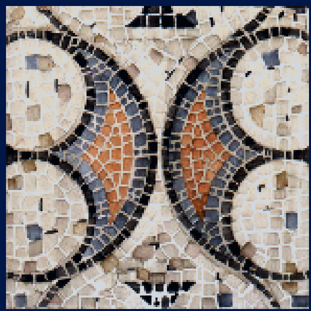
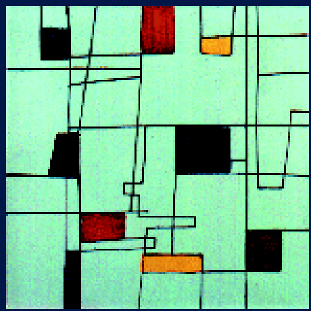
Giorgio Timellini Carlo Palmonari

How and why

Buyer’s and user’s guide to Italian ceramic tiles





Ceramic Tiles of Italy

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Introduction

Presentation

This is a guide to the purchase and use of ceramic tiles.

Ceramic tile is a construction material specifically intended to cover floors and walls. As a construction material, it is the purview of the professional engineer, just as bricks and

reinforced cement for buildings are. But as a finishing material that contributes to the look of an environment, ceramic tiles also have a design function, and must appeal to the final user.

The final user is not an expert in materials and construction but s/he has clear decision-making power in the selection and purchase of tiles; thus s/he plays an important part in the planning of the tiled surface.

Appropriate tile selection will critically affect the quality and durability of the tiled surface, and hence the user's level of satisfaction.

This guide is addressed to all those involved in the selection of ceramic tile, as well as to all end-users: both “professionals” in the field like designers, engineers and tile installers, and final users of the tiled area who are generally not technical experts.

The non-professional user we will call the Homeowner. In this guide she represents the final user of the tiled area: an individual with specific needs and expectations, but only scant technical knowledge of the materials involved or of construction parameters.

The professional user we will call the Specifier. In this guide he represents an expert in home construction and in particular of floors and walls covered with ceramic tile.

The structure of the guide reflects its double orientation: every issue is considered on two levels. One level is simpler and quality-oriented (but not superficial or obvious), and employs no technical terminology; this is addressed to the Homeowner. A second, more detailed level of inquiry, complete with data, measurements and methodology, is addressed to the Specifier.

We come now to the contents and structure of the guide.

The diagram on page 7 presents the Homeowner and the Specifier standing before a floor or wall that must be covered with a material that meets both their needs.
By the end of the process, we would hope that the Homeowner and the Specifier will cover the floor or wall with ceramic tiles for a successfully finished surface that is beautiful, lasting and safe. (We will consider each of these qualities below.)

The contents of this guide trace the stages of the process that will lead the Homeowner and the Specifier toward this resolution. Because there are three such stages, the guide is divided into three parts:

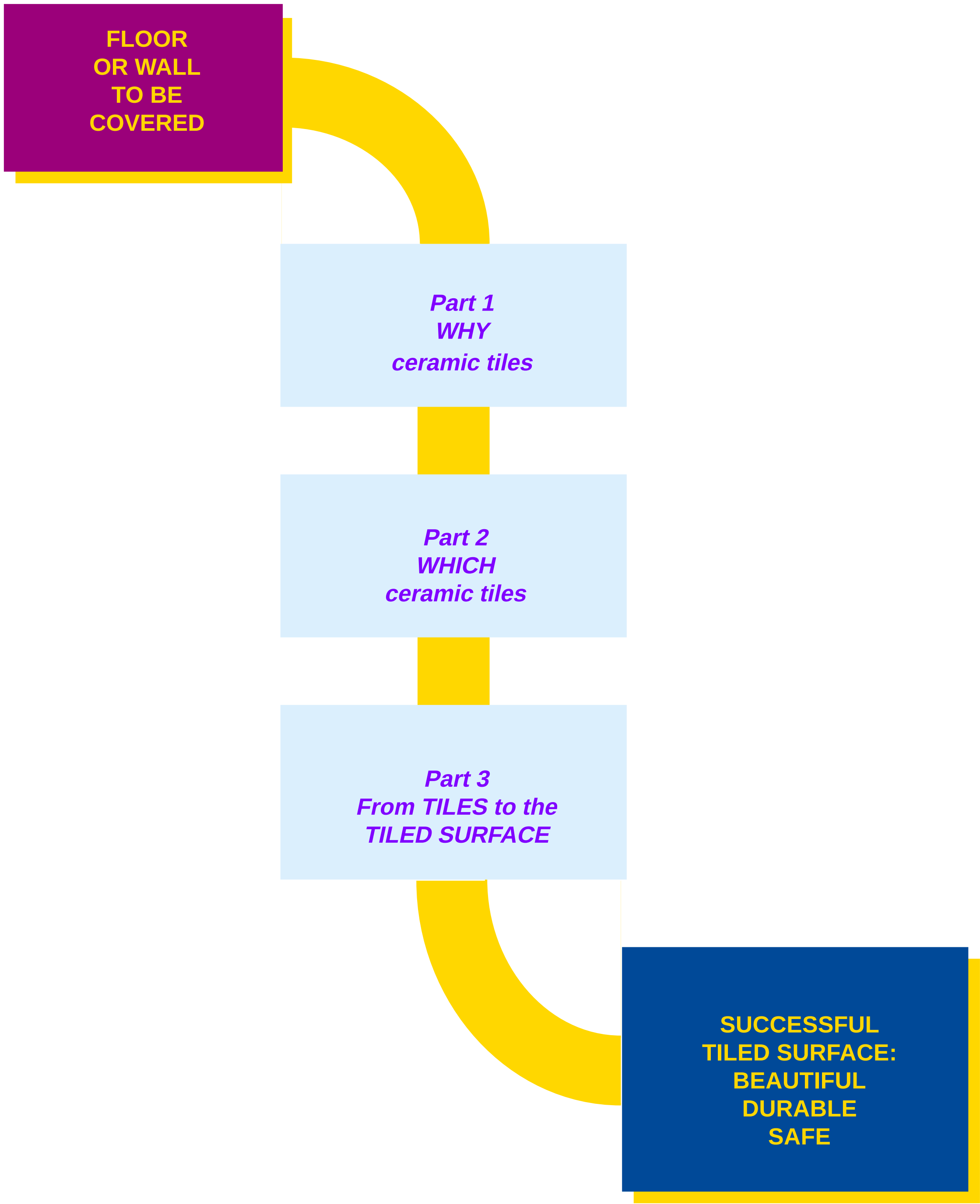
❑ *The first part* (WHY Ceramic Tiles) leads readers to consider the general properties of ceramic tiles in order to make an educated selection among them.

❑ *The second part* (WHICH Ceramic Tiles) follows the Homeowner and the Specifier as they identify the type of ceramic tiles most suitable for the area to be tiled, and most appropriate for their respective needs.

❑ *The third part* (From TILES to the TILED SURFACE) guides readers through an analysis of the various stages starting with the selected tiles and concluding with the actual tiling. The critical importance of these activities (design, installation, use and maintenance) is stressed so as to insure the full achievement of our final purpose: a beautiful, lasting, and safe tiled surface.

The structure of this guide clearly reflects its final aim.
The Italian ceramic tile industry is the world leader in tile quality and production and the originator of product and process innovations. Active on all world markets, it has vastly increased its product range in recent years to offer tiles distinguished by great beauty and ever more sophisticated technical properties. The range of environments in which tiles can be suitably used has expanded just as rapidly. The user of ceramic tiles enjoys an extremely broad selection, with infinite technical and design possibilities. This broad selection accounts for Italian tile's highly competitive status in the industry: a broad selection whose value is enhanced not only by the promotion of a broader use of ceramic tiles, but also by an all-important education in the correct use of these tiles, as a critical precondition to consumer satisfaction.

These are the multiple aims of this guide: to promote the value of ceramic tile, to highlight the advances made through intensive research and development, and to contribute to the complete satisfaction of an educated consumer equipped to make an appropriate selection and use of ceramic tile.


FLOOR
OR WALL
TO BE
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Part 1
WHY
ceramic tiles
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BEAUTIFUL
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SAFE

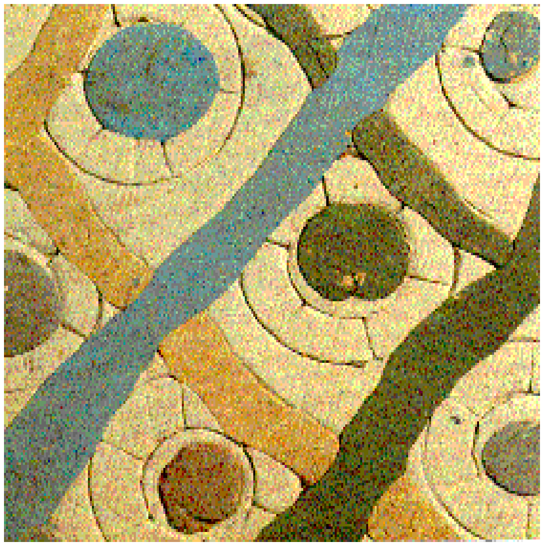
PART 1

Why

Ceramic Tiles

Introduction

As illustrated on page 15, the first stage begins as the Homeowner and the Specifier stand before a floor or wall that must be covered with a material that meets their specific needs.

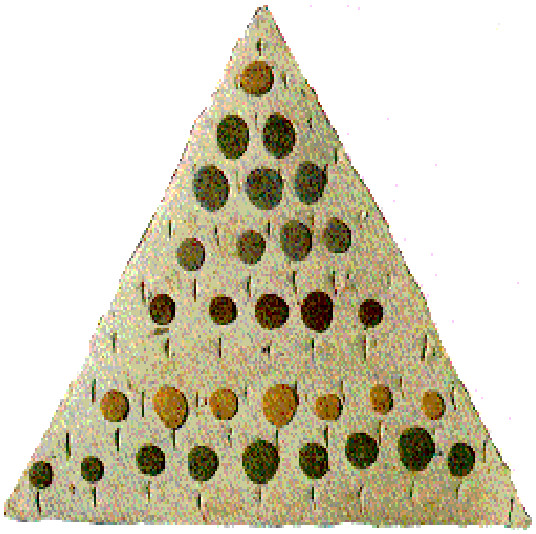


We wish to support our “users” in their decision to select ceramic tile, by offering some pertinent considerations.

