification. For example, both majolica (double-fired) tiles and monoporosa tiles are included in Group BIII according to EN ISO classifications.

5. In general, tiles intended only and specifically for wall covering (especially for interior walls) can be distinguished from those for floor covering – or for both floors *and* walls – by their lesser thickness. Tiles under 7 mm thick are suitable only for wall coverings. Tiles for floors in general are thicker (single-fired tiles for floors, for example, are typically 8-10 mm thick). Using wall tiles (with less thickness) to cover floors carries a substantial risk of breakage and is thus discouraged. To understand why, see the addendum on mechanical properties (Section 2.3).

❑ with porous or compact body

The tile body may be compact (or to use a term of the ceramic trade, vitrified) – almost like glass, and containing pores that are interconnected in various ways. This aspect of the support can only be "seen" with a powerful microscope, but the measurement of this porosity is what determines the amount of water absorbed under various conditions: it is in fact the way that water absorption is measured. The greater the water absorption, clearly, the greater the porosity of the support.

❑ pressed or extruded

Pressing and extrusion are two shaping techniques that can be used in ceramic tiles. Pressed tiles are obtained by compacting and shaping a powder-based mix in a high-pressure press. Extruded tiles start with raw materials in the form of a paste, which is then pushed through a special orifice to give it shape.

❑ with red or white / whitish body

Depending on the raw materials used, the body of the tiles may be colored (from yellow to dark red, with a range of intermediate shades) or whitish (sometimes white).

The color of the body in glazed products is of little relevance.

In some unglazed products, colorations are obtained through the addition of coloring pigments.

❑ of various shapes and sizes, that is, of various "formats"

The most common shapes are the square

and the rectangle, but there are others of various complexity (such as the hexagon, provencal, etc.). Sizes range from the "mosaic" tile to slabs measuring 60 cm or more. Thickness varies from a few millimeters to more than 2-2.5 cm.

❑ for floor or wall covering, for indoors and / or outdoors

Another distinctive aspect is a tile's "destination" : tiles for floor or wall covering, for indoor or outdoor environments. Destination is an important consideration, which we will take up in section 2.8. Suffice it for now to say that some tiles may be considered to have a principal destination (such as indoor floors, or indoor walls).

Ceramic tiles are classified into various types, with specific technical-commercial denominations. The types are distinguished from each other partly according to the aspects listed above, and partly according to production techniques.

The principal denominations used in Italy are as follows:

❑ *majolica, earthenware*: double-fired glazed tiles (a technique that features two separate firings, the first for the support and the second for the glaze), with a porous and colored body, pressed.

❑ *terraglia-white body*: double-fired glazed tiles, with a porous white body, pressed.

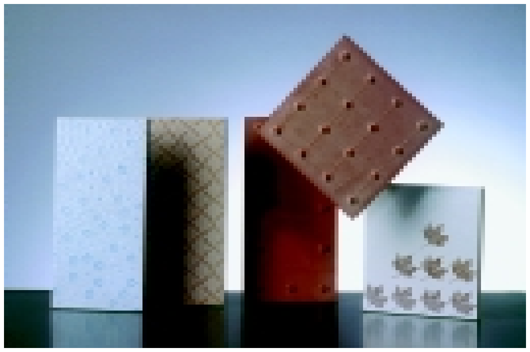
❑ *single-fired tiles*: pressed tiles, glazed in a single firing cycle (a technique that involves a single simultaneous firing of glaze and body), with a body that is colored (red single firing) or whitish, used mainly as floor covering. The term “monocottura” – in Italian – is often used.

❑ *porous single-fired tiles (monoporosa)*: pressed, glazed single-fired tiles, with a body

Brief description of the principal types of ceramic tiles

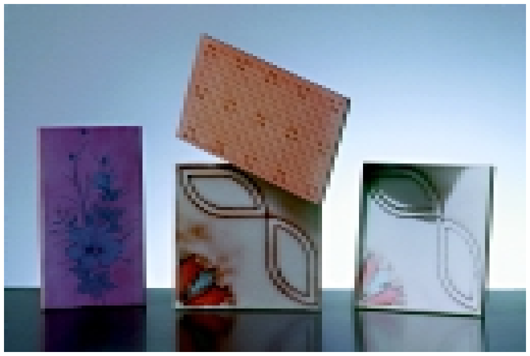
MAJOLICA TILES

This typically Italian tile can also be found in other countries with the suitable raw materials: it contains quarry clay containing not only clay-like and sandy powders but also substantial amounts of carbonates and ferrous oxides. Majolica tiles are always glazed with a non-transparent glaze, covering the rosy color of the body (“bisque”). The typical use of this product is for interior wall coverings, and the most common sizes are 15x15cm, 15x20cm and 20x20cm. Its physical properties are a good level of mechanical resistance despite its high porosity (water absorption can range from 15 to 25%) and an excellent resistance to glaze crazing. The production cycle includes double firing, either of the traditional sort or (more recently) in rapid-firing kilns, bringing the term “rapid double-firing” into common use; the development of this new technology contributed to the revival of majolica tile, which had somewhat declined in the 1980s following the increased popularity of single-fired (or more precisely, monoporosa) tiles.



COTTOFORTE TILES

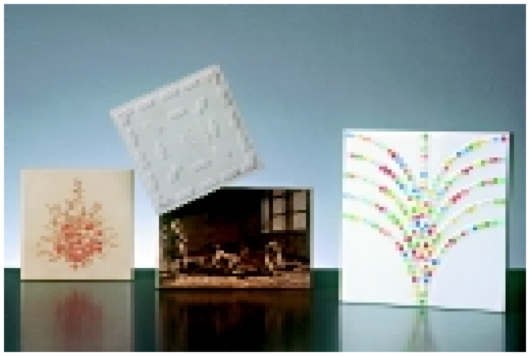
This product is typically Italian from the Emilia-Romagna region (where, originally, it was produced almost exclusively). The tiles are always glazed with a non-transparent glaze and are used mainly for interior floors, though wall-covering products of this type exist as well. This product enjoyed its greatest popularity in the 1960s-70s thanks to the great variety and improvement in the types of decors, and to perfected production techniques. Typical sizes are 15x25cm, 20x20cm and 20x30cm. Properties include adequate to good mechanical resistance, and easy application of glazes and decors. Given both the raw materials and physical properties of the support, this type of tile falls between majolica tiles and vitreous red-body tiles. Cottoforte tile is



that is colored or whitish, used mainly as wall covering.

❑ *pressosmaltatura*: pressed tiles, glazed in single firing, in which the glaze is applied in powder form during pressing.

❑ *clinker*: unglazed or single-fired glazed tile with a variously colored body, generally compact, extruded.



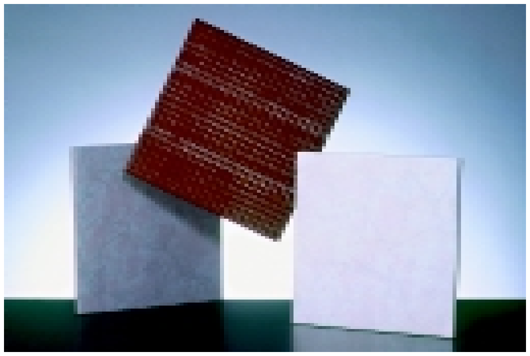
double-fired. Because of the high energy costs of this technique, cottoforte has largely been replaced by red single-fired tile. Thanks to the use of specially formulated bodies and to recent advances in glazing and silk-screening decor techniques, single-fired products now offer the same technical properties and aesthetic appeal as cottoforte tiles, for lower production costs.

EARTHENWARE - WHITE BODY TILES

This type of tile now makes up only a modest percentage of Italian production, due to the high costs of the double-firing technique, and of the precious raw materials (white firing clays, sands and fluxes). The distinction between “soft earthernware” and “hard earthenware” refers to the type of fluxes used: in the former case, calcium and magnesium carbonates, and in the latter, feldspar. The tiles obtained are white, which allows for direct decoration on the bisque surface and a single transparent glaze. The classic size is 15x15cm, and the main use is for interior wall coverings. As noted, this material is in declining use in Italy, due to the competition from monoporosa tiles.

RED SINGLE-FIRED AND MONOPOROSA TILE

This denomination indicates a production technique with the simultaneous firing of body and glaze. It covers a broad range of glazed materials with a great variety of physical properties, due to the high variability of the body’s water absorption (ranging from slightly above zero to about 15%). Common to all tiles of this sort is the use of clays containing iron oxides in the preparation of the body mix. Feldspar-based fluxes are generally used to obtain vitrified materials, while clays containing carbonates (similar to majolica clays) are used for porous materials. The appropriate proportions of the various components will yield either vitrified materials with low water absorption (thus suitable for exterior floors), or more porous materials for interior floors (increasingly as a substitute for cottoforte tiles) or interior wall covering.



❑ *terracotta*: unglazed tiles with a red and porous body, extruded.

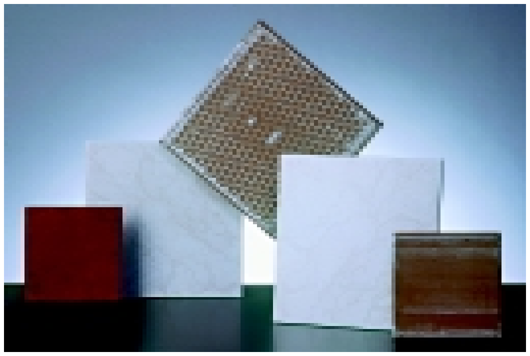
❑ *red stoneware*: unglazed tiles, with a red compact body, pressed.

❑ *porcelain stoneware*: generally unglazed tiles (though there are some glazed porcelains on the market), with a white or colored support obtained with special pigments, in so-

Available sizes range from the classic 10x20 cm and 20x20 cm to as large as 40x40 cm.

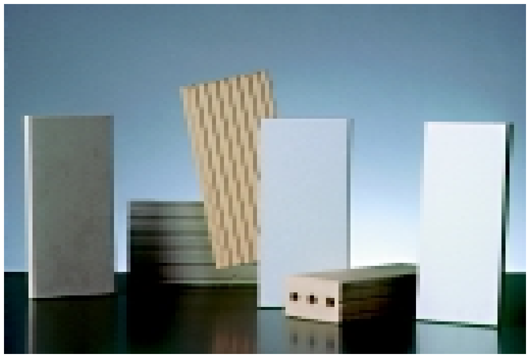
WHITISH SINGLE-FIRED AND MONOPOROSA TILE

This type of product is distinguished from red single-fired tile by the color of the body: the use of clay without iron (usually clay imported from Germany and France) yields a ceramic body of a color that ranges from light gray to beige. Other constituents of the mix include siliceous sands of considerable purity and feldspars. Most products of this type are floor tiles, used for both exterior and interiors; the larger sizes (30x30 cm, 40x40 cm) are more common than the traditional 20x20 cm. There is also a growing production of porous tiles (monoporosa, with water absorption of above 10%) used for interior wall covering.



CLINKER TILES

This denomination, not easily definable given the variety of types it includes, generally indicates a relatively compact structure with notable resistance to mechanical and thermo-hygrometric stress. Raw materials for clinker tile often contain coloring oxides, strong fluxes and coarse fired clay (chamotte). Clinker tile is generally produced by extrusion, but the commercial denomination also covers other types of pressed tiles. The product may be unglazed, glazed or



covered with a thin layer of transparent glass. Its uses are quite varied: interior and exterior floors, exterior wall covering, etc.

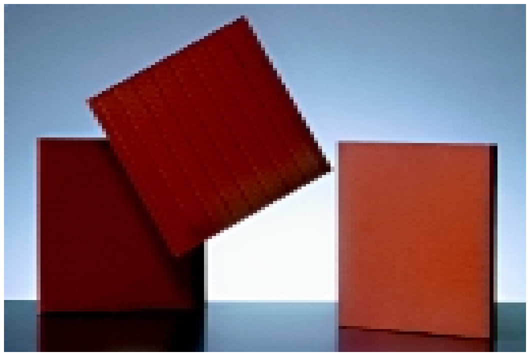
Clinker tile comes in various sizes, the most popular being 12x24 cm, 20x20 cm and 30x30 cm.

The use of the extrusion method allows for the production of pieces that are geometrically complex, like those used for the edges of pools.

TERRACOTTA TILES (in Italian, "Cotto")

This tile is also known as "rustic terracotta", "Tuscan terracotta" or "Florentine terracotta". It usually comes in larger sizes – 25x25 cm, 30x30 cm, 20x40 cm and 40x60 cm. Unlike cottoforte or red single-fired tile, terracotta tiles are not glazed (although lid colors or granular textures (like granite), extremely compact, pressed. Various products (unglazed) are also available with a polished surface.

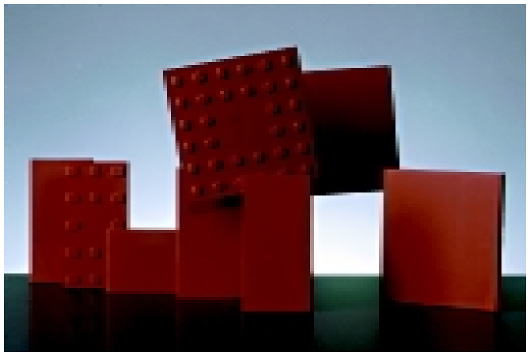
Type descriptions are for the majority of products available on the market. We note however the existence of other products, such as glazed terracotta, or pressed clinker tile.



recently some partially or totally glazed terracotta tiles have been introduced). They are used mostly for interior floors. Unglazed terracotta floors are generally treated with special substances to enhance their color and cleanability. Exterior terracotta floors, on the contrary, are not treated, since the treatment could increase the risk of frost damages.
The use of this type of product is traceable to ancient times and has been updated for modern use thanks to its popularity among architects and designers for its warm and characteristic red color.
Technically speaking, terracotta is halfway between brick, which in the past was the most common flooring for non-luxury type housing, and the modern cottoforte and red single-fired tiles. There are distinguished examples of its use for floors in churches, museums, piazzas and exteriors.