The covering to be used on a given wall or floor must serve two functions:

❑ an aesthetic function, as a design element;

❑ a technical function, as a construction material capable of withstanding a range of environmental stresses without breakage or wear.



These two functions are basic and essential; both are indispensable.

The buyer/user knows that both these functions can be served, in theory at least, by various types of surface coverings. We say “theoretically”, since in general there are a variety of practical and economic options to choose from. In specific cases, though, the number of alternatives is much smaller, and sometimes only one material is technically suitable and economically advantageous.

In the first phase of this process, readers are guided to identify and consider, by general type, the variety of materials available (§ 1.1). These are strikingly diverse not only in appearance but in origin, production technique or treatment, composition, structure, properties and behavior. These are the materials that the Homeowner and the Specifier see on display in their visit to the showroom. The first choice must be made at this level.

The focus then shifts (§ 1.2) to ceramic tile, whose general properties (those common to all tiles and ceramic materials) are presented and illustrated with regard to manufacturing technology, structure and composition.

How does ceramic tile “rate” in terms of fulfilling the “aesthetic function?” Section § 1.3 considers the likelihood that the Homeowner and the Specifier will find a type of ceramic tile on the market that can fulfill their aesthetic and design needs. We see that the range of selection among tiles is almost limitless.

Functionality and durability, the subject of section § 1.4, concern a covering material's capacity to fulfill its technical function. The general properties of ceramic products, which stem from their structure, composition and production techniques, highlight the excellence of ceramic tile from this point of view. This "technical advantage" of ceramic tile also makes for an "economic advantage": the cost/ durability ratio is another aspect of the superiority of ceramic tiles over other materials.

The satisfaction of the user's aesthetic and technical needs cannot be separated from considerations regarding user safety and environmental responsibility.

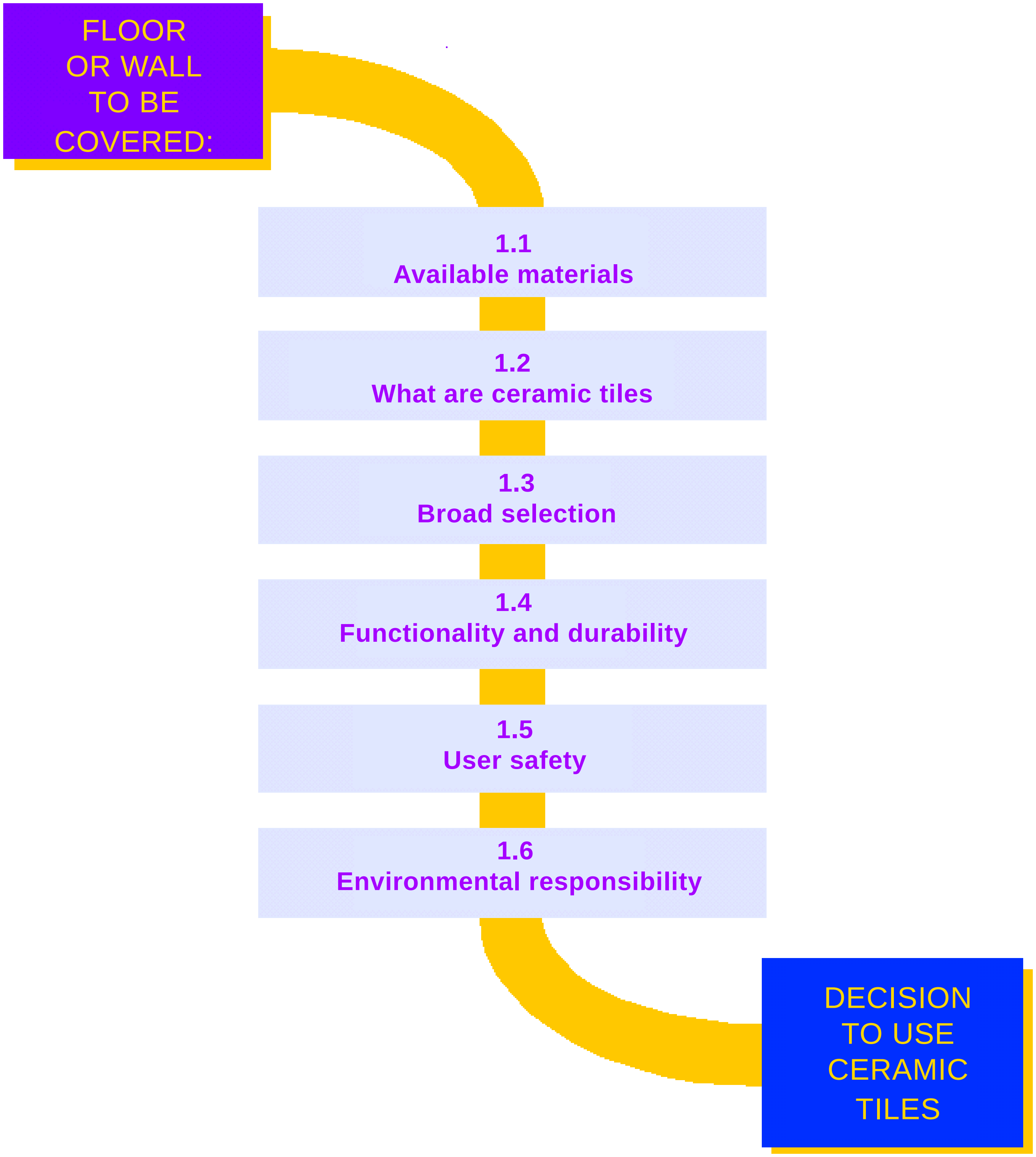
User safety is the subject of § 1.5, where several safety-oriented properties - properties which again stem from the ceramic nature of these tiles are highlighted and analyzed.

Finally, § 1.6 contains some considerations of the environmental impact of ceramic tiles over the course of their life cycle (from the mining of raw materials to the demolition of a tiled surface and its disposal). The life cycle also includes the production stage. From the early '70s on, the Italian tile industry has been committed to limiting the environmental impact associated with tile production. Today, Italy's industry is the world leader in the use of technologies that minimize both the consumption of resources like water and energy, and the leakage into the environment of polluting substances and materials. Ceramic tile can be considered an ecologically responsible material.

In brief, this section demonstrates that ceramic tile is

- ❑ *available in an endless range of styles* (colors, sizes, decors, surface textures, etc.);
- ❑ *functional and durable*, and hence ultimately economical;
- ❑ *safe*,
- ❑ *environmentally responsible.*

These considerations support the Homeowner and the Specifier in their decision to select ceramic tiles.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DECISION TO USE CERAMIC TILES

1.1 - Available materials

What floor and wall coverings must the Homeowner and the Specifier consider, at least in theory, when seeking a product suitable to their aesthetic and technical needs?

As our buyers enter a well-stocked showroom, they face a vast selection of choices: materials of various kinds, shapes and origins, with different looks, technical properties and uses. In what follows we will clearly present these various materials, offering some considerations in support of a buyer's preference for ceramic tiles.

For current purposes we will not distinguish between floor and wall tiles, between tiles exclusively for indoors and those for outdoors as well, or between tiles suitable for many environments and those for specialized use. As a result, not all the materials listed may actually represent true alternatives, in serving the needs of the Homeowner and the Specifier. However, a general overview of available materials will be useful in supporting the following two concepts that the buyer of any type of floor or wall covering must bear in mind:

❑ *every property of a material* - whether technical or aesthetic - is based in its nature, composition and structure;

❑ *every material,* of any kind, must be selected and used in the proper manner; and the user's aesthetic and technical expectations must be based on the properties - that is, the nature, composition and structure - of the material.

Materials of different kinds

A first criterion for classification of available floor and wall covering materials is the material's “nature”. The categories are as follows:

Materials of different kinds

The nature of a given material corresponds to its specific structure and composition, and hence to its technical and aesthetic properties. Deferring until later a preliminary discussion of technical properties, we consider here how every material is associated, in the user's mind and expectations, with a specific aesthetic impact [look and feel] that evokes a particular response. A textile, with its weft and its “thickness”, creates a sense of softness, silence and warmth, whereas a shiny, hard surface, even one of the same color as the textile, creates an effect of brightness, cleanliness and strength.

Ceramic

products obtained by mixing raw materials widely available in nature (clays, sands, etc.), and working this mixture in its unfired state into the desired form. The product is then dried and fired at temperatures from 1000(C to 1200 (C , depending on the composition and type. It may be glazed or unglazed. Examples: ❑ *ceramic tiles, bricks*.

Stone

tiles or slabs obtained by cutting blocks of particular rocks available in nature. Examples: ❑ *natural stones, like marbles and granites.*

Bonding materials

unshaped materials that are ceramic in nature (and hence obtained by firing mixtures

of raw materials containing clays and carbonates, or calcium sulfate, etc., which are then ground to a fine powder). They include cement, chalk and plaster. Such products, mixed with water and sand, form pastes which set and harden over time. This property can be used in making layers of covering for floor and walls.

Examples: *❑ cement-based plaster, chalk-based wall coverings, ❑ cement bedfor flooring.*

Composites

a mix of stone fragments scattered in a cement or polymeric bonding material, to be applied on the floor surface. These materials are available also as slabs or tiles.

Metals

metals are rarely used as materials for floor or wall covering. Some metallicized wallpapers are however available, although these are actually composites made of a thin layer of aluminum, whether solid color or print, soldered to a non-flammable paper backing with a layer of synthetic resin.

Polymers

synthetic organic materials, commonly termed “plastics”. Such materials are useful for making rolls of material or tiles (like vinyl, linoleum and rubber for floors, or vinyl wall-covering), or synthetic fibers for textiles (like polyester- or polyamid-based carpeting).