RED STONEWARE TILES

This product is also typically Italian. It is an unglazed vitrified product. The most common size is 7.5x15 cm, while the 10x20cm size is also fairly popular.
Red stoneware tile is suitable for interior and exterior residential floors, industrial environments, areas of heavy traffic, etc. It also includes tiles with reliefs on the surface, used in areas where special non-slip properties are required. Its ample range of uses is made possible by the product's unique physical properties: good frost resistance, and excellent resistance to both breakage and abrasion. Like all products that are either partially or totally vitrified during firing, red stoneware tile is quite sensitive to the variations of temperature in industrial ovens; for this reason, vitrified products are usually sold in so-called "work sizes", that is, in select and verified sizes that must not be combined with each other when used. It must be noted that the term "stoneware" or "red stoneware" are sometimes used for types of tiles that are not vitrified and therefore do not have the properties detailed

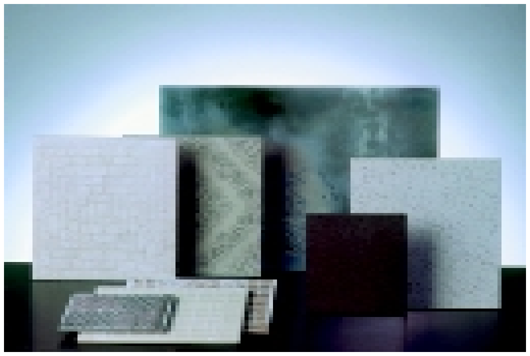


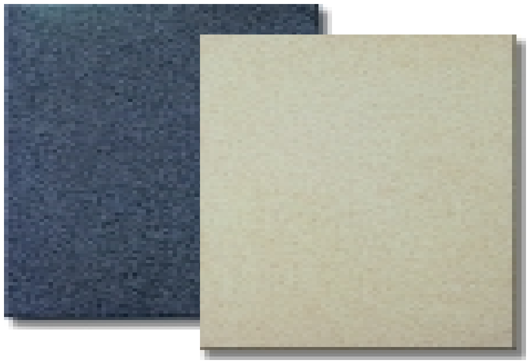
Porcelain tile is the product that, in recent years, has recorded the most consistent increases in production and employment, and extraordinary progress in technical solutions and esthetics. This has made necessary a redefinition of the product aimed at making its identification simpler for the user. The new definition has thus been developed by CERLabs (the worldwide network of national ceramics laboratories of

above. Red stoneware tile can be distinguished by its water absorption level, which must be below 3 or 4%.

PORCELAIN STONEWARE TILE

Porcelain stoneware is obtained from a mix of raw materials whose composition does not substantially differ from that of vitreous china (used in making sanitary ware and dinner ware).
The product is almost completely vitrified, and hence completely impervious and with excellent mechanical properties. Traditional 5x10 cm and 10x10 cm sizes have been disappearing, and larger sizes (20x20 cm, 30x30 cm and 40x40 cm) have grown increasingly popular. Usually unglazed, porcelain stoneware is used for floors of all kinds; recently, large slabs (100x60 cm) have been introduced to be used for exterior wall covering.
Porcelain stoneware originated as a product for technical use, such as for floors in heavily trafficked public and industrial areas. Research and development effort have gradually produced new products that combine porcelain's unique technical strengths with ever greater aesthetic properties, for areas that have design requirements as well (like malls, offices, hotels, restaurants, etc.). The body is often colored by introducing coloring oxides into the mix which blend extremely well, with the matrix during firing. This type of tile, obtained by mixing raw materials of various coloration to obtain a surface and support with a granular look, is sold under various denominations (such as "ceramic granite" or "ceramic porphyry").
Porcelain stoneware tiles, also available with a polished, glossy surface, are used for interior and exterior wall covering.
Besides the unglazed products described above, other variations have also been emerging that feature various types of surface treatments: for example, applications of penetrating salts, or glazes, which create a sophisticated look that is in increasing demand. Porcelain stoneware with surface decors is also growing in popularity.





which the Centro Ceramico Bologna is the leader):

Porcelain tile: Ceramic tiles formed under pressure and having a water absorption less than 0.5% (measured according to ISO 10545.3). In accordance with related classifications, it belongs to group BIa (ISO 13006). Its typical characteristics are higher mechanical resistance and excellent resistance to frost. Porcelain tile can be glazed or non glazed; by glaze we mean an impermeable vitreous coating (ISO 13006).

The addendum “Technical-commercial classification of ceramic tiles” (pages 84-85) presents a chart of the types listed above, with distinguishing characteristics.

The addendum “Types of ceramic tiles” (pages 89 on) presents more complete and detailed information on each type of tile.

2.2 - Regulations

In the preceding chapter's identification and description of the different types of tiles, we often referred to the technical and aesthetic properties possessed by the various types of tiles. These properties will constitute the subject of the following chapters; their description will complete the understanding of ceramic tiles which the Homeowner and the Specifier must possess in order to make an informed and appropriate selection of one type of ceramic tile among all the products available on the market.

The standards are an essential tool for understanding and evaluation of the properties of tiles.

In this chapter we will explain what these standards are, who creates them, what they cover and how they are used. We will then use these standards as a guide to deepen our understanding of the technical properties of tiles.

2.2.1 - Standards

As is the case for most materials, standards exist for ceramic tiles that are not regulatory but that serve as an official, authoritative reference and benchmark for the quality and properties of the various types of tiles. These standards are technical guidelines that allow manufacturers and vendors of ceramic tiles, as well as buyers and users, to ascertain – and prove – if a given product is of good quality.

It should be emphasized that the use of the norm (or standard) is voluntary: the ceramic tile producer is not obligated to produce tiles that conform to the norm. It is also nevertheless clear that if a producer was to decide, voluntarily, to observe the norms, and makes this pledge to the user-purchaser, conformity to the norms will become an obligation for him.

2.2.2 - Who creates the standards

The standards are defined and published by national standardization bodies in each country, instituted for this purpose and composed of groups and individuals

Table1 - European Standardization Bodies.

Country	National Standardization Body
Austria	ON
Belgium	IBN
Denmark	DS
Finland	SFS
France	AFNOR
Germany	DIN
Great Britain	BSI
Greece	ELOT
Iceland	STRI
Ireland	NSAI
Italy	UNI
Luxembourg	ITM
Norway	NSF
Netherlands	NNI
Portugal	IPQ
Spain	AENOR
Sweden	SIS
Switzerland	SNV

Reference Guide to EN ISO Standards for Ceramic Tiles

There are two EN ISO standards for ceramic tiles for floor and wall covering:

EN ISO 13006 Ceramic tiles – definitions, classification, characteristics and marking

EN ISO 10545 Ceramic tiles – test methods

As specified below, each of these standards is divided into several parts, and contains numerous annexes.

We have seen that the ***essential contents*** of the tile standards are as follows:

1. **Classification** of ceramic tiles;
2. List of **characteristics** that ceramic tiles must possess, in relation to their intended use;
3. **Test methods** for the various properties;
4. **Acceptability requirements** that tiles in each of the various groups must meet for each property.

We here consider, point by point, the distinctions contained within the two cited standards.

1. Classification of ceramic tiles

The classification of ceramic tiles is contained in the active in the production, research, characterization and use of the various materials. The Italian Standardization Body is UNI (Ente Nazionale Italiano di Unificazione); the Italian standards are known as the UNI standards.

In Table 1 the acronyms of the national standardization bodies of the European countries are listed.

In order to promote the international

Table 2 - Technical classification of ceramic tiles according to EN ISO 13006

Shaping method	Water Absorption, WA (in %)				
	WA ≤ 3%		3 < WA ≤ 6%	6 < WA ≤ 10%	WA > 10%
A Extrusion	AI		AIIa(1)	AIIb(1)	AIII
B Dry pressing	BIa WA ≤ 0.5%	BIb 0.5 < WA ≤ 3%	BIIa	BIIb	BIII

(1) Groups AIIa and AIIb are divided into two parts (Part 1 and Part 2) that are characterized, as shown in Appendix 2 by different requirements for the various technical properties (for example, mechanical properties). The requirements to be met for the tiles classified as Part 1 are stricter than those for tiles classified as Part 2. With reference to the technical-commercial classification system described in Chapter 2.1, it can be noted that in general, given equal levels of water absorption, **clinker** tile is classified as **Part 1**, while **terracotta** tile is classified as **Part 2.**

standard **EN ISO 13006, par. 4.**
Ceramic tiles are classified into nine groups, according to shaping method (A – Extrusion; B – Dry pressing) and percentage of water absorption, as shown in Table 2.

2. List of characteristics
The characteristics that ceramic tiles must possess, for different uses, are listed in Table 3, contained in the standard **EN ISO 13006, par. 5**.

3. Test methods
The methods for measuring the above-listed properties are contained in the standard **EN ISO 10545.**
This standard is divided into 17 parts (from EN ISO 10545-1 to EN ISO 10545-17). The standard **EN ISO 10545-1** establishes the rules and procedures that must be followed in the sampling and control of a tile lot. For example, it establishes the number of sample tiles that must be taken for each test to be performed, and defines the standards for acceptance and rejection.
Each of the other 16 parts corresponds to a test method, according to Table 4.
Each of the test methods is described in detail in the corresponding standard, according to the following general outline:

1. Scope and application
Specifies the objectives of the test, and which tiles it covers (for example, all tiles, or only glazed tiles, etc.).

2. Principle of the method
Indicates physical principle on which the method is based (for example, the

Table 3 – The characteristics of ceramic tiles

Characteristics for different applications		Floor Int.	Floor Ext.	Wall Int.	Wall Ext.
Dimensions and surface quality	Dimensions and appearance	●	●	●	●
Physical properties	Water absorption Porosity Apparent density	●	●	●	●
	Modulus of rupture (flexural) Breaking strength (flexural)	●	●	●	●
	Resistance to abrasion (unglazed tiles)	●	●		
	Resistance to abrasion (glazed tiles)	●	●		
	Slip resistance (friction coefficient)	●	●		
	Crazing resistance, glazed tiles	●	●	●	●
	Frost resistance		●		●
	Thermal shock resistance	●	●	●	●
	Thermal expansion	●	●	●	●
	Moisture expansion	●	●	●	●
	Small color differences	●	●	●	●
	Impact resistance	●	●		
Chemical properties	Chemical resistance	●	●	●	●
	Stain resistance	●	●	●	●
	Lead and cadmium release (glazed tiles)	●		●	

measurement of resistance to deep abrasion of unglazed tiles is based on a measurement of the length of the groove produced by a rotating disk in contact with the surface, with abrasive material interposed.

3. Equipment and materials
Specifies the required

equipment (such as the principal components, class of precision, calibration method, etc.) and the materials to be used for the test (for example, for the test for chemical resistance, the nature of the reagents, their composition, etc.).

4. Test pieces
Indicates the number and size of the test pieces on which the test must be performed (for example, 10 whole tiles, or samples of 50x50 mm obtained by cutting the tiles), and specifies the way in which the test pieces themselves must be prepared and controlled (for example, the surface of the test pieces must be cleaned with solvent; test pieces with defective surfaces must be excluded from the test).

5. Procedure
Describes in detail the testing procedures, execution methods, environmental conditions that must be maintained during the test, time of execution, etc.

6. Expression of results
Specifies the type of final result which the test must yield (for example, for the measurement of warpage, the result is the departure of the fourth corner of the tile from the plane in which the other three corners lie) and the way and units in which the result must be expressed (for example, the above-defined warpage must be expressed as a % of the tile diagonal).

7. Test report
Specifies all data and information that must be included in the test report.

4. Acceptability Requirements

These requirements are the limit values of the various properties that must be respected in order for the tested tiles to be deemed of good quality.

Table 4 – Characteristics and test methods in EN ISO Norms.

Characteristic	Test method EN ISO Standard
Dimensions and surface quality	10545.2
Water absorption Porosity Apparent density	10545.3
Modulus of rupture (flexural) Breaking strength (flexural)	10545.4
Impact resistance	10545.5
Resistance to abrasion (unglazed tiles)	10545.6
Resistance to abrasion (glazed tiles)	10545.7
Thermal expansion	10545.8
Thermal shock resistance	10545.9
Moisture expansion	10545.10
Crazing resistance (glazed tiles)	10545.11
Frost resistance	10545.12
Chemical resistance	10545.13
Lead and cadmium release (glazed tiles)	10545.14
Stain resistance	10545.15
Small color differences	10545.16
Slip resistance (friction coefficient)	10545.17

The requirements are specific, and generally different, for each of the nine classification groups according to the standards (see Table 2). Hence for each of the nine groups, there exists a specific group or list of requirements.

market, and hence the circulation of products in a variety of markets, the need for international standards common to different nations has been revisited in recent decades. For the purpose of equalizing standards in different countries, international institutes of standardization have been established, which incorporate the national standards agencies of the individual countries.

Tables 5 and 6

The normative Appendix	reports the list of requisites specified for the Group
A	AI
B	AIIa - Part 1
C	AIIa - Part 2
D	AIIb - Part 1
E	AIIb - Part 2
F	AIII

The normative Appendix	reports the list of requisites specified for the Group
G	BIa
H	BIb
J	BIIa
K	BIIb
L	BIII

Table 7

Matter	Reference in Standard
Marking on packaging **Tile specifications** Required or recommended information to be included on packaging; information required to identify the product	**EN ISO 13006** **(sec. 8; all the above-listed normative appendices)**
Order Aspects that must be specified and agreed upon at the time an order is placed	**EN ISO 13006** **(sec. 9; all the above-listed normative appendices)**

All nine lists of requirements, one per group, are included in the EN ISO 13006 standard as “Normative Appendices” (see Tables 5 and 6).

5. Other information

The strandards in question also provide specific prescriptions or recommendations on the matters listed in Table 7:

As discussed in Appendix 2 some properties have no fixed acceptability requirement; that is, no exact reference that allows for the determination as to whether a tile is or is not of good quality. For these properties, a “performance” classification is suggested, as reference, to determine if the tile manifests high or low performance values in terms of the property in question. “Low performance” tiles are still considered of “good quality”, and thus acceptable. Obviously the user must be informed of

There are two international standards institutes:

❑ CEN – International Committee for Standardization, which includes the standards organizations of the European countries; it publishes the EN Standards;

❑ ISO – International Organization for Standardization, which includes all the

this matter, so as to consider it in his decision. An example of a property of this sort – that is, one with no acceptability requirement – is the abrasion resistance of glazed tiles.
The EN ISO 13006 standard sec. 9 establishes that such properties must be considered and agreed upon at the time an order is placed.

Example of use of EN ISO norms to determine the quality of a lot of tiles.