Vegetable or animal organic materials

organic products like those described above, but obtained from materials directly available in nature, in the animal or vegetable world.

Examples: ❑ *wood,* ❑ *cork (for wall and floor coverings),* ❑ *wall-paper,* ❑ *fabrics (carpeting) in natural fibers (wool, cotton).*

Materials in different forms

The above-listed materials are available in different forms. which obviously affect installation techniques and appropriate use. From this perspective, we can divide the materials in question into three main types:

Rolls of material

Examples: ❑ *vinyl* ❑ *linoleum* ❑ *rubber* ❑ *carpeting* ❑ *cork* ❑ *paper.*

Tiles, slabs, etc.

Examples: ❑ *ceramic* ❑ *bricks* ❑ *conglomerates* ❑ *natural stone* ❑ *wood* ❑ *cork* ❑ *vinyl* ❑ *lino-leum* ❑ *carpeting.*

Loose materials used in installation

Examples: ❑ *plaster* ❑ *screeds* ❑ *conglomerates.*

➔ **Materials of different forms**

Materials in rolls (as well as materials of the same kind in tiles, like carpeting and vinyl) require relatively simple installation techniques, and are thus available to non-professional do-it-yourselfers: the roll needs only to be glued to the properly prepared floor or wall surface to be covered. The speed of installation is greater than for other materials, and the process of replacing such covering materials is simpler. Tiles and slabs- especially ceramic, natural stone, conglomerates and wood - require more complex application techniques, which recommend the use of professional installers. Installation is a lengthier process, since an actual substructure must be built to insure both the visual appeal and the functionality and durability of the installation. Replacing tiles is also a lengthier and more difficult matter, since it requires the demolition of the existing surface, the preparation of a new one and the installation of the new material.

Materials with various properties

Every type of material (like ceramic materials, plastic, etc.) has a unique structure and composition, and hence also unique technical properties relevant to use and behavior. The broad classification most commonly used, from this perspective, divides materials into two groups:

Materials with different properties

The property of hardness signifies in essence a resistance to scratching, scoring and puncturing by pointed implements, and hard materials are in general less vulnerable to such stresses. Hardness is associated with resistance to wear and tear, an important property, as will be discussed below in connection with ceramic tile as a floor covering material. These materials are also highly resistant to compression: installed and well anchored to a floor, they are highly resistant even to extremely heavy and concentrated loads (like furniture legs), without buckling or perforation. Hard materials are highly resistant to deformation: they are rigid and thus will not fold or grow appreciably shorter or longer. However, they are also fragile: this does not mean that they are "weak" - in fact they are quite "strong", as noted above - but it does mean that, when subjected to an extremely heavy load, or to impact from an equally hard body, they may break suddenly, without warning or first suffering deformation (as occurs instead with ductile materials). Hard materials are therefore "non resilient".

By contrast, "soft" materials are more easily deformed, shock-resistant, and, in many cases, sufficiently resistant to puncture (so that they are often "resilient"). However, their surface mechanical properties are notably inferior: they are more vulnerable to cuts, scrapes, scratches and wear and tear.

“Hard” materials

Typical examples: ❑ *ceramic* ❑ *natural stone* ❑ *conglomerates.*

“Soft” materials

Typical examples: ❑ *carpeting* ❑ *vinyl* ❑ *rubber* ❑ *cork* ❑ *wood.*

In this context, ceramic tile can be described as follows:

❑ *nature:* ceramic

❑ *format:* tiles / slabs

❑ *property:* “hard” material.

1.2 - What are ceramic tiles

Ceramic tiles are variously sized slabs of ceramic material, used to cover floor and walls.

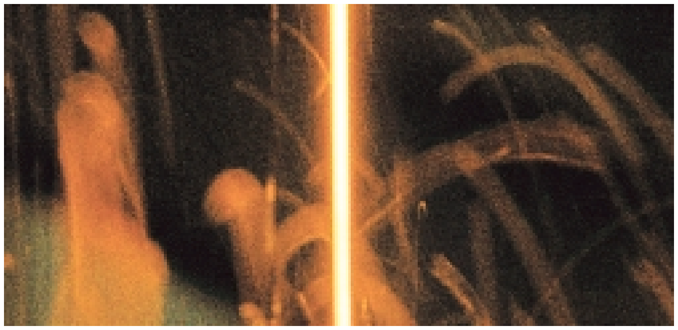
A slab (or tile) is defined as a "component with a flat surface, whose length and width are distinctly greater than its thickness". Tiles come in different sizes, ranging from mosaics whose surface measures less than 90 cm^2, to tiles with sides as long as 1 meter. The thickness of tiles ranges from about 5 mm for some small wall-covering tiles, to 20-25 mm for extruded and large-sized tiles.

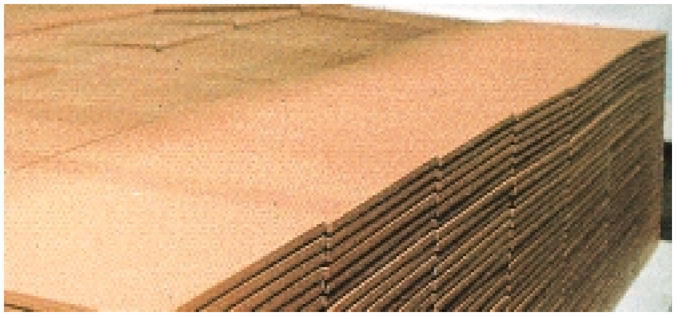
The term "ceramic" describes the kind of material that composes the tiles. As suggested in the section above, the term "ceramic" refers to products derived from mixes of clays, sand and other natural substances. After proper treatment, such mixes are molded into a desired shape and then fired at high temperatures (from 1000°C to 1250°C, depending on the type of tile). There are many ceramic products in common and everyday use for the Homeowner: for instance, kitchenware (plates, cups, etc.), bathroom units (sinks, bidets, bowls, etc.), brick-type materials (bricks, roof tiles, flooring slabs, etc.). Ceramic material is one of the oldest human products: consider terracotta statues and vases, witnesses of remote civilizations. But it's also one of the most contemporary and progressive materials: special ceramic materials are coming into increasing use in the electronics and chemical industry and for machinery and nuclear plants.

The general properties of ceramic material, and hence of tiles, are traceable to their structure and composition, as determined by their specific type of production. These general properties are:

- ❑ hardness and mechanical strength
- ❑ rigidity
- ❑ fragility
- ❑ inertia.

The "hardness" - which as we noted in the previous section, is a distinctive property of ceramic tiles as opposed to other families of materials - is the result of reactions and transformations that occur in the tile body during firing. These reactions lead to the formation of a partially glass-like structure, compact and with a high level of internal cohesion: in brief, a "hard" material. The





specific nature and strength of the chemical bonds created among the elements that compose this structure make ceramic tile highly resistant to breaking and also to damage: like all ceramic materials, tiles cannot be deformed or bent: they are "rigid", even under loads heavy enough to break them. A material which reaches a breaking point without first buckling (or undergoing a "plastic" deformation, to use the technical term) is termed "brittle", while a material that behaves in the opposite way is called "ductile". It must be stressed that brittleness is not a defect. Brittleness is associated with a moderate degree of shock-resistance that typifies all ceramic material: just as a plate may break when dropped, so too a tile that receives a blow - for example, from the impact of a heavy falling object - may break. A ceramic tile floor, therefore, is not "resilient" the way that a vinyl floor is.

The compounds formed in the ceramic high-temperature firing process are stable compounds that tend to react either not at all or extremely little with other substances or with the environment. Ceramic tiles are hence "inert". Ceramic materials are insoluble and inalterable not only from contact with water, but also with most chemical substances (only a particular acid, hydrofluoric acid, is able to dissolve glass, and therefore also ceramic). This inertia occurs not only at room temperature, but also at high temperatures: not even the flames of a raging fire can alter the composition of ceramic tiles: a material produced through a firing process at temperatures higher than 900°C.

Ceramic tile is, we repeat, a floor- and wall-covering material. Although its hardness and mechanical resistance gives ceramic tile the capacity to sustain relatively heavy loads, it remains a covering, which must be seen as intimately linked to the basic structure on which it is applied. It is this basic structure that must serve the load-bearing function,

The making of ceramic tiles

Ceramic tiles are made through the same process that typifies most ceramic products. The process involves various phases during which, through a series of treatments, the initial raw materials are gradually transformed into the final product, the ceramic tile.
Ceramic tiles can be either glazed or unglazed. In glazed tiles, the surface is covered with a relatively thin layer of basically glassy material whose composition differs from that of the body of the tile (the bisque); the function of this surface is to lend aesthetic properties (like color, shine, design) and technical ones (like impermeability and hardness) that the body alone cannot insure to the required degree. Therefore glazed tiles are composed of two layers of differing structure and composition: the surface glaze and the underlying body. By contrast, unglazed tiles are homogeneous and uniform throughout.
The manufacturing process varies in detaildepending on the type of product, glazed or unglazed, to be produced. Roughly speaking there are three basic cycles (Fig. 1) involved in the production of the entire range of ceramic tile types, as will be illustrated in Part 2 of this guide.
The first cycle pertains to **unglazed tiles**.
The second cycle pertains to **glazed double-fired tiles**. This process is so named because it involves two distinct thermal treatments, one to consolidate the body and one to stabilize the glazes and decors, which (as the diagram illustrates) are applied to the fired body.
The third cycle pertains to **glazed monocottura tiles**, a process during which glazes and decors are applied to a body before firing, so that only one final thermal treatment is involved. In a "mono-cottura" or "mono-firing the ceramic body is consolidated and the glazes are stabilized simultaneously.

The raw material department.

Raw materials for the body

The mixes for the manufacturing of ceramic tiles are blends of various raw materials, including:
❑ *clay-like raw materials*, whose function is primarily to give the humidified mix the plasticity needed in to order to obtain, through a shaping process, tiles which already in their unfired

not the tiles that are applied to it. Take the case of a floor covered with ceramic tile: it will not break under heavy loads (the weight of people walking on it, or the weight of furniture or even moving vehicles), only if the tiles are properly anchored to the foundation.

In order to achieve a durable tiled surface, it

Mills for wet grinding of tile body raw material.

state have the mechanical properties that will allow them to be manipulated, transported and moved;

❑ *quartz-like raw materials*, composed basically of quartz sand, whose function is to form the virtual skeleton of the ceramic body: a structural and reductive function, needed to limit the dimensional variations that invariably result from the treatments of drying and firing;

❑ *feldspathic and carbonatic raw materials*, containing feldspaths (silico-aluminates of sodium, potassium, calcium etc.) or carbonates (especially calcium), whose function is to produce, during firing, a melted, viscous phase, which results in the relatively glassy and dense structure of the finished product.

The preparation of the mixture

The preparation of the mixture consists in a series of operations that homogenize the material, with the appropriate grain size distribution so as to be relatively fine, and with enough water for the subsequent molding process. At the end of this phase, the mixture may consist of: a powder with a 4-7% water content (for pressure molding); or a 15-20% water content (for extrusion molding) In both cases, the basic operations of this production phase are three: grinding, mixing-blending, and regulating the water content.

Some comments must be made on the preparation of powders for pressing (in regard to the shaping technique used in over 95% of Italian ceramic tiles). There are two available techniques: the *dry method*, that consists in a dry grinding of the raw materials and the subsequent regulation of humidity by means of special humidification devices, and the *wet method*, consisting of the grinding of the raw materials in water, and thesubsequent spray-drying (atomization) of the resulting suspension or slip. The choice between these two processes depends on the kind of mixture and on the qualities of the product to be made.

Shaping

Most of the tiles produced in Italy are molded by dust pressing. During the is thus of critical importance that the tile installation be correctly planned and implemented, as we will see in the third part of this guide.

It is not too soon, though, to stress that a thin slab of ceramic may be hard and resistant, but it is not made to independently fulfill a load-bearing function.

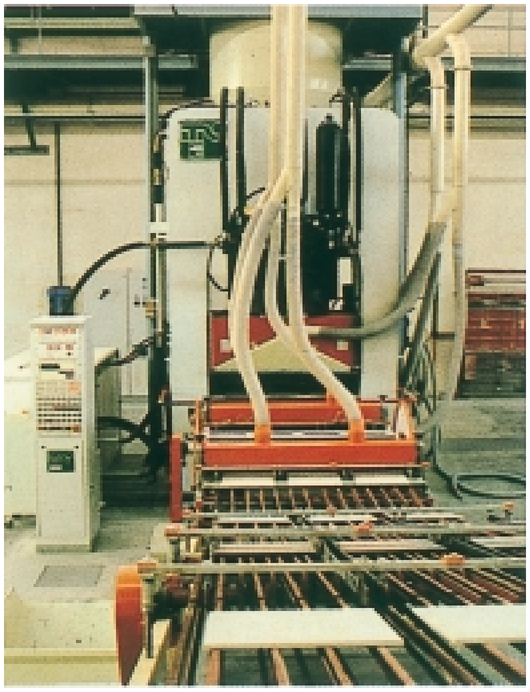
pressing process, the mixture — a powder with an average humidity of 4-7% — is compressed between two surfaces, with an average pressure between 200 and 400 kg/cm^2 that causes the reorganization and partial deformation of the grains, so as to produce a sufficiently dense and resistant tile.
Some products (terracotta and clinker tile) are molded by the plastic method, starting with a mixture whose humidity content ranges from 15 to 20%, depending on the type of product. A continuous ribbon of material is emitted by the extrusion machine, and is then cut as desired.

Drying

The drying phase has the important function of removing water from the shaped product The conditions for removing this water from the mixture are critical to the integrity of the product, and hence must be rigorously monitored so as to prevent distortions, cracks or other damaging phenomena.
The most commonly used dryers in the ceramic tile industry today are hot air rapid dryers.
These are used in such a way as to both heat the material (to draw the water from the interior to the exterior), and evaporate and remove the water from the surface of the tiles.
The speed of this process (which takes about 30-60 minutes) depends on proper conditions for thermal exchange, adequate ventilation and the relatively high temperature of the air for drying.

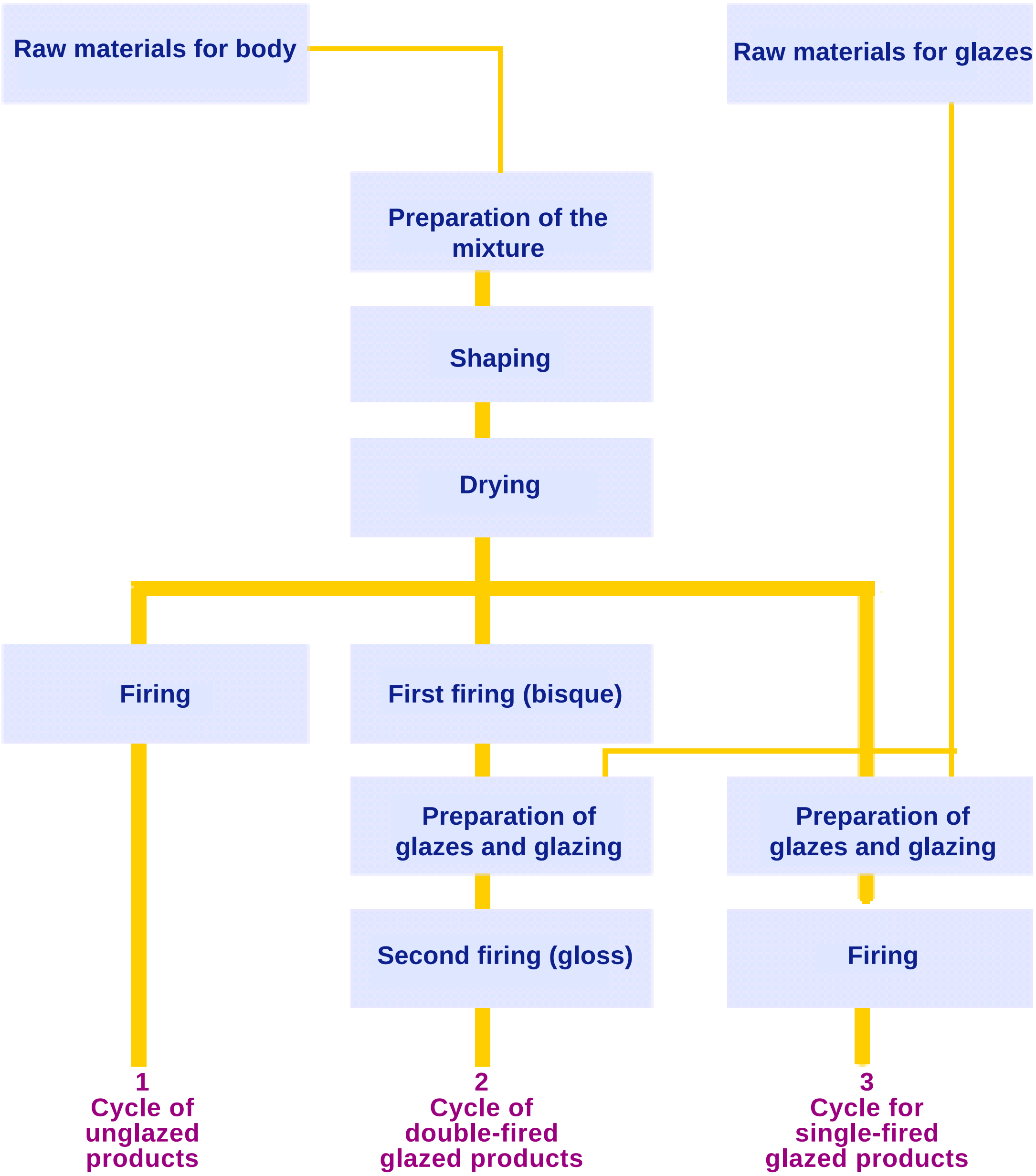
Glazes and glazing

Glazes are mixtures of different minerals and composites (frit, which is prefabricated glass, kaolin, silicious sand, various oxides, coloring pigments) that are applied to the surface of the tile and then fused to it.
During the subsequent cooling phase, the fused layer hardens to form a layer of glass, which gives the tile surface the specific properties noted above.
The preparation of the glazes consists of the dispensing of the various raw materials and their grinding in water, so as to obtain a suspension containing about 40-50% water which is ready for application.
This glazing process



Tiles coming out from the presses.

Fig. 1 - Technological cycles for the manufacture of the different types of ceramic tiles.



can be performed either on a fired body, in the double-fired process, or on a body that is simply dried, as in the case of monocottura tiles.
The instruments for application are various (bell-waterfall dripping or orifice machines, disk-sprayers, aerographs) and are integrated into entirely automated systems which also include decorating equipment such as silk-screen machines.
Decorations can be added even after the glaze is baked; this requires a third firing.

The firing

As is the case with all ceramic materials, tiles emerge from the firing process with the mechanical properties required for their various specific uses, and the associated properties of chemical inertia.
These properties are achieved through chemical reactions and physical

transformations of both the tile body and, in the case of glazed products, the glaze.
The firing takes place in continuous ovens consisting of tunnels where the tiles are moved along on special transportation systems, which lead them to be first preheated and then brought to firing temperature (which ranges from about 900 °C to over 1250 °C, depending on the product).
The tiles are kept at firing temperature for some time, after which they are gradually cooled - while still inside the oven - to a temperature that will allow them to be safely removed from the oven.
In the course of the firing, various reactions and transformations take place that determine the properties of the product.
At high temperature a suitable melted phase is formed, which binds all the particles firmly together and leads to the creation, after cooling, of a strong structure.
These structural transformations, which are important in relation to the microstructure and the application properties of tiles, are further accompanied by a rearrangement of the particles, with size shrinkage that is generally greater in cases where the desired product is less porous.
The firing is the production phase that has most conspicuously evolved in the last ten to fifteen years.
In the 1970s, ceramic tile ovens were almost all tunnel ovens in which tiles were loaded and moved in piles or boxed in special refractory supports.
These ovens featured firing cycles of 12 to 24 hours, depending on the type of product and the type of loading.
Toward the end of the 70s, the single-layer rapid firing method was introduced, in ovens where the material to be fired is loaded in a single layer and moved on rolls.
The firing cycles in these ovens range from about 40 to 70 minutes, depending on the type of product, with further basic benefits regarding energy conservation, evenness of firing, temperature regulation consistency, flexibility and automability.