Problem:
Suppose one has a lot of porcelain stoneware tiles with an average water absorption of 0.1%, which we want to measure against EN ISO standards for surface flatness.

Solution:
In qualitative terms, the procedure to be followed is as follows:
❑ take a sample of tiles from the lot in question;
❑ measure its flatness;
❑ compare the obtained results with the requirements established by EN ISO standards.
Consider in Table 8 how EN ISO standards guide us through this inquiry.
It must be noted that the knowledge of a tile's EN ISO group constitutes an important step in this inquiry. Without this information, the determination in question cannot be effected.

Table 8

Question	The answer is in this standard
How many tiles must be sampled, and how must the sample be taken?	**EN ISO 10545-1**
What method must be followed to measure flatness?	**EN ISO 10545-2**
To which EN ISO classification group does the product in question belong?	**EN ISO 13006, sec. 4** Pressed tiles, with WA = 0.1%, belong to **Group BIa**
Where can the requirements on flatness befound, to compare against the results of the measurements taken?	**EN ISO 13006, normative appendix G**

world's national unification agencies, and publishes ISO Standards that are valid around the world.

EN ISO Standards are now being published for ceramic tiles.

2.2.3– What the EN ISO Standards on tiles include

The standards in question basically include four things:

1. a classification of ceramic tiles into groups (types);
2. a definition of the properties that the tiles of each group must possess, in relation to their intended use;
3. a specification and description of the methods of measurement for the various properties;
4. an indication of the acceptability requirements that tiles in each group must meet for each property. The requirements are essentially limits or benchmarks which the tiles must comply with in order to be considered of good quality.

2.2.4 – Practical function of the standards

The norms serve to clarify business relationships between:

❑ manufacturers and vendors, or suppliers of ceramic tiles, and

❑ the Homeowner and the Specifier, or buyers of ceramic tiles.

Supplier and buyer can use the standards to define a product's nature and establish its benchmark properties; hence a common language provides clarity.

For the same product, a supplier "promises" certain properties, pledging his commitment and responsibility to the buyer who may use

the standards to verify that such commitment has been fulfilled: hence the standards insure fairness in the business relationship, as a way of safeguarding both parties and above all the consumer.

These are important aims, whose achievement depends on an adequate knowledge of the standards by all parties (suppliers and buyers). The person with the greatest challenge here is the Homeowner, who generally has no professional expertise or experience in the field.

The addendum “EN ISO Norms for Ceramic Tiles. Reference Guide” offers a clear and complete guide for using the standards. The starting point and key to an understanding of the structure and use of tile standards is the classification of ceramic tiles themselves. It must be stressed that the EN ISO standards use a different classification system from the one based on technical-commercial denominations that is presented in the preceding chapter.

The classification of EN ISO standards is based on only two parameters:

❑ shaping method, which may be, as set forth in the preceding chapter, either

– A: Extrusion, or

– B: Dry-pressing

❑ porosity, measured in terms of water absorption.

These sole two parameters are used to subdivide tiles into nine groups (for example, BIa, AIIb, BIII) as presented in

Table 2 in the above-cited addendum (page 97). The relations between the two classification systems, the one based on technical-commercial denominations and the other based on EN ISO standards, have been discussed in the preceding addendum "Technical-commercial classification of ceramic tiles" (pages 84-85). It must again be stressed that the correspondence between the two classification systems is not exact, since a single given class in the technical-commercial classification system may correspond to more than one group in the EN ISO classification system, and vice versa.

Some observations …

The fact that there exist two separate classification systems for ceramic tiles which, as discussed, bear no precise relation to each other, may seem to the lay reader a baffling or unjustified complication. The following questions will arise:

A. why are the EN ISO standards based on a system of tile classification that is new and different from the technical-commercial classification system which is well-known and commonly used in business relations? Could not the EN ISO standards have maintained the same technical-commercial classification system?

B. what information about a given tile is added, by knowing its EN ISO classification? Can we adequately know a tile without knowing its EN ISO classification?

These questions are not theoretical but practical, with concrete and practical implications as shown in the following answers:

A. the technical-commercial classification system described is national, used only in Italy (considering, for example, that cottoforte tile, terracotta, and red stoneware tile are typically Italian). Other counties use different denominations to describe tiles some of which are similar to the Italian ones, and some quite different. The international EN ISO standards cannot incorporate all the various national denominations (of which almost a hundred exist) nor take into account their various distinctions. Hence the need for the EN ISO classification system, a standard valid throughout Europe and the world: a classification system that is *general*, covering any product, and *meaningful*, since it is based on parameters which, as we will see, are the basis of many of the technical properties which distinguish the various types of products;

B. the knowledge, for a given product, of its EN ISO classification adds important information about its level of porosity, which distinguishes between products that share the same technical-commercial classification but possess different properties and performance features (for example, between a vitrified single-fired tile (BIb), suitable for interior and exterior floors**,** and a more porous single-fired tile (BII) suitable only for interiors). Furthermore, knowledge of a tile's EN ISO classification allows one to consult the appropriate product standard, which contains quality requirements for that product. Hence unless we know a tile's EN ISO classification, we cannot be said to adequately know the tile.

In conclusion:

- *there exist ceramic tile standards that are valid around the world (the EN ISO standards);*
- *these standards classify tiles into nine group, each with its specific standards containing the requirements with which tiles in that group must comply in order to be considered of good quality;*
- *in general, in order to define and identify a "type" of tile, one must know both its technical-commercial classification (for example, whitish single-fired tile) and its EN ISO classification (for example, BIIa). More often than not, both these classifications are noted on tile catalogues and cartons.*

2.3 – Technical properties

Technical properties are the properties that tiles must possess in order to adequately and dependably perform their function as floor or wall covering. They are therefore critically important properties, on which the “functionality” and “durability” of the tiled surface depend. It is of course equally important to be familiar with these properties, and to keep them in mind as one is moving toward the identification and selection of tiles that meet with one’s needs.

The most important technical properties that distinguish the various types of ceramic tiles, and the individual products within a single type, can be grouped into several categories:

❑ regularity; ❑ structural; ❑ mechanical/mass; ❑ mechanical/surface; ❑ thermo-hygrometric; ❑ chemical; ❑ safety.

This classification of properties demonstrates that the main technical properties possessed by tiles, and covered by the current standards, *clearly and directly* reflect:

❑ the main sorts of stress tiles will be exposed to in their conditions of use.

For example, surface mechanical properties measure the resistance - and hence the performance - of tiles with regard to the mechanical stress caused by the environment and agents on the tile surface. The following equivalence emerges:

HIGH level surface mechanical properties	**=**	**performance and resistance levels adequate for HIGH levels of surface mechanical stress produced by the environment**

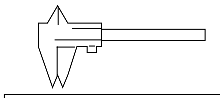
❑ basic user needs.

Technical properties of ceramic tiles considered in the current standards, and relative areas of application.

Property		Test method EN ISO Standard:	Floor		Wall	
			Int.	Ext.	Int.	Ext.
Structural properties	Water absorption Porosity Apparent density	10545.3	●	●	●	●
Regularity properties	Dimension and surface quality	10545.2	●	●	●	●
	Color differences	10545.16	●	●	●	●
Massive mechanical properties	Flexural modulus of rupture Flexural breaking strength	10545.4	●	●	●	●
	Impact resistance	10545.5	●	●		
Surface mechanical properties	Abrasion resistance (unglazed tiles)	10545.6	●	●		
	Abrasion resistance (glazed tiles)	10545.7	●	●		
Thermo-hygrometric properties	Frost resistance	10545.12		●		●
	Thermal shock resistance	10545.9	●	●	●	●
	Thermal expansion	10545.8	●	●	●	●
	Moisture expansion	10545.10	●	●	●	●
	Crazing resistance (glazed tiles)	10545.11	●	●	●	●
Chemical properties	Chemical resistance	10545.13	●	●	●	●
	Stain resistance	10545.14	●	●	●	●
	Lead and cadmium release (glazed tiles)	10545.15	●		●	
Safety properties	Slip-resistance (friction coefficient)	10545.17	●	●		

Properties of regularity

These properties determine the suitability of a batch of tiles for the creation of a "regular" tiled surface, one free of "irregularities" like troughs or bulges, steps between adjacent tiles, irregular course of joints, etc. Ceramic tiles are not like other ceramic products which are used individually (plates, for example). A ceramic tile is considered a "module", whose regular repetition on a



Technical properties

Properties of regularity

Dimensions and surface quality
The **dimensional properties** as pertain to ceramic tiles are as follows:

Measurement of tile dimensions:
❑ dimension of sides and thickness;
❑ straightness of sides: ascertained by insuring that the sides do not curve outward or inward within the plane of the tile
❑ rectangularity: ascertained by insuring that the sides of the tile are perpendicular to each other.

Measurements of the tile surface flatness:
❑ center curvature (the departure of the center of a tile from the plane in which three of the four corners lie);
❑ edge curvature (the departure of the center of one edge of a tile from the plane in which three of the four corners lie);
❑ warpage (the departure of the fourth corner of a tile from the plane in which the other corners lie).
A complete grasp and proper use of the measurements of regularity requires an understanding of the following definitions:
❑ *nominal size: the* size used to describe the product (for example, 20 x 20 cm);
❑ *work size: th*e size of a tile specified for manufacturing to which the actual size has to conform within specified permissible deviations (see Appendix 2);
❑ *actual size:* the size obtained by measuring the face of the tile in accordance with ISO 10545-2 standard methods.

Note:** According to EN ISO standards, work size must be indicated on tile packaging after the nominal size, preceded by the letter W, as in the following example: **20x20 cm (W 198x198 mm).

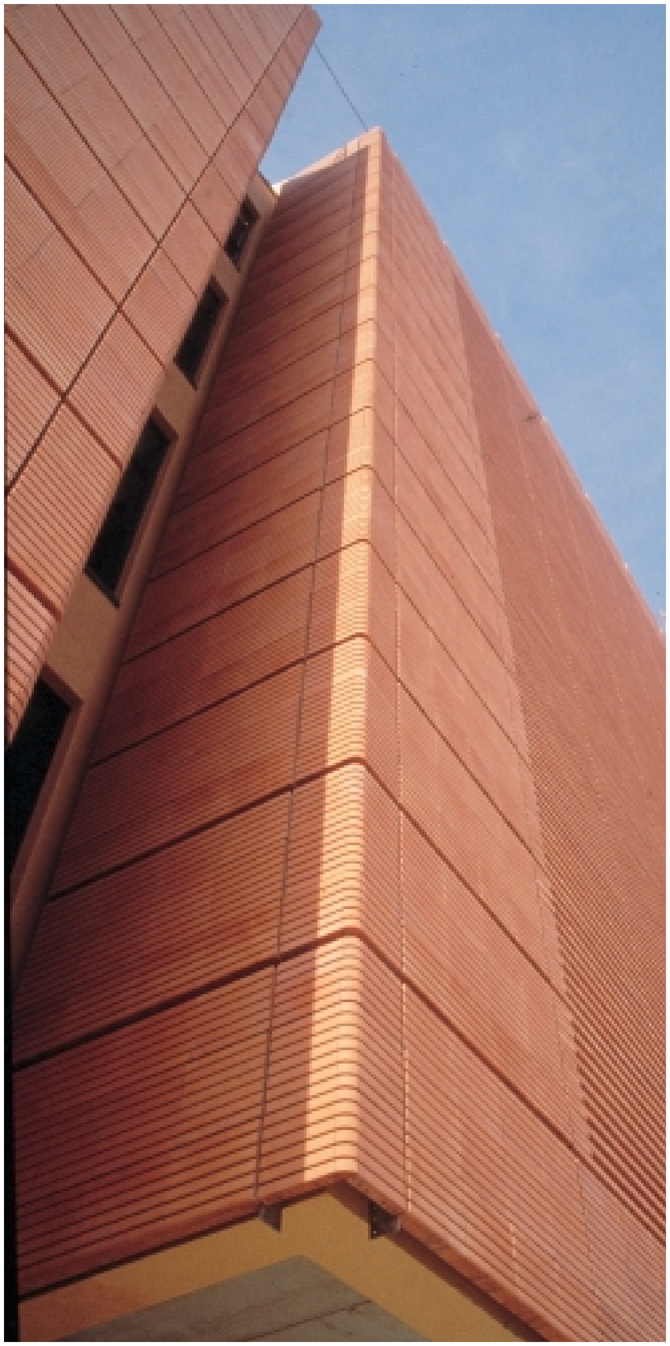
As regards **surface quality,** defects such as the following are insured against:
❑ cracks
❑ crazing
❑ dry spots
❑ uneveness
❑ pin holes
❑ glaze devitrification
❑ specks or spots
❑ underglaze faults
❑ decorating faults
❑ chips
❑ blisters
❑ rough edges
❑ welts

Measuring methods and technical properties tests, see Appendix 1.

surface generates a tiled surface containing tens or thousands of tiles laid out next to each other. In order for the tiled surface to be visually pleasing (leaving aside questions of the personal taste which led to the selection of that particular product), the tiles must have specific size and appearance properties. The tiles of a single lot may contain small differences of size and appearance, or small deviations from flatness. Therefore, these differences and deviations must be controlled to insure that they do not compromise the regularity of the tiled surface to be constructed.

The degree to which the various types of tiles can fulfill the demand for size regularity must be associated to the EN ISO classification parameters, that is to the shaping method and to water absorption levels.

Extrusion shaping usually allows for a less accurate control of size and of surface finishing, as compared to pressure shaping. The appearance of the tiled surface is affected by this: extruded tiles like terracotta and clinker generally give a floor or wall a more “rustic” look, while pressed tiles yield a smoother, more uniform surface. This uniformity is also enhanced by the possibility, with pressed tiles, of achieving relatively narrow joints, which are not easily achievable with extruded tiles. It must be noted that the differences presented here in no way constitute a value judgment in regard to quality: we are not establishing a scale of quality or value, but only clarifying a distinction regarding production technologies. Suffice it to remember that the “rustic look” of some extruded products (like



certain terracotta tiles), far from being considered a defect, is to the contrary a highly desirable effect for many environments.