A fast firing one layer kiln for ceramic tiles.

The selection

The firing is the concluding technical phase of the production cycle of ceramic tile.
The material that emerges from the oven is the final product, with the exception of specific surface treatments for some types of products, like the polishing of porcelain tiles.
Before they are sent to be packaged and warehoused, tiles undergo a careful selection.
The functions of this phase are basically three:
❑ elimination of defective pieces;
❑ separation of top-grade from inferior grade tiles;
❑ grouping of tiles by category, by work size and by chromatic tonality (so-called “tone”).

In Section 1.1, we saw what materials were available on the market for floor and wall coverings; in Section 1.2, we introduced ceramic tile, highlighting a few of its intrinsic properties associated with, its composition and production methods.

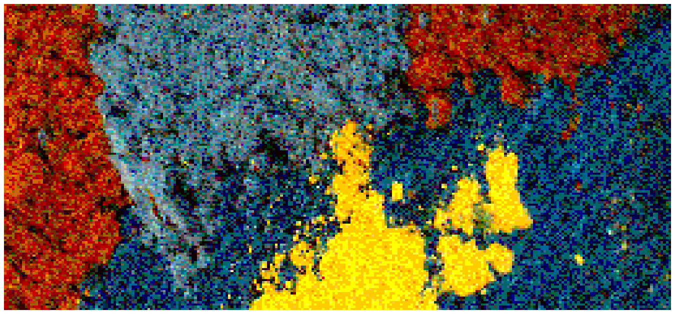
We will now lead the Homeowner and the Specifier to reflect on some important consequences of the concepts here presented, and to consider how effectively ceramic tiles serve their particular needs.

1.3 - Broad selection

The Homeowner and the Specifier have distinct personal tastes and aesthetic and decorating needs. How likely are they to find ceramic tiles that suit these tastes and fulfill these needs?

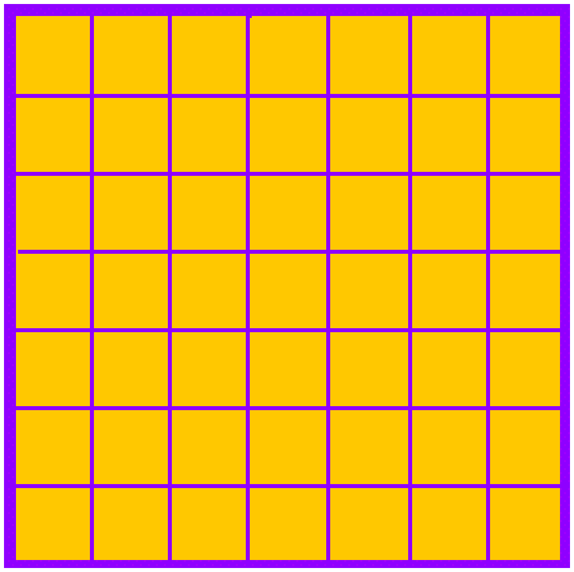
Ceramic tiles are obtained through the various combinations of many raw materials, for the purpose of obtaining products with pre-defined properties.

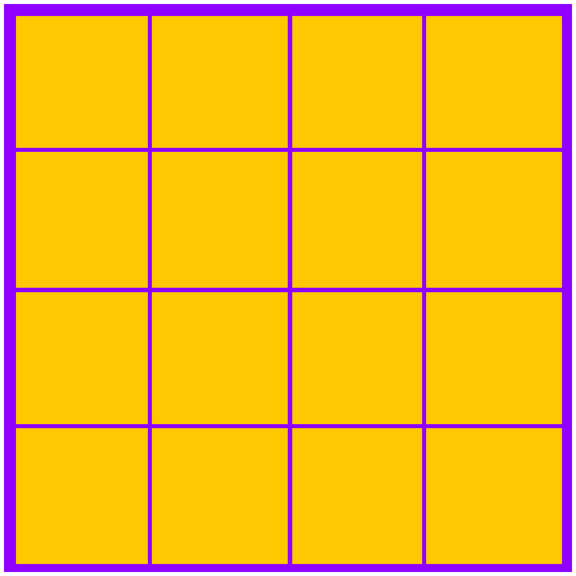
Consider any color, any chromatic texture, design or decor: ceramic technology can reproduce it. The palette of colors obtainable with ceramic glazes is indeed infinite. Furthermore, any shade can be executed in a glossy finish or a non-reflecting (mat or satin) one. Existing



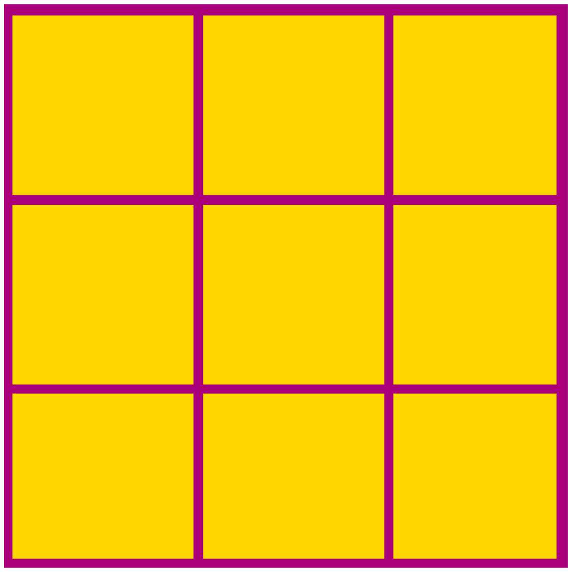
techniques allow for the faithful reproduction the most complex and articulated design, like a painting or a photograph. Even the surface of a natural stone like marble or granite can be reproduced in ceramic.

For unglazed tiles the possibilities are slightly less vast, but even here, the range of expressive options has broadened greatly in recent years. Porcelain is by now available in a wide range of colorations, thanks to the use of special pigments in the mixture. For unglazed products, the coloration is uniform for surface and body. Solid colors can be created, as well as more complex chromatic textures (such as granular looks, with grains clearly outlined against a background, or with overlapping grains and areas of solid color, as is the case with some natural stones). Further



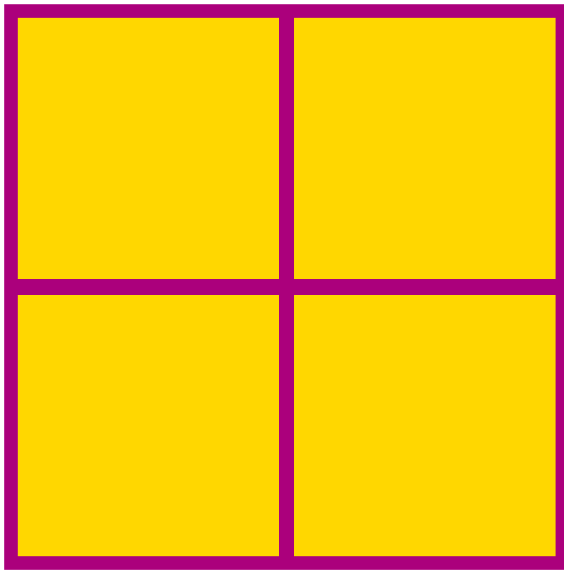


expressive possibilities are created, especially among unglazed tiles, by surface reliefs that can be introduced in the pressing stage to achieve any design in relief or any degree of roughness.



Equally vast is the selection of formats. A tile's format is its shape and size. The format of the pieces that make up the tiled surface creates a distinct aesthetic effect, no less than the color and decor. Shape variations will alter the "network" and the visual impact of the connections between the various tiles, to achieve a startling range of distinctive decorating effects.

The most common shapes are squares and



rectangles, but other polygonal shapes (hexagons, octagons, etc.) are also available, as well as more complex forms including Moorish, Provençal and the like. At least in theory, current technologies

allow for the creation of any shape. As for size, tiles range from only a few centimeters a side (mosaics) to slabs as long as a meter wide.

In conclusion, the Homeowner and the Specifier are sure to find ceramic tiles on the market with a color, design and format that meets their specific design needs, whatever these may be.

The broad selection of ceramic tiles available today is due not only to the versatility of the ceramic process, but also to the ongoing research and innovations of the Italian ceramic tile industry.

Today's large sizes, as well as many of the colors and decors, did not exist a mere ten or fifteen years ago.

So as the Homeowner and the Specifier consider selecting ceramic tile, they are choosing a product with high technological content, the product of intense research that distinguishes the Italian industry around the world.

1.4 Functionality and durability

Among the critical requirements for their floor and wall covering, the Homeowner and the Specifier must include functionality and durability.

❑ The concept of "functionality" is associated with the types of application and restoration. A covering will be that much more functional if its installation and its maintenanceare simple. By maintenance we mean the set of operations required to re-establish and maintain the surface finish of a covering material so that it fulfills its technical and aesthetic functions.

❑ The concept of "durability" has to do with time: the time over which, in the specific conditions of use and maintenance, the surface finish will continue to exhibit the technical and aesthetic functions for which it was chosen This time comes to a close when the finish has deteriorated enough to be no longer "functional" in the sense described above. At this point, no ordinary or special maintenance can recover the functionality of the surface finish, which has thus come to the end of its "useful life", and must be replaced. It will not escape our users that the question of durability has important economic implications.

The Homeowner and the Specifier wish to select a covering material that is functional and lasting. What are their chances of finding an answer to their needs in ceramic tile?

Let us first consider functionality, in terms

of ease of installation. We have seen that ceramic tiles are slab-shaped and thus require, for the covering of a floor or wall, a strong, firm bonding to a support that has been properly designed and prepared. As the third part of this guide will show, the installation of ceramic tiles is a relatively complex process, which generally requires the involvement of professionals both in the planning stage and in the execution. Ceramic tiles, like all hard materials of the same shape (for example, natural stones like marble and granite) cannot simply be “glued” onto the surface to be covered.

The strength and tenacity of the bond between the ceramic tile and the support are not only a basic requirement of a successful installation but also a guarantee of the installation’s durability. There are tiled surfaces that are still perfectly functional and intact many decades after their installation - a boast which cannot be made, in general, for materials with simpler techniques of application.

This strong, firm bonding of ceramic tiles to the tiled surface will still exist when, many years down the road, the Homeowner may decide to change her tiles. The procedure required at that time will be much lengthier and more complicated than the stripping of a surface covered with a fabric or material in rolls: the tiled surface must be literally demolished, since the combination of tiles, setting material and background become, after installation, a single indivisible system. The same considerations will impact the partial replacement of a tile floor or wall covering in the course of its useful life. The ease of such replacement will depend on how firmly the covering is anchored to the subfloor. The partial replacement of ceramic tiles some time after installation is possible in theory but not easy in practice. We will return to this subject in the third part of this guide, where we stress the importance of taking utmost care in the planning and installation stages of the tile job (so as to prevent errors and defects which would be difficult or inconvenient, if not impossible, to remedy after the fact).

The above considerations point to the fact that durability and ease of installation, strength of the system and ease of replacement of individual pieces of the covering are separate needs which cannot be satisfied simultaneously to the same degree. Ceramic tiles are highly competitive with respect to durability of installation, quite apart from the question of ease of installation and replacement of individual pieces.

The matter of "durability" merits further reflection.

As a material that is "hard" in the sense defined in the preceding pages, tiles are highly competitive compared to soft materials, in the matter of durability. Consider nature, and the number of possible stresses that the environment can inflict on the surface finish of a floor or a wall.

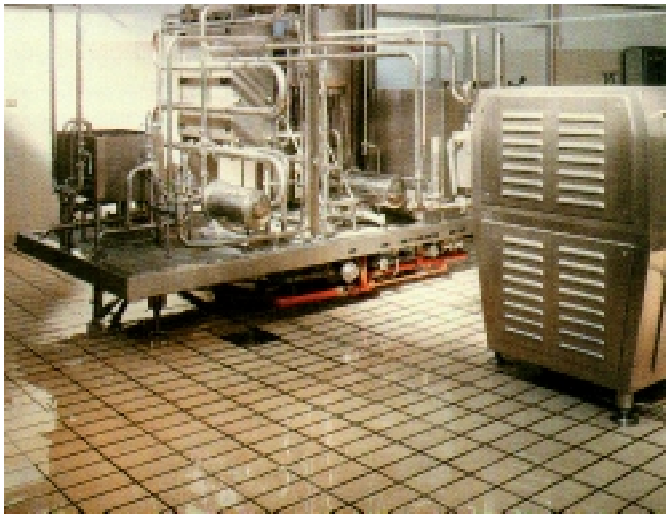
For example, on a floor:

❑ people walk, often with dirty shoes, or move chairs, carts or other objects, subjecting the surface to abrasive wear, and exposing it to the risk of scratches, cuts, and blows. Hard materials absorb these assaults fairly well, in clear contrast to other types. The only limitation, as noted above, is the limited resistance to blows that distinguishes hard materials from "resilient" ones.

❑ liquid substances, sometimes even chemically aggressive ones, can spill onto the tile and remain there for extended periods. All hard materials are highly resistant to water: unaltered by it, they absorb either none or extremely little of it, in contrast to other materials. Thus hard materials are less at risk of deterioration than materials like fabrics or wood. But ceramic surfaces are unique, among hard materials, in their resistance to chemically aggressive liquids, and generally enjoy a resistance that is even higher than many natural stones. (Much marble is composed of calcite, a mineral that is soluble even in diluted weak acids, like lemon juice and Coke.)

❑ dirt is tracked in along with substances that may contaminate the environment (dust, spores, pollen, microorganism, etc.); the floor thus must be cleaned and disinfected. Hard materials generally have fairly smooth and compact surfaces that are impermeable, not filamentous, inert or at least minimally reactive: surfaces that do not absorb liquids or vapors, odors, smoke. The high degree of chemical inertia of ceramic surfaces, due to their structure and their production technology, makes them among the least soilable surfaces and the most easily and effectively cleaned. The average cleaning is almost unbelievably easy: in the home, a cleaning with a moist rag or at most a detergent for hard surfaces will usually be sufficient.

With appropriate and frequent maintenance, floor tiles will never need any special cleaning in the entire span of their useful life. All types of soiling can be generally removed from a ceramic surface - even the mark of a lit cigarette, which would cause much greater, and permanent, damage to organic



materials. Successful cleaning is also guaranteed thanks to the generally high resistance of ceramic surfaces to the chemical and abrasive effects of strong detergents needed to remove particularly deep stains (like those caused by lit cigarettes): detergents that, if applied to other less resistant materials, might not remove the stain without damaging the surface.

In brief, ceramic surfaces are the most easily cleaned and hygienic that exist.

In the discussion above, we have often used the term “in general” with statements about the quality of tiled surfaces. The term is used to stress that the claims we are making will be sustained depending on two conditions:

❑ that the ceramic tiles have been properly selected for the area where they are to be used (according to the instructions given in the second part of this guide);

❑ that the tiled surface has been properly planned and installed, following the guidelines set forth in the third part of the guide.

With due regard to the above, we reach the following conclusions:

❑ *in the universe of floor and tile coverings, ceramic tiles are extremely competitive with respect to durability and functionality in terms of ease of maintenance;*

❑ *by contrast, they are more demanding in their installation methods;*

❑ *the cost/benefit ratio (factoring in the cost of materials, of installation and of special maintenance, as well as the technical durability* *of the tiled surface) is, however, superior for ceramic tiles, as detailed in the addendum "The costs of flooring materials".*

So the Homeowner and the Specifier can definitely find ceramic tiles that will satisfy their respective needs for functionality and durability.

The cost of flooring materials

(taken from: Ceramicaacta n. 6/97)

Introduction

Cost constitutes a basic selection criterion for flooring materials.
However, the cost of materials and installation alonedoes not represent a complete economic evaluation of the available solutions, or an accurate comparison of the various options.
A full economic evaluation must consider the total expense of the flooring in relation to the useful life of a building: the calculation must be global,including not only the construction cost but also the cost of any special maintenance and possible replacement that can be projected over the life span of the home in question.
We seek below to supply the data, techniques and information necessary for making a thorough comparison between the various types of flooring, calculated in terms of the total costs to be sustained over the useful life of the floor.
This is a more complete and accurate comparison than the simpler one based strictly on material and installation costs.
The data used in this study has been obtained from a survey of a representative sampling of flooring distributors (materials + installation) in Italy.
An analysis of the results obtained yields a complete economic comparison between the various materials.

Research approach

Materials considered

The study undertaken considers the following types of flooring materials:

1. Ceramic tiles
2. Natural stone
3. Conglomerates
4. Wood
5. Cork
6. Rubber
7. Vinyl
8. Carpeting.

Method and geographic coverage of the survey

For every type of material, a questionnaire was prepared and delivered to numerous manufacturers and construction and installation companies with a substantial presence on the market and distribution in northern, central and southern Italy. A total of 92 completed questionnaires were returned.
For the purpose of allowing a valid comparison of cost data, we have limited our inquiry to a specific room in the home: the living room.
The inclusion of rubber and cork among the materials considered in the survey may be questioned, since these are not likely to be used in such an area; but we have included them so as to generate comparative data for these materials as well.
Costs for the various operations are based on a living room of 20 square meters.

Definitions for the life cycle of flooring

Table I - Life cycle of floors and related materials.

FLOORING Service life	Period, from the time of installation, during which the flooring is able to satisfy the functional and aesthetic requirements of the user.
MATERIALS Physical lifetime	Period, from the time of installation, during which the material maintains its functional and aesthetic features.
Technological lifetime	Period, from the time of introduction on the market, during which the material is competitive regarding the progressive technological and production advances.
Market life	Period, from the time of introduction on the market, during which the material is in line with fashion trends.
AVERAGE LIFETIME OF THE BUILDING: 40 YEARS	

materials
The parameters of the life cycle of the flooring types considered in the questionnaire, as terms of reference for subsequent analysis, are listed and defined in Table 1.
The useful life of a floor is defined as the briefest among: the physical life, the technological life and the market life of the flooring material.
As regards the physical life in particular, our calculations are based on a proper planning and installation of the floor.
Obviously, the durability of a floor, in specific working conditions, will depend on proper planning and installation, and will suffer greatly in the absence of these.
We are presupposing that the flooring material itself was adequately serviceable for the use levels associated with the area in question (the living room of a private home).
Survey answers suggested that in general, market life is considered to be the briefest of the three, although the sometimes inconsistent results made it difficult to statistically define the relation between the end of a product's market life and the actual replacement/ reconstruction of the related floor, when the material's physical life has not yet ended.
As a general reference point for evaluative and comparative purposes, we have assumed an average useful life of a building to be 40 years, in keeping with data in the CRESME (1997) report on the state of residential construction in Italy.
This is the maximum time considered in the survey taken: for any material, it is thus assumed that, after 40 years, the construction or home itself will have concluded its life cycle, prompting demolition or at least a radical restructuring that will necessarily involve the floor as well. We are thus supposing that after 40 years, any floor must be replaced and reconstructed, regardless of its condition.

Format of questionnaire
As noted, for every material covered in the survey, an appropriate questionnaire was devised, structured in sections that concern the costs associated with:
❑ different types of material
❑ pre-installation techniques and costs
❑ installation techniques and costs
❑ types, techniques and costs of possible surface treatments
❑ special maintenance: types, frequency and costs
❑ methods and costs of demolition and removal of the floor at the end of its life cycle.