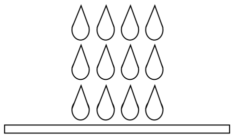
As regards the role of water absorption, it must be noted that the compactness of the structure created in tiles with vitreous support (Groups AI and BI) is a result achieved with special raw materials and by firing at relatively high temperatures. The firing process in these products entails the substantial formation of a liquid phase, which then leads to an equally ample and compact vitreous phase during cooling. All of this creates substantial shrinkage, which in general terms can be said to be proportionately greater where the desired level of water absorption is lower. The formation of liquid phases during firing and size shrinkage entail some risks: the risk of deformations, of size irregularity, of irregularity in the sizes of tiles produced at different times or in different areas (hence at different temperatures) of the oven: risks, in brief, of having several "production sizes" for the same product. These risks, typical of vitreous products (red stoneware tiles, porcelain, clinker tile, single-fired tile with low water absorption) tend to diminish gradually as porosity increases and eventually to disappear for those highly porous products (like majolica, cottoforte, and monoporosa tile, etc.) whose raw material and whose lower firing temperatures allow for a negligible liquid phase during firing and hence a very low degree of shrinkage.

It must however be noted that even with vitreous products, a conformity with size tolerances is required and strictly adhered to by most producers.

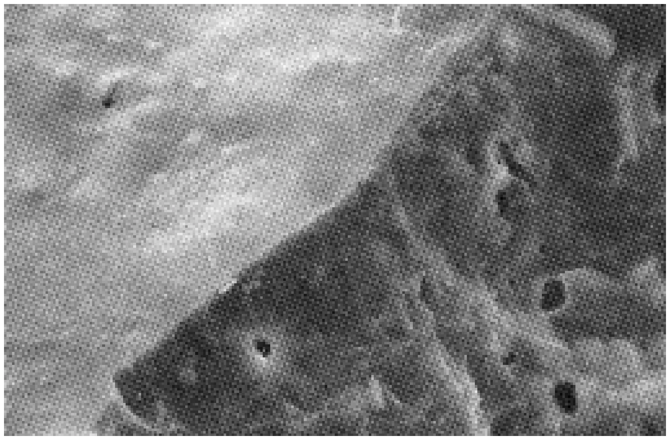
Structural properties

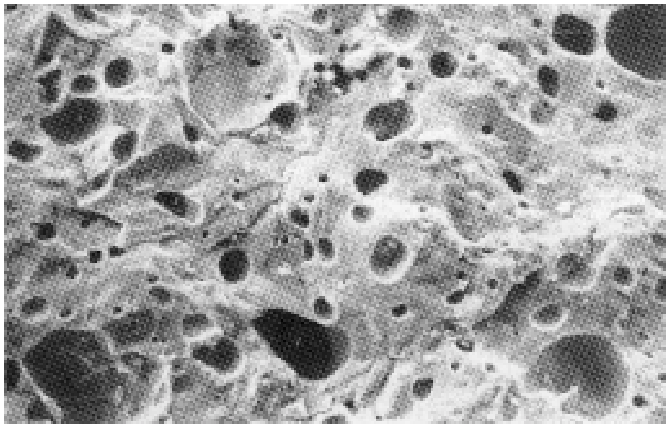
Water absorption

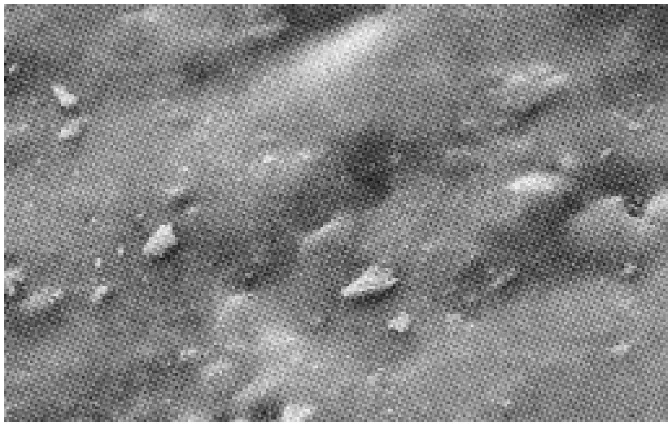
Water absorption is a measure of the amount of water a tile can absorb under specific experimental conditions. Given that such absorption occurs through the pores of the material which are in contact with the exterior surface, the absorption of water constitutes a measure of the quantity of such pores, or "*open porosity*". ("*Closed porosity,*" by contrast, is formed by pores which are non-communicating and thus not accessible from the exterior surface).
Water absorption thus directly indicates the structure of the material: a high level of water absorption corresponds to a porous structure, a low level of water absorption to a compact (vitrified) structure.
Note: *In the case of glazed tiles, the measure of water absorption indicates the structure of the tile's body, that is its mass, and not the structure of the glaze.*
Knowing a tile's water absorption is important not because it corresponds – as do other properties here explored – to a performance feature or to a particular behavior of that tile. Rather, it serves essentially to position the tile in its appropriate group according to EN ISO classifications.



Three examples of porosity of ceramics, seen with a microscope.







Structural properties

Structural properties describe the "structure" of the material that constitutes the tile: specifically, its porosity or porous structure.

The most important of these properties is water absorption (one of the two factors on which classification according to the EN ISO standards is based), which constitutes a measure of porosity (or more precisely, of "open" porosity). It is a classification property, inasmuch as several other important properties are dependent upon it.

The type of product that is typified by the lowest levels of water absorption is porcelain stoneware; porcelain stoneware products available on the market possess water absorption levels of under 0.5%, and in the great majority of cases, water absorption levels are under 0.1%.

Products with very low levels of water absorption are also available among whitish and red single-fired tiles, clinker tiles and red stoneware tiles; these classes however contain considerable variety, and the products they include have a much greater range of water absorption levels.

The products marked by the highest levels of water absorption are monoporosa, majolica and cottoforte tiles.

In practical terms, a tile's water absorption level is significant not as a measure of any particular performance of that tile, or of the tile's resistance to any specific stress. Rather, its significance lies in the fact that many of the properties described below are critically (if not exclusively) determined by it, since water absorption is an indicator, if a partial one, of a material's microstructure. For this reason, water absorption has been selected as a classification parameter for tiles.

Massive mechanical properties

Modulus of rupture and breaking strength

Resistance to bending, or **flexural modulus of rupture**, is a material property, and indicates the maximum tension that a sample of the material, subjected to an increasing stress from being bent under specific conditions and with specific procedures, can withstand before breaking.

The resistance to bending is a property of the material that makes up the tile, and does not directly define any mechanical performance of the tile. It is measured to check the correctness of the production process used, to achieve the desired consistency and compactness.

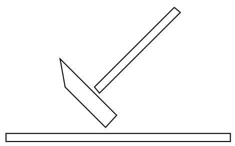
The **flexural breaking strength** is the weight that, when applied under specific conditions and with a specific process, makes the tested tile break.

As its definition indicates, the breaking strength is a performance property of the tile, and is determined by both the structural properties of the material, and the size of the tile. The breaking strength tends to increase with the increase of the material's modulus of rupture and of the thickness of the tile.

Massive mechanical properties

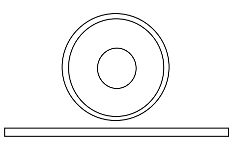
These properties concern resistance to loads (such as for instance the weight of people and of furniture on a floor) to which the tiled surface will be subjected, and which it must withstand without breaking. We call these properties “massive” since they concern the tile in its entirety or “mass”, and in order to distinguish them from the “surface” properties that concern only the working surface of the tile. These properties are significant especially in the case of floors.

It should be said that the breaking strength of a single tile, measured according to the method specified in the EN ISO 10545.4 standard, is usually much lower than the real weight-bearing capacity of the same tile in use when installed into a floor. Mathematical models and calculations show that the weight-bearing capacity of an installed tile is often greater by a factor of 20 to 80 to the weight that causes the break of a single free-standing tile during a test of resistance to bending conducted in a laboratory. This conclusion stands to reason, considering the help in resisting mechanical stress that the tile receives from other layers (the bedding, the structure) that are firmly bound to it.



Impact resistance

A flooring material’s impact resistance, or resilience, is its resistance to breaking from blows caused by falling bodies.
Like most ceramic materials, tiles are not resilient, so that the mechanical impact of a falling object may initiate the process of fracturing. Thus in general, the use of ceramic tiles requires a degree of care in avoiding the fall of heavy blunt bodies, care not needed for so-called resilient floors like linoleum and rubber. Ceramic tile’s limited resistance to blows is a function of its fragility, a characteristic of ceramic and many other materials.
Impact resistance is measured, according to the EN ISO 10545.5 standard, by means of the **coefficient of restitution:** by measuring the time elapsed between the fall and the consequent bounce of a steel ball on the surface of a tile installed under specific conditions on a proper support. The test result supplies an indication of the elasticity of a tile in standard conditions, so that results may be used in establishing comparisons.
Generally, it can be said that the higher the coefficient of restitution, the higher the impact resistance.
Note that fragility does not mean weakness; a material is considered fragile if it breaks under mechanical stress at the termination of the range of elastic deformation, without an intervening stage of permanent, or plastic, deformation. A fragile material normally has low resilience, even if it has extremely high levels of breaking strength and modulus of rupture; for instance, some particularly hard and resistant types of steel are fragile in this sense. Thus in the case of tiles, and of ceramic in general, fragility must not be seen as a defect, but as a property that, like all the other mechanical, chemical and physical properties, is determined by the nature, chemical bonds and microstructure that are characteristic of ceramics.



Resistance to “roulage”

Resistance to “roulage” (literally, to the circulation of

The mechanical properties that are measured in tiles are flexural modulus of rupture and breaking strength. The modulus of rupture is a property of the material that constitutes the tile, and is generally inversely proportional to the level of water absorption (for example, it is much greater in porcelain stoneware, whose water absorption level is below 0.5%, than it is in monoporosa tile, whose water absorption level exceeds 10%). The breaking strength from bending is instead a property of the tile, with its own

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transport vehicles) is a particular mechanical performance characteristic whose measurement is required only in relation to the NF-UPEC Mark (Marque NF - Carreaux céramiques pour revêtement de sol associées à la marque UPEC): a mark used in France for flooring materials. This property is not considered in the EN ISO standards.
Resistance to "roulage" is the resistance of a sample tiled area (not an isolated tile but a tiled area: that is, a sample of a floor installed according to a specific method) to mechanical stress produced by a trolley with specific properties and weight, rolling over it for a specific length of time. Different test methods with different conditions are specified for glazed and for unglazed tiles. For glazed tiles the test is called "*resistance to light roulage*" (light circulation). A trolley on three wheels made of hard plastic is loaded with a weight of 450 kg; the test lasts one hour.
The more exacting test for unglazed tiles is called "*resistance to heavy roulage"* (heavy circulation). It is a test of resistance to the

simultaneous stress of moving loads and of a blow. A steel wheel loaded with 30 kg is used; the blow is produced by two steel sheets positioned on the route of the wheel, so as to bounce and thus confer a blow to the edge and, separately, to the center of the tiles that constitute the sample floor. The test lasts for four hours, simulating a total route of 14 kilometers (about 9 miles).

structure and size. It is therefore not only a function of its water absorption level but also of its thickness: the thicker the tile, the greater its breaking strength. Among these properties we also include the impact resistance.

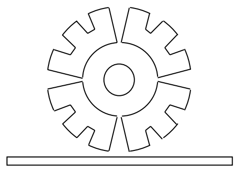
Surface mechanical properties

These properties pertain to the working surface of the tile; they concern the resistance to scratches, scraching, trampling, deterioration from the movement of hard bodies / materials across the surface. These properties too are especially significant for floors, on which one walks, drags chairs and sometimes furniture, carts, and the like. The most important surface mechanical property is abrasion resistance, which measures a tile's tendency to wear down (in the case of unglazed tiles) or to alter its physical appearance (in the case of glazed tiles) as a result of the aforementioned actions / conditions.

As regards this property, the observations and considerations pertaining to glazed tiles are quite different from those pertaining to unglazed tiles.

For unglazed tiles, abrasion resistance (meaning the resistance to the removal of material, as measured with the method specified in EN ISO 10545.6) tends to increase as water absorption decreases, that is as the structural compactness increases. Therefore the best performance is to be expected especially from porcelain stoneware and other types of products (like red stoneware and clinker tile) which are typified by low levels of water absorption.

Even if the data supplied by testing abrasion resistance essentially constitute standards of quality for tiles, and do not directly indicate a tile's durability, it must be acknowledged that, in regard to durability under abrasive usage, unglazed tiles are absolutely outstanding. Unglazed tiles are clearly composed homogeneously throughout, a fact with two consequences: first, that the eventual removal of material from abrasive



Surface mechanical properties

Abrasion resistance

Abrasion resistance is the resistance of a surface to wear and tear connected with the movement of bodies, surfaces or materials that come in contact with it. There may be a variety of bodies that move intentionally or accidentally over a tiled surface, especially when such a surface is a floor: for example, the soles of the shoes of the people using the floor, the wheels of carts or other vehicles, furniture, chairs, and other loads that may be dragged across the surface. A variety of materials may also be interposed between these bodies and the tiled surface, such as water, mud, snow, sand and organic substances. The ordinary operations of cleaning and maintenance with brooms, rags, detergents in powder, and the like also cause the movement of hard materials over the tiled surface.

The abrasive actions caused by all such actions create effects of two types:

❏ the removal of material from the surface, which is thus gradually worn down;

❏ the alteration of the aesthetic appearance of the surface, with loss of brightness, variation of color, and the like.

The effects are various, not always simultaneous and often not even linked to each other: since, for example, a substantial removal of surface material does not always or necessarily accompany a conspicuous aesthetic deterioration [of a tile's appearance], and vice versa. An important fact must in any case be stressed: apart from immediate aesthetic effects, the removal of material generally weakens the surface structure, leading to the creation of porosity and micro-cracks that although invisible (except under a microscope), become vulnerable to the tenacious penetration of dirt, residues and the like. The effect that abrasion can have on some important functional properties of the surface, like chemical and stain resistance, and on ease of maintenance, is of clear importance.

The test methods for unglazed tiles (EN ISO 10545.6) and glazed tiles (EN ISO 10545.7 PEI method) are different, since the effects of abrasion are different in the two cases.

For unglazed tiles, the volume removed in specific conditions of abrasion (deep abrasion) is measured. A tile is considered resistant in inverse proportion to the amount of material removed.

For glazed tiles, surface abrasion of an increasing intensity is created, and the effects are assessed visually according to specific conditions of observation.

Depending on the results of these observations, the measured tile is assigned a class of abrasion resistance (PEI 0, I, II, III, IV, V, in increasing order of resistance).