Analysis of the data
As explained, the aim of the survey was to calculate and compare the total costs of‘ the various flooring types.
The definition of total cost is set forth in Table II.
For the calculation, reference has been made to the time schedule and the cost - pegged at Septem-ber of 1997 - of the various operations to be conducted over the 40 year life of the building.
Established formulas of financial mathematics, also set forth in Table II, were used.
It was assumed that any floor has no residual value at the end of the 40 years.

As can be seen, the unit interest rate to be used is a function of the inflation rate and the bank interest rate. For these two parameters, the selections made are set forth in Table II.

Results and discussion

We summarize below the main results of this survey.

Table III presents a chronological profile of the actions that will generally need to be taken for each type of floor over the course of the 40 years of the building's useful life, with reference to the **physical life** of the floor covering materials used.
In the case of ceramic tile and conglomerates, the time line of such actions is different for market life than it is for physical life. Ceramics and conglomerates are in fact the only products for which the data suggests a market life that is different, and briefer, than the physical life.
Table III shows a clear distinction between "soft" materials, which generally require at least one reconstruction over the 40 years, and hard ones (ceramic, natural stone and conglomerates) for which the physical life will generally be equivalent to the useful life of the building, given that no intermediate reconstruction is necessary.
"Soft" and "hard" materials could thus also be respectively defined as "temporary" and "permanent" materials.

On the basis of price and unit costs extracted from responses to the questionnaire, and considering the time schedule of the actions presented in Table III, a profile of costs has been created as seen in Table IV.
This chart shows the average values of the following costs (all in Euro per sq.m.).

Table II - Global cost of flooring: definition, calculation, parameters used.

GLOBAL COST: Definition	**Initial capital,** assumed to be at the disposal of the user at the time of purchase and installation of the flooring, including the **indexed costs** of construction, maintenance, treatments, renovation, etc., to be expected during the service life of the floor
Calculation of the indexed costs	$P = \frac{S}{(1+i)^n}$ where $i = \frac{(1+i_b)}{(1+i_i)} - 1$ and therefore $P = S\frac{(1+i_i)^n}{(1+i_{bi})^n}$ with **P** = initial or current amount of money **S** = future or accumulated value of P after n years **i** = unit interest rate **i_i**= inflation rate **i_b** = bank interest rate
Parameters and references used	Cost reference date: September 1997 i_i = 2 % i_b = 3 %

1. Construction cost of the floor, including:
❑ cost of material to be installed
❑ cost of preparation of the support surface,
❑ cost of installation,
❑ cost of later surface treatment/s required before floor is ready for use.

2. Cost of special maintenance, including:
❑ actions beyond standard cleaning that must periodically be undertaken to insure optimal floor maintenance.

3. Cost of reconstruction, including:
❑ cost of demolition of the existing floor,
❑ cost of removal of the rubble,
❑ cost of the preparation of a new support surface
❑ cost of construction of a new floor.

Table III - Summary of the interventions on the various types of floors to be expected during the lifetime of the building (40 years), in reference to the physical lifetime of the material.

Year	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
CERAMIC TILE	★																				
• Single-fired tile	★																				▲
• Terracotta tiles	★					●					●					●					▲
• Stoneware tiles	★																				▲
• Klinker																					▲
NATURAL STONE																					
• Marble	★					●					●					●					▲
• Granite	★									●									●		▲
CONGLOMERATES																					
• Marble-cement	★						●										●				▲
• Marble-resin	★			●					●					●					●		▲
• Siliceous resins	★																				▲
WOOD	★						●				❑						●				▲
CORK	★					❑					❑					❑					▲
RUBBER	★			❑		❑			❑		❑			❑		❑			❑		▲
VINYL	★			❑		❑			❑		❑			❑		❑			❑		▲
CARPETING	★	●	●	❑	●	❑	●	●	❑	●	❑	●	●	❑	●	❑	●	●	❑	●	▲

Key: ★: Construction ●: Maintenance ❑: Renovation ▲: End of the lifetime of the building

4. Total cost (with respect to both market life and physical life), calculated as illustrated in Table II.

Fig. 1 compares the following costs (again expressed in Euro per sq.m.) for the various types of flooring materials:
❑ cost of purchase (price) of material;
❑ cost of construction;
❑ total cost, based on physical life.

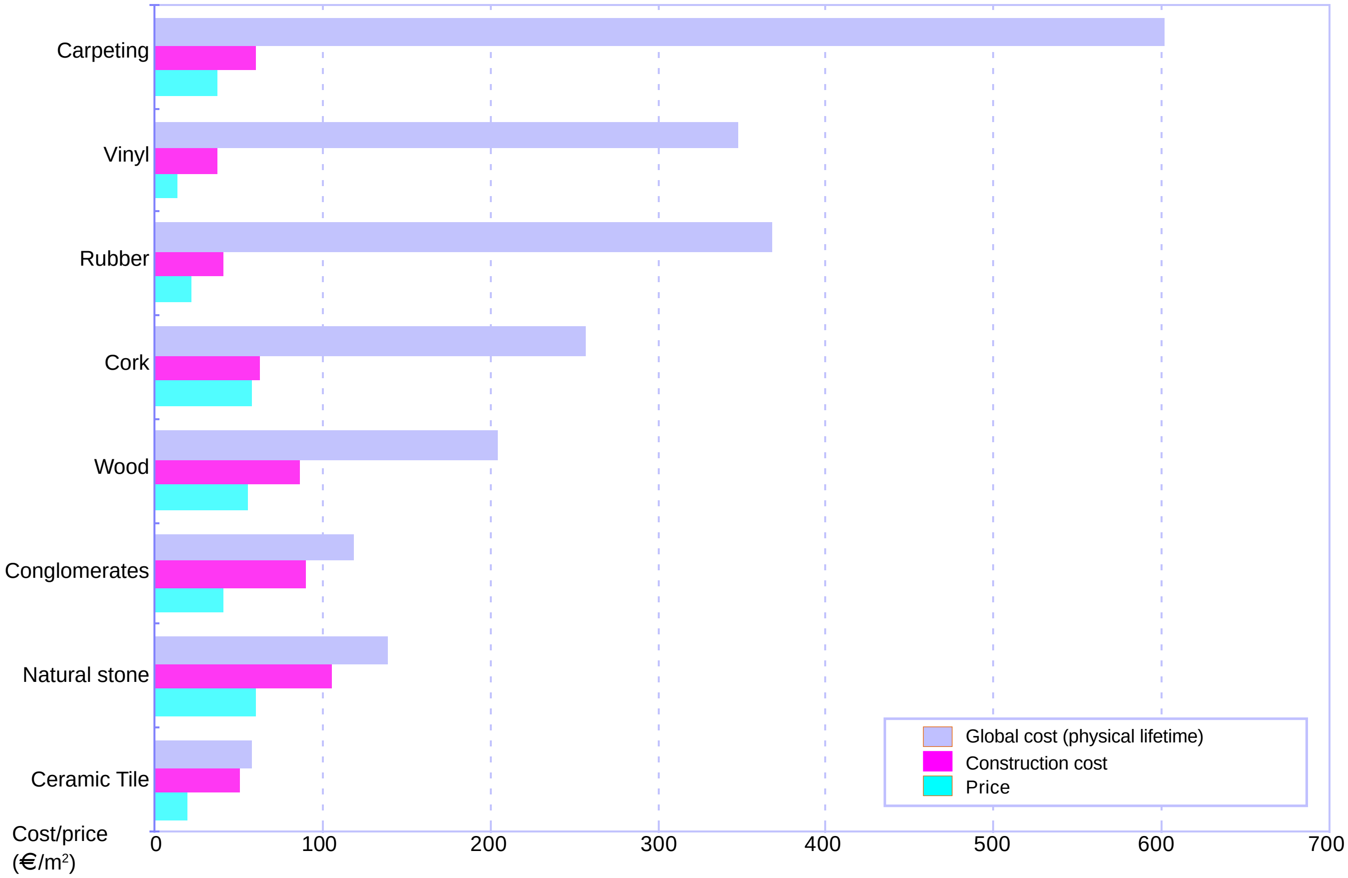
The diagram in Fig. 1 indicates the following conclusions:
❑ the average total cost is substantially different from average purchase price and construction costs;
❑ the materials defined above as “temporary” are, as to be expected, the most expensive from the point of view of total costs, while the “permanent” materials are from this same point of view more economical although their construction costs are generally higher;
❑ for many materials (in particular for all permanent materials-ceramic, natural stones and conglomerates), the cost of construction is appreciably higher than the purchasing cost of the materials;
❑ ceramic emerges as in general the most attractive material economically, thus supporting the information collected in a preceding survey, carried out with the same methodology in 1984.

If, instead, total costs are calculated with reference to market

Table IV - Summary of the costs.

Product	Cost construction (€/m²)	Costs maintenance (€/m²)	Costs renovation (€/m²)	Global cost (market life) (€/m²)	Global cost (physical lifetime) (€/m²)
Ceramic tile					
• Single-fired tile	42		62	195	42
• Terracotta tile	55	13	75	89	89
• Porcelain stoneware tile	61		80	191	61
• Clinker	42		62	142	42
Marble (prepolished)					
• Sicily pearl marble	67	15	90	106	106
• Guatemala green marble	128	15	152	166	166
Granite (to be polished)					
• Sardinia Pink	94	18	112	122	122
• Indian Juaparanà	141	18	159	169	169
Conglomerates					
• Marble-cement	102	18	120	245	146
• Marble-resin	94	18	111	415	138
• Siliceous resins	76		93	308	76
Wood					
• Iroko	75	13	91	183	183
• Teak	101	13	117	231	231
Cork	63		79	260	260
Rubber	41		57	375	375
Vinyl					
• PVC	38		55	358	358
• Asbestos-free vinyl	33		50	324	324
Linoleum	41		57	376	376
Carpeting					
• Needled fabric	31	8	48	425	425
• Synthetic bouclé	35	8	52	451	451
• Synthetic pile	40	8	57	484	484
• Valuable bouclé	90	8	106	823	823
• Valuable pile	98		115	881	881

Fig.1 - Global cost, in reference to the physical lifetime of the material, construction cost and purchase price of the material, for various types of flooring materials.



life, the picture changes somewhat. As mentioned above, changes regard only ceramics and conglomerates, since for all other products, physical life and market life are considered identical. The total cost for ceramic is similar to that for natural stone, whereas conglomerate costs are higher, in absolute as well as percentage terms.
In every case, ceramic maintains an excellent competitive position.