Note that the PEI V class of resistance is assigned to tiles that not only show no visual evidence of abrasion, but also continue to manifest adequate stain resistance and thus adequate cleanability.

usage gradually exposes underlying layers of the tile that are substantially equal in composition and very similar, if not identical, in appearance; and second, the possibility (at least in theory) of polishing a tile (that is, carefully removing its topmost layer) to regenerate a surface that has been somehow damaged.

It must be stressed that the method for measuring abrasion resistance for unglazed tiles does not consider the question of visual effects. The mechanical surface properties depend not only on the type of product but also, to a significant extent, on any specific surface treatment to which tiles may have been subjected either during production or after installation. Examples of such treatments are: for terracotta, treatment with various natural or synthetic substances like linseed oil or waxes); in the case of porcelain stoneware, polishing.

For glazed tiles, even more complex and challenging factors must be kept in mind.

We must first underline that surface abrasion resistance is a function exclusively of the glaze; the structural properties of the support are generally not relevant to the issue in question. Therefore, contrarily to what has been said for unglazed tiles, the higher levels of abrasion resistance do not necessarily apply to glazed tiles of the groups “I”, according to ISO classification.

That being said, it must be observed that the PEI class, which essentially measures the risk of aesthetic deterioration, and more specifically the risk of color change, also depends appreciably on the tonality and chromatic texture of the surface: it is generally higher for lighter glazes, and lower for darker glazes. However, light glazes can more clearly show the effects of use: a decline in cleanability, for example, may occur sooner and more visibly.

Shiny glazed tiles, whatever their PEI classification, generally run the risk of becoming opaque in high-usage areas (since shiny glazes are generally less hard and hence less resistant to scratching than matt glazes.

Thermo-hygrometric properties

Frost resistance

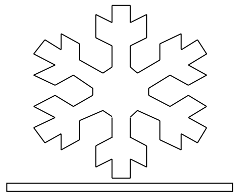
Frost resistance is the property possessed by some types of ceramic tiles, of resisting the effects of frost in humid environments and in temperatures under 0 degrees Centigrade.
The mechanism of frost includes two distinct phases. The first is the penetration of water from the environment (from weather, in the case of tiles installed outdoors, or of water from cleaning or other process needs, in the case of tiles installed in certain indoor areas like cold storage areas) to the interior of the tile pores. The second is the solidification of such water within these pores. The transformation of water to ice entails an increase in volume, since ice is less dense than water; when the water in the pores freezes, the pores are subjected to substantial mechanical stress, which may lead to the process of cracking and to the detachment of pieces of material. The action of frost may thus cause the appearance, on non-resistant tiles, of fairly common fractures and scaling/ spalling, usually conchoidal in shape.
Given the mechanism described, a material's frost resistance is dependent on two parameters: first, the presence and quantity of pores, which make it possible for the water to penetrate to the interior of the material; and second, the shape and size of these pores, which make it possible, once the water has completely filled these pores, for it to expand as it freezes, determining the degree of stress created.
There is thus a relation between frost resistance and water absorption: the lower the water absorption, the greater the probability that the material will be frost resistant, since water will less easily penetrate to the interior of the material. It must be noted, however, that some ceramic building materials are very porous and nevertheless possess, as common experience will confirm, a resistance to frost: consider bricks, whose water absorption may exceed 10 to 15%.
The good response to frost of such materials is due to the characteristic shape and size of their pores.

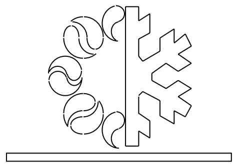
Thermal shock resistance

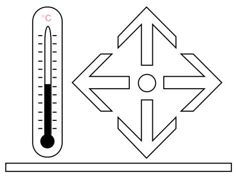
Thermal shock refers to the sudden and unexpected variations of temperature of floor or wall tiles due to accidental or intentional contact with hot or cold bodies (such as from the fall of a boiling liquid, for a cleaning with steamer machines, or, in the case of exterior floors or walls, from sudden temperature shifts).
The resistance to thermal shock is the property by which tiles can withstand such events undamaged.

Thermal expansion

Thermal expansion is the property by which any material is reversibly altered in size when its temperature changes: more precisely, it expands when the temperature increases, and contracts when the temperature falls.

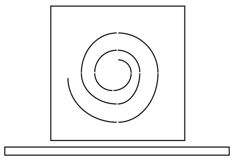


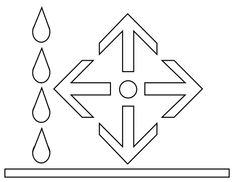




Thermo-hygrometric properties

These are the properties of resistance to specific temperature ("thermo") and humidity ("hygrometric") conditions, and include thermal shock and frost resistance, and, in the case of glazed tiles, crazing resistance. Abrupt shifts in temperature (which occur, for instance, when a hot pan is placed on a tiled kitchen counter) and exposure to frost (which occurs with floors





This behavior is monitored by measuring the coefficient of thermal expansion, α, whose average value in a given temperature interval ΔT is defined as the ratio between the amount Δl that a test sample of the material lengthens ΔT increase of is temperature, and the amount of its initial length l. multiplied by ΔT.
The unit of measure of the coefficient of expansion is thus $°C^{-1}$.
For ceramic materials for floors and wall coverings, the linear coefficient of thermal expansion normally varies between 4 and $8x10^{-6}$ $°C^{-1}$.
This means that an increase in temperature of 1 °C provokes a lengthening varying from 4 to 8 thousandths of a millimeter for every meter of initial length.
The coefficient of thermal expansion of tiles must be checked and considered throughout the planning and installation of the tiled surface, in association with the same coefficient for the other materials that are part of the flooring and wall covering complex.
Once installed, tiles, which are firmly fixed to the bedding, are not free to expand or contract, so that any substantial variation of temperature can create substantial stress.
The variations in temperature to which the tiled surface is exposed, especially if located outdoors, are sometimes considerable, as great as several tens of degrees Centigrade.
It is essential to avoid the risk that expansion will compress the tile covering, causing possible detachment and buckling from the background.
This can be prevented by planning, especially in extensive areas, ample and well-positioned expansion joints.
It must in any case be stressed that effects like detachment and buckling are due to a combination of causes of which thermal expansion is only one.

Moisture expansion

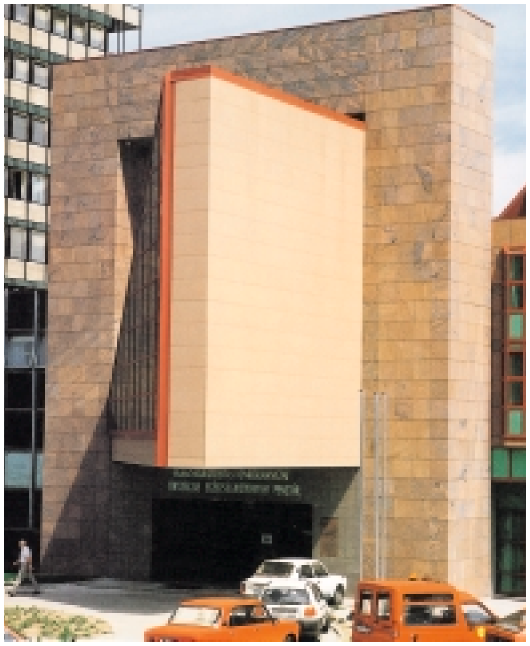
Moisture expansion is the expansion in size, expressed in mm/m, that a tile may undergo from exposure to humidity. The tendency to such expansion, whose effects are similar to those created by a rise in temperature (see thermal expansion above), is basically a function of the porosity of the material.

Crazing resistance

Crazing is a typical and occasional effect consisting of subtle, irregularly shaped cracks in the glaze of a tile. Generally in a ceramic tile crazing is considered a defect, although in particular cases it can be a deliberate effect, intentionally created during production to give the surface an "antiqued" look (as in the "craquele'" effect on certain antique vases).
It must first be pointed out that the cracks in question, though extremely fine, constitute a break in the glazed surface which entails not only a visual, aesthetic alteration of the surface but also a loss of impermeability.
The causes of crazing are due to an incorrect dilatometric ratio between glaze and support, thanks to which, under particular thermal and

and wall coverings in cold climates) must not damage tiles at all. Crazing consists in the fine cracks that may appear in a glaze due to some construction or environmental conditions. These properties also include thermal expansion and moisture expansion, which measure how much a tile may expand if exposed to higher levels of temperature and humidity.

Frost resistance is substantially influenced



hygrometric conditions, the glaze is subjected to a higher tensile stress than it can withstand, given its microstructural properties and its slight thickness. Just when this defect may emerge varies considerably: sometimes at the conclusion of the production cycle (that is, tiles may emerge from the oven already crazed), or several days after installation, or even after many months of use. In any case, the tendency of a tile to craze may also be due to some other external cause.

by the open porosity measured by water absorption. On the basis of the frost mechanism as detailed in the relevant addendum, we can say that the tiles with least water absorption, like porcelain and other equally compact products of other types, are certainly the most reliable in terms of frost resistance. Since water cannot penetrate to the interior of these materials, the process that leads to frost damage cannot even begin.

It must be noted, though, that among the most porous products (with porosity as high as 10%), extruded products that are neither glazed nor treated (such as various terracotta tiles) are often resistant to frost (that is, they pass the frost resistance test specified in the EN ISO standard 10545.12), while pressed products of comparable porosity rarely are. This difference in performance is due to the particular distribution of the shape and of the sizes of the pores, which results from the extrusion method.

The resistance to crazing basically depends on the composition of the glaze: some types of glazes, used to achieve various effects, run a higher risk of crazing. For this reason, norms have included resistance to crazing among the standardized properties. The high porosity of the support, or rather the support's eventual tendency to expand as the result of exposure to high humidity, may represent a further "risk" factor, especially because defect may appear in later time.

As regards thermal expansion, no substantial differences exist between the various types of tiles, though it must be noted that in general the amount of the glassy phase in products with a more compact and vitrified support tends to somewhat increase the thermal expansion coefficient (to 7-7.5 x 10^{-6} °C^{-1}, as against levels of 6-7 x 10^{-6} °C^{-1}, which are typical of more porous products).

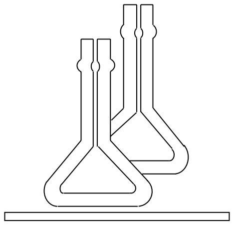
This difference is of minor importance, however, and reflects no particular distinction in usage risks over and above what has already been noted.

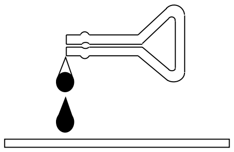
Finally, as regards moisture expansion, this is generally correlated to water absorption, although considerable variations exist, presumably due to the effects of other microstructural properties like the type, composition and distribution of the various phases included.

Chemical properties

These are the properties of resistance to the chemically aggressive or staining action of substances that may come into contact with the tile surface. Chemical properties measured are stain resistance, resistance to household chemicals, acid and alkali resistance.

The compactness of the surface layer of the tile is extremely important in this regard: the greater its porosity, the greater the specific surface or interface that comes into contact with the chemical agent. Clearly, a greater porosity promotes the absorption of the substances; furthermore, the pores, because





Chemical properties

Chemical resistance

Chemical resistance refers to the behavior of the ceramic surface when exposed to chemicals which, due to their composition and properties, corrode the ceramic surface so as to penetrate it permanently or at least alter its aesthetic appearance.
Acid or base chemicals may include various process liquids (like milk in a cheese factory, lubricating grease and oils in an automotive repair shop, blood in a slaughterhouse, and laboratory chemicals), other materials that may come accidentally into contact with floor or wall tiles (like foods, ink and the like in a private residence), as well as detergents for ordinary and special cleaning and maintenance.
Deterioration of a ceramic tile surface caused by the above-cited chemicals generally includes two distinct mechanisms effects: an actual chemical action, whereby the alteration of the ceramic surface is due to a reaction between the chemical and some component of the surface itself (ceramic surfaces are generally quite inert with regard to the chemicals cited, with the sole exception of fluorohydric acid); and a physical action of absorption, according to which the chemicals penetrates to the interior of the surface so as to lodge there permanently or at least firmly enough to be extremely difficult to remove.

Stain resistance

Stain resistance, closely linked to chemical resistance, refers to the behavior of a ceramic surface exposed to staining substances, and is measured as a function of the effectiveness and ease with which stains from specific substances, when applied to the tile surface under specific conditions, may be removed. Stain resistance thus measures the “cleanability” of a ceramic surface.
This is an important property, both because quite a variety of staining substances can come into contact with a tiled surface under normal conditions of use, and because ceramic tile’s cleanability represents one of its competitive strengths relative to many other competitive materials.
The staining substances used in the test are various and are selected to represent the typical working mechanism of a staining substance: tracing action (by substances like ink), chemical/oxidating action (by tincture of iodine, for example), filming action (such as by oil).
The compactness of the surface is certainly a major factor with regard to this property: the more compact the surface, the less chance that staining substances will penetrate and lastingly adhere.

The hypothesized mechanism of chemical attack and of staining reflect the fact that often, as noted in the preceding discussion on abrasion resistance, resistance to chemicals and stains tends to decrease in surfaces exposed to relatively heavy abrasive use, which often develop a micro-porous surface.

of their shape, constitute areas of penetration of the substance itself, which can thus become irremovable by even the most aggressive cleaning procedures.
As for glazed products, the layer of glaze that covers the surface renders the working surface compact and non-absorbent. A good practical measure of this compactness is the tile's resistance level to stains: obviously, a high resistance reflects a non-absorbent surface, while a low resistance level reflects the presence of microporous veins / channels through which stains and chemical substances may penetrate the interior of the glaze. Glazes also usually possess a high level of chemical resistance, despite the fact that some colorations and decors are quite sensitive to acids and other chemical agents. Their resistance to bases, instead, is considerably greater.
In unglazed products, chemical resistance is generally excellent for all products. Stain and soil resistance is in this case more directly correlated to compactness; hence the best

The combination on a surface of both stresses, mechanical and chemical, may lead to a deterioration that is greater than the sum of its separate effects. This is generally true for both glazed and unglazed tiles.

performance can be expected from porcelain stoneware and other types of products with similar compactness. These materials are also subject to a higher firing temperature, which creates not only compactness but a correspondingly greater chemical inertia. It must be stressed though that the surface porosity which is important in containing the risk of chemical attack, according to the mechanism described, is not always precisely correlated to the more macroscopic porosity which determines the degree of water absorption. In other words, even those unglazed products which are of extremely low levels of water absorption can still be microporous on the surface and admit a certain absorption of chemical or staining substances.

In the case of unglazed products of greater porosity, like terracotta, the initial disadvantage of the porosity and the surface porosity is corrected with the application of the impermeability agents mentioned earlier. Properly treated terracotta floors require greater caution on the user's part than other types of floors, but their chemical resistance and ease of maintenance (cleanability) are more than adequate for many residential environments.

Safety properties

These properties are especially significant for the safe use of tiled areas: safety against risk of accidents or regarding hygiene for the user. The principal safety property is slip resistance, which is very important for tiles intended for floors in certain exterior public and industrial areas. Safety properties also include lead and cadmium release (metals sometimes contained in glazes), which is especially monitored in the case of tiles whose usage brings them into contact with substances associated with food. The most common use of this sort is for kitchen counters.

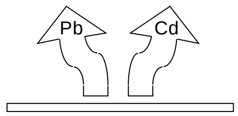
As regards slipperiness, certain types of ceramic tiles can insure excellent safety performance. Along with smooth-surfaced

Safety properties

Lead and cadmium release

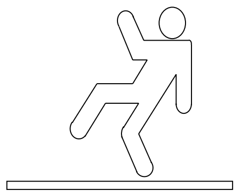
More than a safety property, this is a chemical property pertaining to glazed tiles. Testing is advisable for tiles used to cover kitchen counters: that is, surfaces that may come into contact with food substances which may potentially extract contaminating lead and cadmium - two metals often contained in glazes - from the glazed surface. The monitoring is a measurement of the amount of lead and cadmium released by the surface to an acid solution (acetic acid) held in contact with the surface under specific conditions.

The release of lead and cadmium is listed among the safety properties, since the purpose of the test is to protect the consumer from the risk of contamination from the elements in question.



Slip resistance

The slip resistance of a surface depends on the kinematic and dynamic conditions of movement of a body in contact with that surface.
In the case of floors, slipperiness is obviously linked to safety in walking, and is thus a very important feature; it is in fact the object of increased focus, thanks to laws and regulations that establish precise responsibilities on the part of the manager of a floor with respect to accidents and damage suffered by parties due to falls.
One parameter used to measure the slipperiness of a surface is the **coefficient of friction**, static or dynamic, which is proportional to the force, parallel to the surface of contact, required to create movement between two bodies, and thus also of the force that defines its conditions of equilibrium.
The higher the coefficient of friction, the less slippery the surface.
The coefficient of friction depends on the nature of the two bodies in contact, and on the conditions of the contact itself: in particular, the state of the surfaces, the possible presence of interposed materials, the humidity and temperature conditions.
As regards the nature of the surfaces, the coefficient of attrition for floor materials (in contact with the sole of a shoe) is that much lower to the degree that the surface is smooth, polished, resistant to deformation (or perforation), and the greater its tendency to remain covered by a thin and continuous film of water or the like.
Compared to dry, clean surfaces, the coefficient of attrition decreases in the presence of oil, grease, dirt, water, all materials that function as lubricating agents between a sole and the surface of a floor, making it more slippery and thus increasing the risk of falls and accidents.
Surfaces with a higher coefficient of attrition are rough and wrinkled ones; the roughness may be natural, as it were, or artificial, created through shaped reliefs.
Such surfaces maintain a relatively high coefficient of attrition even in the presence of water or other liquids, since the reliefs mentioned retard the development of the continuous film that reduces friction.
It should be noted that the surface reliefs that create optimal non-slip conditions conversely make cleaning more difficult.



glazed ceramic tiles with a low-to-medium friction coefficient (but not lower than that of other non-ceramic floor materials), there are many commonly used types of glazed tiles with a rough surface, and unglazed tiles with surface reliefs, both of which meet anti-slip requirements for all residential and industrial environments. It must further be noted that the floors for which anti-slip safety requirements are most important are

This is an important fact that must be taken into consideration in the selection of a flooring material. Environments where safety demands are critical are indoor and outdoor public areas with high pedestrian traffic, in conditions as to make walking potentially dangerous; pools, especially dressing rooms and the walkways around the pool; industrial areas, where floors are very often soiled with oil, grease and the like.

generally public and industrial environments - the same environments that also have the strictest requirements for resistance to surface mechanical stress (especially to abrasion), chemical resistance, cleanability and hygiene. Since resistance to slipping is generally achieved by making the surface rough, effects which tend to diminish the surface's cleanability, one can easily see how, for the cited environments, the best selection is slip-resistant tiles with especially high levels of mechanical and chemical resistance. Flooring materials which can meet these special and severe demands are to be found mostly among unglazed tiles with low water absorption levels, like porcelain stoneware. There are in fact various products of this type, made with special surface reliefs, that combine a compliance with the anti-slip requirements with excellent mechanical and chemical resistance.

All the above-cited properties are considered in the technical standards on tiles.

Some properties, it should be noted, refer only to tiles for certain specific applications (for instance for floors, or for exterior environments).

For example:

❑ frost resistance is a relevant property only for tiles to be used for exterior floors or walls (in climates with the risk of frost). It is irrelevant for tiles for interior areas;

❑ abrasion resistance is a property relevant only to tiles to be used for floors, that is for areas that will be walked on.

The addendum *"Technical properties of ceramic tiles in the current standards, with their areas of application"* (p. 109) presents a detailed diagram as discussed above. This table serves as a guide to understanding the most important properties — those to be kept most clearly in mind and monitored with special care – in their various applications.

The addenda *"Technical properties"* (starting from page 110) offer some technical details to explain more thoroughly the significance of each property.

Appendix 1 sets forth in table form the methods for measuring the various properties, as contained in the EN ISO standards.

Appendix 2 presents an overview of the requirements contained in the EN ISO 13006 standards for the various Groups of ceramic tiles.

2.4 Technical specifications

A tile's technical specifications consist of a document containing the list of those properties included in the standards and relevant to that tile, with respective values obtained through measurements and tests conducted in accordance with those standards.

For every property, next to the measured value of the tile in question, the technical specifications usually also report the acceptability requirement (when that exists) for that tile's EN ISO classification group. The comparison between the measured value and the respective requirement yields an immediate assessment of the quality of the product, or its conformity with EN ISO standards.

These standards are applicable only to "first choice" tiles. For subsequent grades, the requirements may differ. This matter will be taken up at a later point (section 3.2 - The supply of tiles). Appendix 4 contains requirements for second and third choice tiles proposed by the European Federation of Ceramic Tile Manufacturers (CET).

From what has been said one deduces that the technical specification is a sort of "identity card" by which the Homeowner and the Specifier are put in a position to know and value the tile from a technical point of view.

The responsibility for preparing and presenting the tile's technical specifications lies with the manufacturer.

Often the technical specifications are contained in the catalogs, and are brought to the buyer-user's attention through the

Examples of technical specifications of glazed ceramic tiles for interior floors

PROPERTY		Measured in keeping with EN ISO	REQUIREMENT (Group BIIa EN ISO 13006 Annex J)	Technical specifications Glazed Ceramic Tiles	
				XYZ - 20x20 cm Whitish single firing Group BIIa	ABC - 20x20 cm Whitish single firing Group BIIa
Water absorption	Average value	EN ISO10545.3	3 < E ≤ 6%	5.1%	3.3%
Resistance to bending	Modulus of rupture (average value)	EN ISO10545.4	≥ 22 N/mm^2	27 N/mm^2	30 N/mm^2
	Breaking strength (average value)		≥ 1000 N	1060 N	1100 N
Abrasion resistance (glazed tiles)		EN ISO10545.7	PEI Class and # cycles to be specified by the manufacturer	PEI V > 12000 revolutions	PEI III 750 revolutions
Crazing resistance		EN ISO10545.11	requested	resistant	resistant
Chemical resistance	Household chemicals	EN ISO10545.13	Resistance class ≥ GB	GA	GB
	Swimming pool salts		Resistance class ≥ GB	GA	GB
	Hydrochloric acid, 3 % v/v		to be specified by the manufacturer	GA	GC
	Citric acid, 100 g/l		to be specified by the manufacturer	GA	GC
	Potassium Hydroxide, 30 g/l		to be specified by the manufacturer	GA	GA
Stain resistance	Green staining agent	EN ISO10545.14	Resistance class ≥ 3	5	3
	Iodine/alcohol solution		Resistance class ≥ 3	5	3
	Olive oil		Resistance class ≥ 3	5	3

The comparison is between two products – XYZ and ABC – of the same type (whitish single-fired tiles) and the same EN ISO group (BIIa). Their respective technical specifications – an abbreviated version is presented, including only some of the most important properties – demonstrate that both products meet the normative requirements, and are thus **both of good quality**.
From the point of view of the **performance** to be expected under conditions of use, the products **are not equivalent:** product XYZ has *lower massive mechanical properties*, but *higher mechanical and surface chemical properties*. Therefore, the two products cannot and must not be used interchangeably.
One notes, in particular, that product ABC is not resistant to acids and bases (resistance class GC), while product XYZ offers excellent resistance (resistance class GA).
For the meanings of the resistance classes quoted, refer to Appendix 1, in which the respective measurement methods are described.

vendor. But it is the manufacturer, through the vendor, to whom the Homeowner and the Specifier must turn for any desired technical information.

Many catalogs specify an individual product's EN ISO group (for example, BIIa) and its conformity (for first-choice batches of tiles) with requirements contained in the corresponding product standards (for example, EN ISO standard 13006, Annex J).

We come to the following question:

"What is the relation between a simple declaration of conformity with the standards and the technical specifications, as above defined?"

A declaration of conformity with the standards constitutes an actual technical specification for the tile in question, since it implies that the properties included in the EN ISO standards have been measured (by an official Lab., like Centro Ceramico, Bologna) and yielded results that, though not explicitly reported, are declared to conform with the requirements established by the relevant standard.

Nevertheless, a technical specification abbreviated as follows is considered *incomplete,* and hence *not always sufficient and satisfactory:*

"product XYZ belongs to Group BIIa and is in conformity with the requirements listed / included in EN ISO standard 13006, Annex J".

What is missing?

1. First, information on certain technical properties for which the EN ISO standards do not establish acceptability requirements, is lacking, leaving these areas to the agreement of manufacturer / vendor and buyer / user.

The properties in question include abrasion resistance and resistance to acids and bases in glazed tiles. EN ISO standards do not establish "absolute" acceptability requirements for these properties, indicating that even glazed tiles with low levels of abrasion resistance and resistance to acids and bases can be adequate — and hence "acceptable" – for use in areas where they will be exposed to equally low levels of abrasion and chemical attack (for example, for the floor of a residential bedroom).

This choice by the drafters of the standards is certainly correct and justified. The Homeowner and the Specifier must however be aware that the declaration by the manufacturer / vendor that "*XYZ glazed tiles are of top quality and meet the requirements of the EN ISO Standard 13006 Annex J*" does not necessarily imply that these tiles are resistant to acids and bases.

This information must be supplied – and if necessary, requested – as information over and above the statement of conformity with the standards.

2. Secondly, a simple statement of conformity with the standards does not constitute complete and sufficient technical information about the tiles.

Consider, for example, the stain resistance of XYZ glazed tile belonging to Group BIIa. The requirement established by the relevant standard (EN ISO 13006 Annex J) is that the class of resistance to each of the considered stains must be equal to or higher than 3. This means (see Appendix 2) that Classes 3, 4 and 5 are considered acceptable, while classes 2 and 1 are not. Suppose that our XYZ tile has been tested and assigned to Class 5 for resistance to all stains: this is the highest class, assigned when the stain can be removed simply by washing with water or rubbing with a damp cloth. The mere statement of conformity with the standards places this tile on the same level, as it were, with another tile (which we will call ABC) which is assigned Class 3 for resistance to all stains (the minimally acceptable class of resistance which is assigned in cases where the stain is not completely removed either by running water or a light detergent and non-abrasive sponge, but only with mechanical cleaning – with a hard-bristle rotating brush and strong detergent). Obviously the two products possess different levels of stain resistance performance: a difference which the Homeowner and the Specifier can appreciate – and make use of – only if they possess the complete technical specifications of the two products.

In sum, we can conclude that:

- *the technical specifications of a tile is the document that supplies the measured values of all the technical properties pertinent and applicable to the tile in question, relative to acceptability requirements, when these exist;*
- *the complete technical specifications for the tile in question, supply more thorough (and also more reliable) information on the quality and performance than can be expected.*

The official Italian testing laboratory for the properties of ceramic tiles is the Centro Ceramico Bologna.

CENTRO CERAMICO
Via Martelli, 26 - 40138 Bologna
Tel 051/534015 - Fax 051/530085
e-mail: centro.ceramico@cencerbo.it
internet: www.cencerbo.it

Further information is supplied in Appendix 5.

A tile's conformity with the standards can be simply declared by the manufacturer, in regard to a completed delivery, or certified by an appropriate agency (in Italy, UNI) which, after testing the product and establishing the controls and reliability of the production, grants the product the UNI mark.

UNI

P0000

This symbol is noted both in the product catalog and on each package of the tiles.

Further information on the UNI Mark is supplied in Appendix 3.

2.5 Areas of intended use

We have repeatedly noted how important it is that a correct and educated choice of ceramic tiles be made when considering the area of intended use and the conditions of use to which the installed ceramic surface will be subjected.

"*No single type of tile or single product can be considered suitable for all uses and environments*", as we have stated in the introduction to this second part of the manual, and the preceding discussion on technical characteristics has underlined the fact. What this implies is that a selection cannot be made casually, but must consider the intended use.

In this section we seek to guide the Homeowner and the Specifier in their analysis of the area of intended use for the tiled surface. The analysis will serve as a basis for the practical application of the technical and aesthetic standards for the selection of a type of tile that is suitable for their respective needs, as considered in the following sections.

The area of intended use and the conditions of use – that is, conditions to which the tiled surface will be exposed in the course of its useful life – are two closely linked factors.

We begin with the conditions of use, which we describe in terms of the type of stress the area will expose the tiled surface to, and which the tiled surface must withstand over time.

Such stresses can be classified as follows:

- Massive / mechanical stress: mechanical stress on the tiled floor or wall, to which these surfaces respond and react in their entirety.

❑ Surface mechanical stress: mechanical stress upon the surface of the tiled floor or wall.

❑ Chemical stress: chemical aggression on the surface of the used surface and sometimes on the underlying strata as well, produced by chemical substances of various kinds which come intentionally or accidentally in contact with the tiled surface.

Examples of assessment of various environments

We present several examples of an analysis of intended areas of use.

❑ Exterior floors and walls:
all outdoor spaces must be considered exposed to high levels of hygrothermic stress. Further information regarding the climate of the area in which the tiled surface will be installed will also be useful (for instance, if the temperature will fall below 0 degrees Centigrade in the winter, if the humidity is especially high, and the like).

❑ Floors for industrial plants:
in general, these are exposed to high levels of stress of the following kinds: massive mechanical (presence of vehicles, heavy equipment), surface mechanical (presence of pedestrians and vehicles, abrasive dirt), chemical (presence and falling upon the floor of chemical substances – like fuel and oil in a car garage, blood in a slaughterhouse, milk and whey in a cheese factory, etc.), and safety needs (related to risks of slipping, increased by the presence, sometimes continuous, of liquids on the floor). In plants where food substances are processed, thorough and deep cleaning must be possible so as to insure absolute cleanliness and hygiene.

❑ Floors in public spaces, like cafes:
generally these are exposed to extremely high mechanical and chemical surface stress due to the passage of many people [heavy pedestrian traffic], who, in the case of areas directly accessible from outdoors, can bring in abrasive dirt on shoes. The high level of chemical stress is due both to conditions of use (for example, in a café, the beverages falling on the floor) and to predictably severe maintenance and cleaning demands (with the use of strong detergents containing abrasive substances).

Aesthetic considerations are also important (certainly more so than in an industrial space).

❑ Floors of entryways in private residences:
conditions of use and stresses vary depending on the characteristics of the home itself. Pedestrian traffic is among the heaviest in the home, but the conditions of abrasive usage vary depending

❑ Hygrothermic stress: stress connected with the exposure of the tiled surface to particular conditions of temperature or humidity.

It should be noted that this classification of types of stress is exactly congruent with the classification of tile properties presented and explained in section 2.3. This fact simplifies the selection of tiles suitable to an environment.

The areas of intended use and, consequently, the conditions of use of the tiled surfaces can be characterized in terms of the predictable level – from very high to very low – of the various classes of stresses. A qualitative characterization can be made using standards of classification for environments as described below.

❑ Horizontal or vertical positioning of the tiled surface

Whether the tiled surface is a floor (horizontal positioning) or a wall (vertical positioning) has relevance especially with regard to mechanical stress. A floor is

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on whether the home is located, for example, on the fifth floor of a condominium (in which case whoever enters has already adequately cleaned the soles of his shoes before reaching the apartment), or on the ground floor of a house surrounded by a garden, with direct access from the outdoors, via a path with sand or pebbles. In the latter case the stress from abrasive usage are much greater than in the preceding cases. In conclusion: such areas are exposed to surface mechanical stress varying from medium-low to very high levels.

❑ Kitchen floors and walls of private residences: among the environments in a home, this floor is perhaps exposed to the greatest stress: it is more walked and stood upon, with preferential pathways (for example, in the area between stove, sink and refrigerator), receiving correspondingly high levels of surface mechanical stress. This type of floor has the highest level of exposure to soiling, and thus requires more frequent and rigorous cleaning: hence subject to high levels of chemical stress. Walls are obviously exposed to low levels of mechanical stress, since they are not walked upon, but they are exposed to high levels of chemical stress from foods and detergents.

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meant to sustain loads, while a tiled wall need only sustain its own weight. For a ceramic floor, composition and size are significant in determining load-bearing capacity, while for a ceramic wall, the most important factor is the strength of the bond between the tile and the backing. Surface mechanical stress, then, can be substantial only for floors; it is negligible for walls.

❑ Location, interior or exterior, of the tiled surface

This factor is important especially in relation to the conditions of exposure to hygrothermic stress: conditions which are often severe outdoors (weather, sun, frost, broad temperature ranges, prolonged contact with water, etc.), and usually mild indoors. Indoor areas with high levels of hygrothermic stress include cold storage

areas,which are often covered with ceramic tiles; or areas whose function involves a high level of steam and prolonged contact with water (bathrooms, laundry rooms, industrial environments, etc.).

❑ Intended use of the building or the area: private or public, residential or industrial

Private residential spaces are generally exposed to relatively low levels of stress, except in cases that will be detailed in the next paragraph. Public spaces with heavy traffic (meeting halls, stores, churches, etc.), with trolleys and other means of transport (supermarkets, malls, waiting rooms and subway corridors, platforms and airports) are generally subjected to extremely high levels of mechanical stress, especially surface stress. Chemical

stress is high as well, due in part to the risk and frequency of contact with chemicals, but mostly to the particular demands for rapid and effective cleaning, which require chemically and mechanically vigorous cleaning methods. In such areas, like hospitals, schools, and restaurant or cafeteria kitchens, hygiene is a priority requirement: this need for thorough cleaning tends to raise the level of chemical stress. To this picture we add more safety requirements, typical of high traffic areas: safety from risks of falling (hence floors must have suitable levels of slip-resistance), safety from risk of fire, safety from risks connected with static electricity.

Industrial areas, depending on the specific manufacturing activities involved, are generally exposed to extremely high levels of every kind of stress.

❑ Further characteristics and conditions which are specific to a room

Substantial differences, especially in the level of surface mechanical stress, can exist between different rooms in residential spaces. Such differences must be considered in relation to the following factors:

- use of the room: levels of stress range from the very low, as on floors of bedrooms and bathrooms for night use, to much higher levels in entryways, hallways and stairs, especially where uni-directional traffic stresses a central pathway;

- location of the room and conditions of access: especially high levels of abrasion stress are predictable in rooms with direct access from outdoors, especially in cases where the outdoor walkway is covered in abrasive or loose materials that may adhere to shoes;

- use of the residence: this factor influences not only the intensity of traffic but also (and especially) the length of exposure to stress. Clearly a private vacation residence, inhabited for only a month or two a year, receives less stress than a residence lived in year round.

2.6 – Technical criteria of selection

The preceding analysis of the areas of intended use suggests important guidelines in the selection of tiles, which as we have shown are available in different types, with varying degrees of resistance to different types of stress, as documented in technical specifications.

The basic technical criterion which the Homeowner and the Specifier must consider

Examples of application of technical selection criteria

Here are several examples of the application of technical criteria, based on a comparison between expected stress and technical properties to be specified.

❑ Exterior floors and walls:
Select tiles with certified and declared resistance to frost. Generally these are pressed tiles with low water absorption, glazed (single-fired) or unglazed (porcelain stoneware), or extruded tiles (clinker or terracotta).

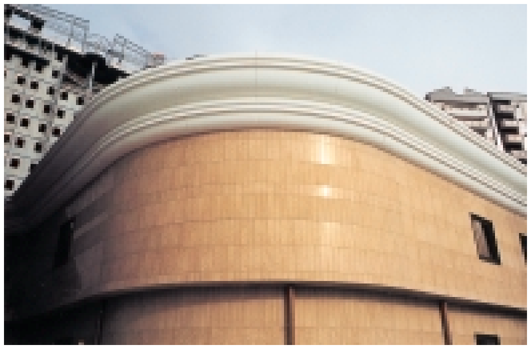
❑ Industrial plant floors:
The selection should focus on tiles with a compact support, since these possess superior mechanical properties, and generally greater thickness, with a resulting higher level of breaking strength. The tiles must be especially resistant to abrasion and chemicals, and the surface must be hard and compact so as to limit the penetration of soil and facilitate cleaning. In areas with a high risk of slipping, tiles with a non-slip surface must be selected (with appropriate roughness or reliefs). Occasionally porcelain stoneware or red stoneware or clinker tiles may be selected.

❑ Floors in public spaces, like cafes:
The selection must focus on glazed or unglazed tiles with higher degrees of hardness, and resistance to abrasion, stains and chemicals. Caution must be observed in using glossy glazed products, especially in cases where there is direct access from outdoors and hence more abrasive soil dragged in on the shoes of pedestrians: this creates the risk of rapid loss of shine.

❑ Entryway floor of a private residence:
The following guidelines should be observed:
– select tiles with appropriate surface mechanical properties;
– do not limit the selection to tiles of a high class PEI (for glazed tiles), but consider other surface properties as well (stain and chemical resistance and cleanability – all properties in some way associated with a compact and resistant surface);
– consider the possible effects on the tiled surface of other appearance factors, like color and chromatic "texture" (the process of abrasion generally increases soilability, and soil is more visible on light, solid color tiles and less visible on darker tiles with granulated texture), or glossiness (glossy surfaces show scratches more, and are likely to become dull in the more frequented areas).

❑ Kitchen floor and walls of a private residence:
For floors, tiles with especially strong surface mechanical and chemical resistance are recommended. For walls, which are exposed to little mechanical stress

in choosing a type of tile suitable to their respective needs is the fact that the selected tiles must possess mechanical, chemical and hygrothermic properties which are adequate to the relevant levels of stress.



but high chemical stress, tiles should possess strong chemical resistance (including resistance to acids and bases).

In other words, an area with high levels of mechanical surface stress will require tiles with a high degree of resistance to mechanical surface stress.

The failure to observe this criterion will inevitably create a risk of rapid and serious deterioration of the quality of the tiled surface, even if the type of tile selected is of good quality and meets all standard requirements for that type of tile.

The analysis of the area of intended use also suggests further important design guidelines regarding the choice of materials for the other layers of the tiled surface (especially the bedding layer, that is, the mortar or the adhesive), and also regarding the most suitable design solution. These aspects will be explored in the third part of this Manual.

2.7 – Aesthetic criteria of selection

We have seen that in order to fulfill their function as floor and wall covering, ceramic tiles must also satisfy aesthetic and design requirements: since they become a part of an environment's decor (or of the urban decor), they have a substantial visual impact on the environment in which they are installed.

The aesthetic properties of ceramic tiles, or rather the critical parameters or considerations for the satisfaction of aesthetic and design requirements, are basically three:

- ❑ the format, that is the shape (square, rectangular, etc.) and size of the tile;
- ❑ the color
- ❑ the decor.

These are clearly associated with the tile surface. The support, or body of the tile, meaning the part below the usable surface which is thus not visible, is absolutely irrelevant aesthetically (although, as we will see in the following chapter, it is of critical importance technically).

For every type of tile that we have considered in the preceding chapters, there are many thousands of products available on the market, all differing from each other in regard to the properties in question.

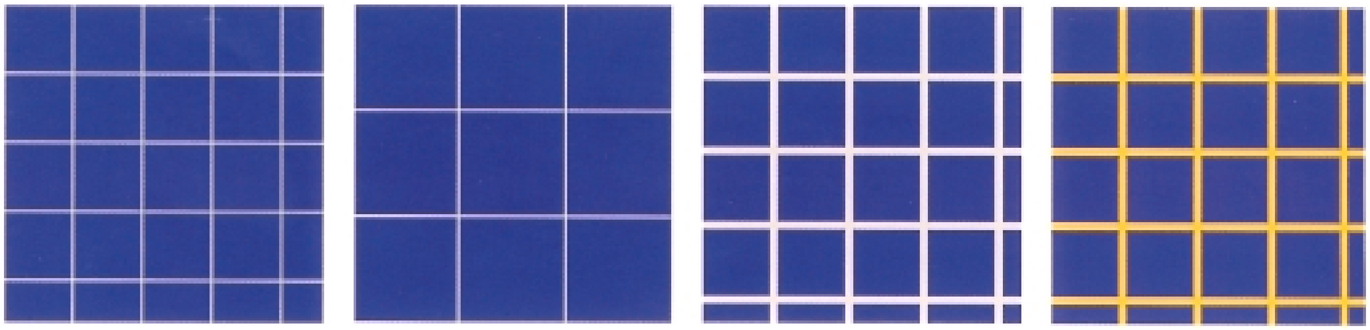
Format

The format of tiles significantly affects the visual impact of the tiled surface. The "density" of the framework of the joints is in fact a function of a tile's format: the framework appears increasingly dense and "visible" as the format grows smaller, while conversely it appears larger and less conspicuous if the format is larger. The visual weight of the framework of joints may be varied, within limits, by altering the thickness of the joints and the color of the material used to fill them.

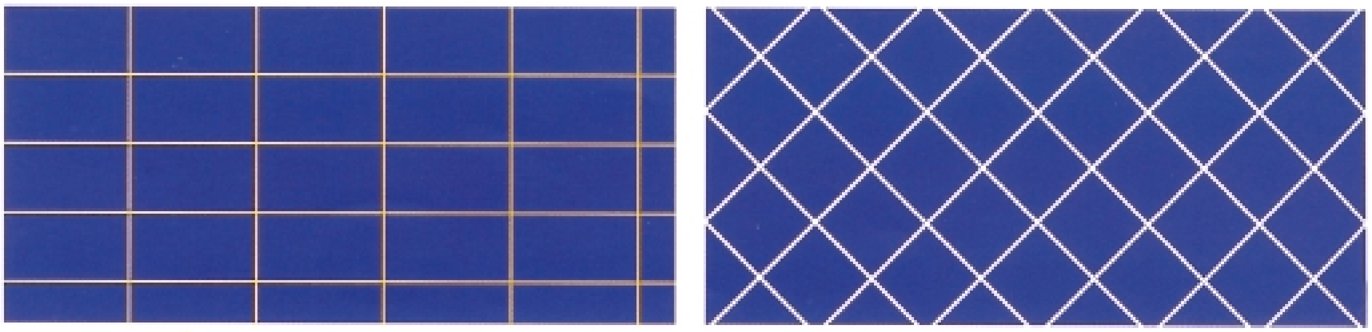
The most common forms for ceramic tiles are the square and the rectangle. Although these forms are very simple,

Format

Format and visual impact of joints. Comparative diagrams:

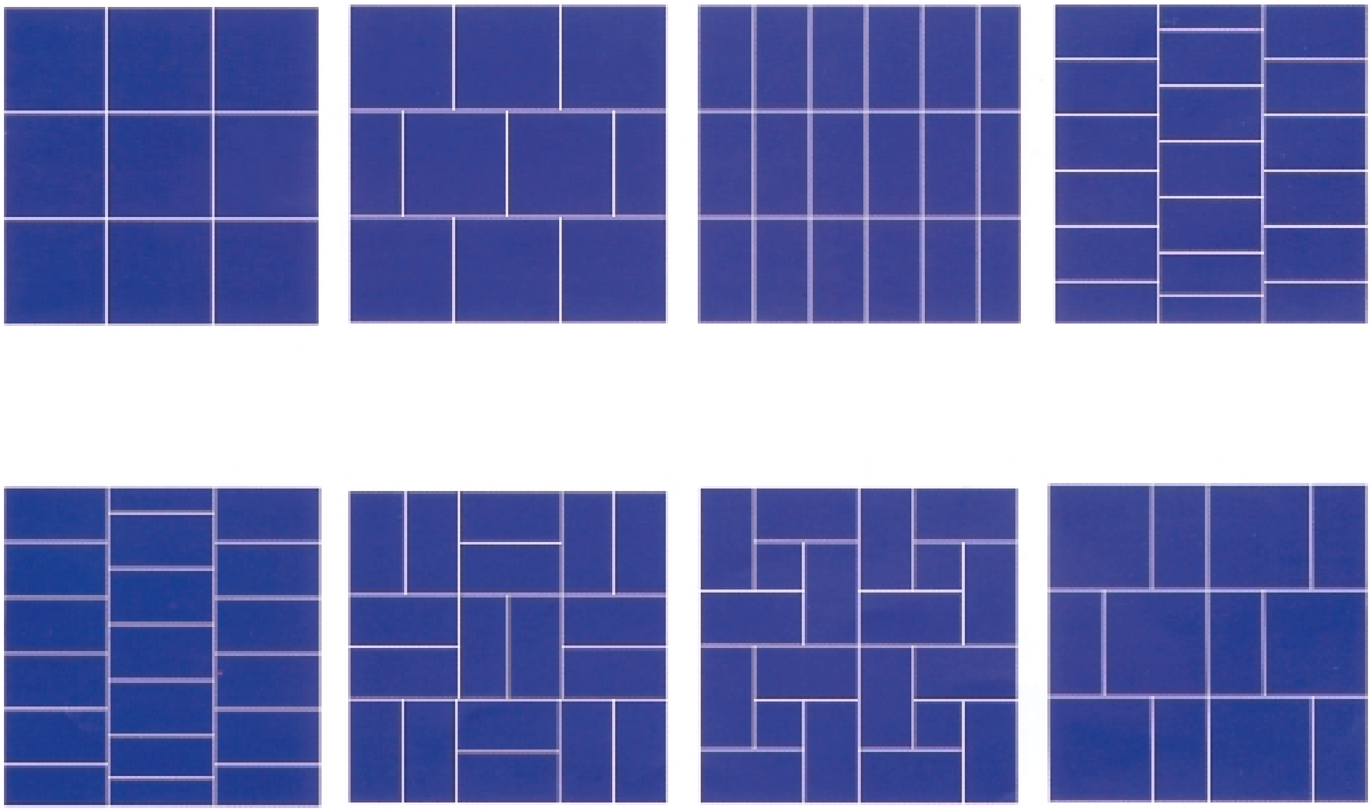


Parallel installation and diagonal installation



they yield a wide range of solutions, with an extremely diversified visual impact, even using the same tile. One need only change either or both of the following factors: the path of the joints (from continuous joints in both directions to offset joints), or the orientation of the joints in relation to the sides or the axes of the surface to be covered (parallel or diagonal).

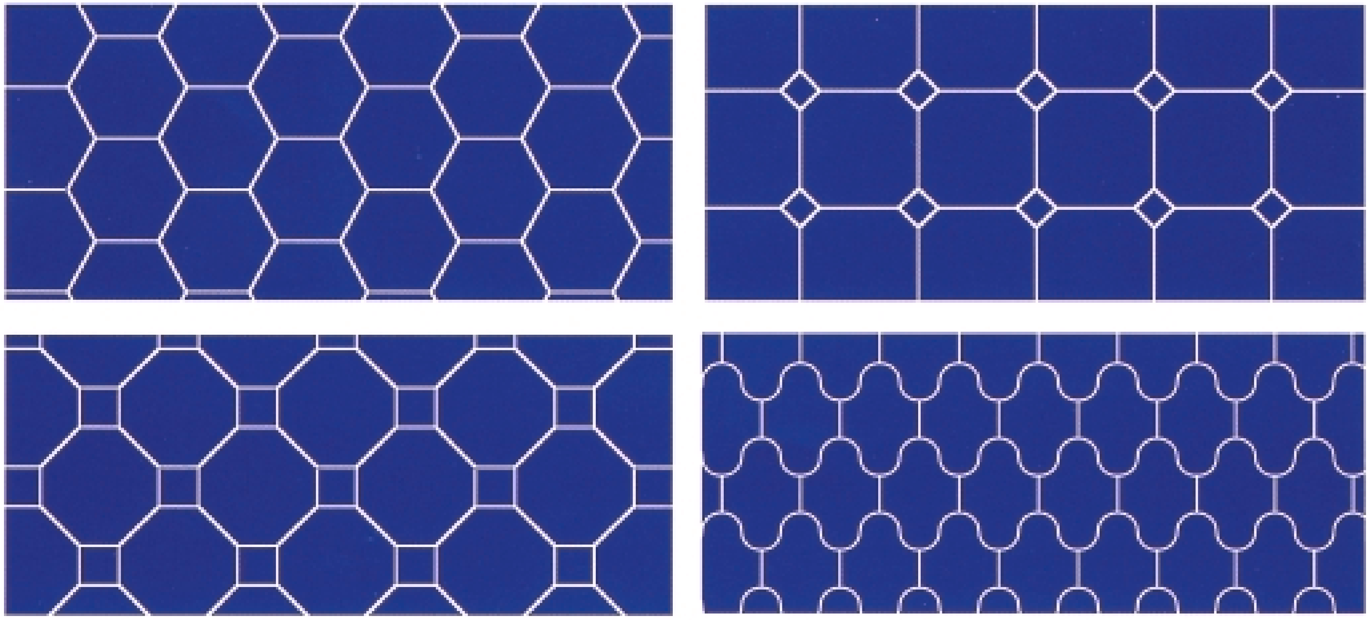
Examples of combinations of square and rectangular tiles



Further solutions are made possible by combining tiles of different formats.

If we consider all the design possibilities available within the same format, with available formats ranging from mosaic (with 2-3 cm sides) to slabs of 60 x 60 cm and larger, we can see that the range of aesthetically diversified solutions available is almost limitless.

Examples of other formats



It must be stressed that this variety of formats, and especially the availability of large formats for some products like porcelain stoneware, are available today but did not exist years ago. They are the result of intense and on-going research and development both in technology and in production, on which the Italian industry depends to reinforce its position of world leadership and its competitive status.

Besides the square or rectangular formats, others exist as well: hexagon, octagon, provencal, moorish, octagon and the like.

Color

In the case of glazed tiles, the color of the working surface is given by the glaze which, as we have noted, is a thin glassy layer covering the surface. The palette of colors available for ceramic glazes is virtually infinite: every basic color, every shade, every tonality can be technically produced, using the appropriate pigments and glaze. For the

Color

Glazed tiles

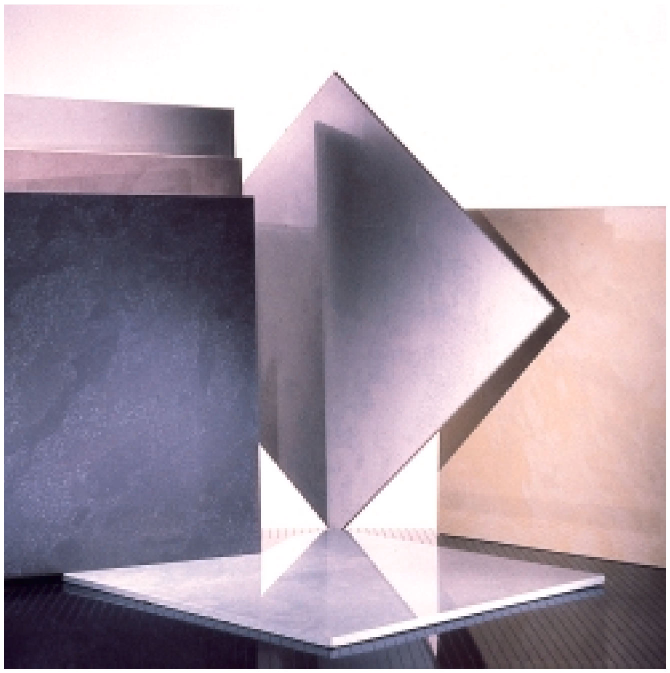
same color, tile surfaces may vary in glossiness (glossy or non-reflective, the latter called “matt” in the trade) and in chromatic texture. In brief, absolutely any color should be achievable in glazed ceramic tiles.

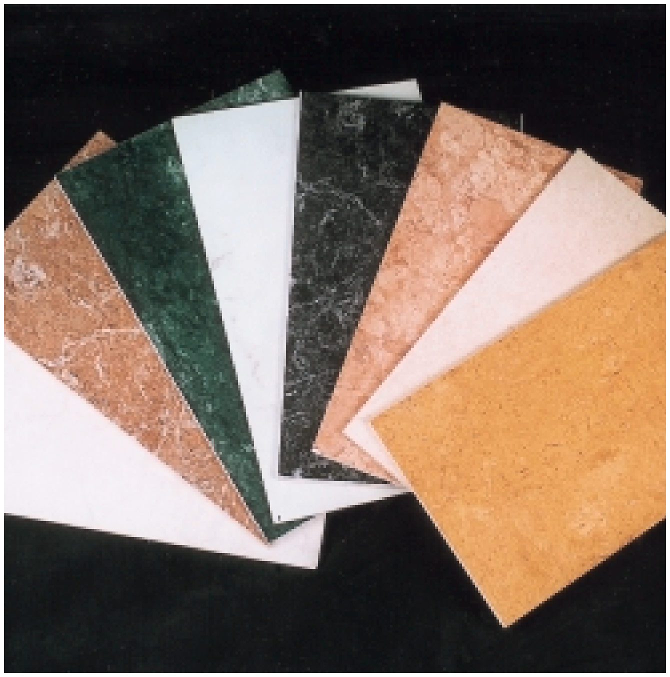
In the case of unglazed tiles, the issue is more complex. One begins with the fact that the color is basically the same for the support, and in fact depends on the support; this clearly limits the range of solutions.

Unglazed tiles

In a product like terracotta, the limited color range is not considered a “limit” but a virtue, a characteristic and identifying aspect: terracotta is beautiful, appreciated and sought after precisely because it is of that typical color (“terracotta” color); a color that evokes nature and tradition; a color to be enhanced (but not changed) by the treatments generally applied to tiled surfaces.

Porcelain stoneware does not possess a





similar uniqueness of color, so that the evolution and development of new products and solutions has taken an entirely different direction. From the neutral shades – from ivory white to gray – to which porcelain stoneware was limited a few short decades ago, when it was a strictly technical product with high performance properties meant for use in areas with few aesthetic requirements, it has gradually developed to include a

wider range of solid colors and subsequently granular color textures and imitations of some natural stones (among the commercial labels introduced are terms like “ceramic granite” and “ceramic porphyry”). New developments in this product type are in the area of increasingly accurate imitations of natural stone. These objectives are achieved, technically, by modifying the composition and the treatment of the initial powders, and by modifying the surface through techniques that create special effects (like veining, nuances, color blends and the like).

This wealth of color solutions is further enhanced by the possibility of creating glossy and reflective surfaces through polishing. Many porcelain products are thus available on the market with both untreated and polished surfaces.

Decor

As regards decor as well, considerations differ for glazed and unglazed tiles.

For glazed tiles, the range of possible decors is unlimited, thanks in part to advances in

Decor

Glazed tiles

the techniques of decoration. Silk-screening makes it possible to reproduce any design or photograph , however complex and multi-colored, on the surface of a tile. Any nuance, any color texture can also be achieved with specific glazing effects. Some decor details can even be created on the glazed surface after firing. Tiles decorated in this manner are then subjected to a further firing (third firing).

Some decors are contained within a single tile (so that each of the decorated tiles in a batch are identical), while others span several tiles, to be installed in such a way as to create a complex and larger design. The result obtained can approximate the look of a painting or a fresco.

Unglazed tiles are usually not decorated (except for the engobes sometimes applied to products like red stoneware). Once again

Unglazed tiles

porcelain stoneware is the exception: research on this product has led to the development of special decorating techniques with interesting results. Silk-screens, penetrating salts, decor inserts, satined motifs on a glossy background and glossy motifs on a satined background are just a few examples of the ever increasing range of possibilities available.

It should be noted that the reliefs achievable

can serve a technical as well as an aesthetic function: in fact they yield specific levels of slip-resistance, as required for specific environments and applications.

How best to take advantage of the wealth of solutions that ceramic tile puts at the user's disposition? A detailed and in-depth discussion of the design criteria of a ceramic tile, from an esthetic and furnishings point of view, would carry us into a field that is extremely wide and fluid, and in continuous evolution, hand in hand with ever more rapid changes in taste and fashion.

The fundamental rule that can be suggested to the Homeowner – if he would like to be the "designer" of his own tile, without taking advantage of the advice of the architect – is to begin, in this case as well, from a careful analysis of the destination environment. Its dimensions, the amount of tiling, the use and the location where the tiling is to be installed, the lighting conditions, the furniture and furnishings that will be located in that environment, the color, the chromatic weave and the material with which the walls will be covered in that environment, are all fundamental aspects to be considered. The tile must insert itself into this environment harmoniously and increase its value according to the personal tastes of the user. For this to happen, there must be an equilibrium, for example, between the size of the tile and its shape, between the color tones of the tile and the furnishings and the lighting, etc. The Homeowner, in making his own choice, must force himself to think about the finished tiled area rather than on the individual tile on a display card that he is given in the showroom. The tiled area in the environment where it is to be installed, that is the fundamental esthetic criterion of choice.

The Homeowner and the Specifier have now identified, from among the various ceramic tiles available on the market, the types that are best adapted to the respective technical and esthetic requirements, as a function of the destination environment.

In this journey, the Homeowner and the Specifier have been led to consider and “see” the tile not only as a material in itself, but also as a whole tiled area, as a “system” of which the tiles are only a part.
From a tile correctly chosen to a satisfying tiled area: this is the next stage.