1.5 User safety

The Homeowner and the Specifier are conscious of the importance of user safety, and consider this factor when choosing a covering material for a floor or wall.

How do ceramic tiles rate as regards risk factors for user safety?

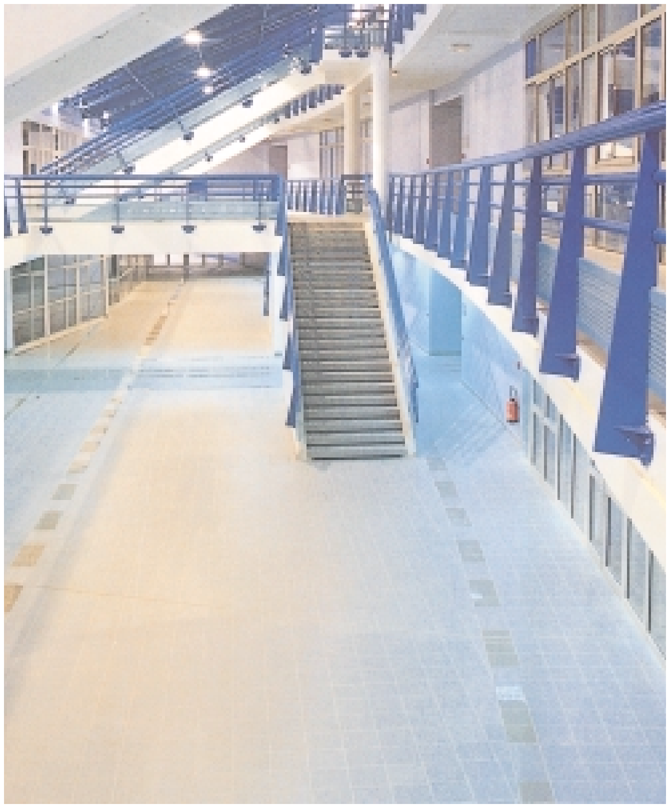
To answer this question, we will seek to identify the major user risks potentially associated with floor or wall covering, considering both the risks inherent in normal use and those due to accidents and under emergency conditions.

The risks we will consider are the following:

- ❑ risk of pollution of the environment in which the covering material is installed, due to the material's emission of toxic or noxious substances, or due to the material's tendency to absorb any substances from the environment that may be dangerous to the health of the residents;
- ❑ in the case of floors, the risk of falls due to slipping or tripping;
- ❑ again in the case of floors, physiological disturbances due to the surface's accumulation of static electricity;
- ❑ in the case of fire, risks to personal safety regarding the ability to reach safety.

Safety from environmental pollution

The superiority of ceramic tiles from this point of view is due to the very nature of ceramic materials, and specifically to their chemical-physical inertia achieved through



the high-temperature firing which concludes the production process, as detailed in the preceding pages.

Whatever the chemical composition of the tile surface (especially in the case of glazed tiles, whatever the composition of the glazes), the structure achieved through the firing process effectively prevents the leaching of any polluting substances. In other words, the chemical elements that make up the material are combined in insoluble, stable compounds and thus immobilized in a compact and inert structure.

Therefore, for floors and walls covered with ceramic tiles and under conditions of normal use, no metals contained in the glazes are released or dispersed into the environment. (In the case of tiles due to be in contact with food, the release of metals is specifically monitored, as will be demonstrated in the second part of this manual.) It must further be stressed that, even in conditions of heavy use, the material removed from the tile surface due to wear is practically negligible (given, naturally, that the tiles in that location have been properly selected, considering properties and services needed). At any rate, the material to be potentially removed must be considered inert, toxicologically speaking and with respect to environmental impact.

The properties of chemical-physical inertia also make ceramic tiles the safest material in terms of the risk of absorbing dangerous substances from the environment, thus exposing the user to their effects. This subject was introduced in the preceding section, where it was shown that ceramic surfaces are the most easily cleaned and hygienic surfaces available. In fact where the problem of pollution of internal environments does exist, it is due to inadequate cleaning and hygiene measures of all surfaces, including floors and walls. The environment contains and "produces" substances dangerous to the health (dust, pollen, spores, bacteria and even germs) which can accumulate and be trapped by some surfaces or objects, thus exposing people who live in this environment to the risk of sickness.

"Carpeting is responsible for 90% of asthma in children" was the headline some years back in the weekly journal of the National Federation of the Order of Physicians, commenting on the conclusions reached by a convention of allergists from fourteen countries. This quote was cited in a preceding edition of this manual (Ceramic Tile, User's Manual, ed. Edi.Cer., Sassuolo, 1984).

With their hard, inert, dense, non-filamentous surface that can withstand the most vigorous cleaning, ceramic tiles contain all the properties that make for easy and effective cleaning; indeed, the original, traditional use of ceramic tiles was in areas where cleanliness was most important: bathrooms and kitchens. Ceramic tiles, with their superior qualities and features made possible by unflagging research and development undertaken mostly by the Italian industry in cooperation with research institutions like Centro Ceramico Bologna, are today the favorite and most popular covering material specified for public and industrial areas where issues of hygiene are paramount: hospitals, the food industry, community kitchens, etc.).

Accident prevention

Accidents associated with surfaces treated in this manual are mostly falls from slipping or tripping, and thus regard only floors. The risk relates to the physical and geometric properties of the surface: with the properties of regularity (for example, the different levels of contiguous pieces, which can cause tripping) as well as the properties of roughness (which can influence the slipperiness of the surface). As is well known, slippage risks depend on many factors other than the floor's covering material. One of the most important is the presence of liquids on the surface (for example, water in an exterior floor or on poolside walkways; oils or other liquids in an industrial environment).

A properly planned and installed tiled surface can be considered safe from the risk of tripping. This will be confirmed in the third part of this manual.

As for slippage, it can be generally stated that a floor will be that much more slippery to the extent that the material covering it has a surface that is smooth, glossy and impenetrable. Therefore a slip-resistant material must have a rough surface; the purpose of this roughness, in case of the presence of liquids, is to prevent the formation, between the sole of the shoe and the surface of the floor, of a continuous "layer" or "film" of liquid. In the presence of such a layer, the adherence (the friction) between sole and pavement is greatly reduced, and the risk of slipping increases substantially (this same mechanism explains the high risk of accidents that occur on a wet road).

We have frequently noted that with ceramic material we can obtain any kind of surface.

For instance, there are ceramic tiles on the market that are specifically designed to be slip-resistant. The issue will be taken up in detail in the second part of this manual (Sec. 2.3, Safety Properties), but we can already note that the surfaces involved here must be either rough or with suitably designed reliefs.

The conclusion is that, if the specific area of application entails a risk of slipping, there are ceramic tiles that make it possible to contain and prevent this risk, whatever it might be.

But this is not all that can be said on behalf of ceramic tile. If we compare the conditions for good slip-resistance with the conditions for easy and effective cleaning, we will see that these are in opposition to each other. In fact, slip-prevention requires rough and scabrous surfaces, while easy and effective cleaning requires smooth surfaces. But ceramic tiles are the material which most successfully resolves this “contradiction”. The solution is supplied by ceramic tiles - available on the market - which are slip-resistant (having a rough surface or a surface with reliefs), and characterized as well by a high degree of surface hardness and chemical resistance, enough to endure even the most vigorous cleaning without alteration or deterioration.

Safety from static electricity

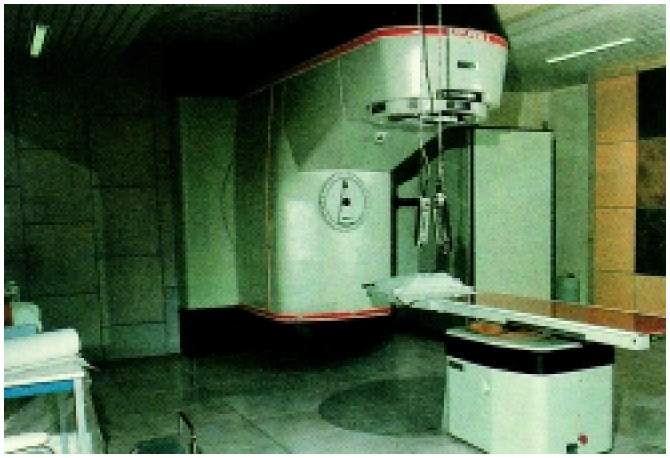
Some types of flooring materials allow for the accumulation of static electricity on the surface. This accumulation, which can be generated and activated by the rubbing action that occurs when a person walks, can lead to an electric shock, often to the person’s body. Some materials are able to inhibit such an accumulation: this property is generally associated with not extremely low levels of electrical conductance (linked to the material’s capacity to transport electric charges, according to the definition given in the addendum).

The use of anti-static materials for floor covering insures, on the one hand, the absence of physiological disturbances: that is, of the discomfort to the human body, however slight, that is generally caused by an electric shock; and on the other hand, the achievement of more complete safety in those particular environments (operating rooms, laboratories or chemical plants) where the presence of potentially explosive substances could entail the risk of explosion

Electrical conductitvity - antistatic properties

The electrical conductivity of a material is associated with the flow of electrical current that crosses a portion of the material itself. Its opposite bears the name electrical resistivity (or specific resistance). Materials with high resistivity, and thus low conductance, constitute that class of materials termed *"electrical insulators".* Ceramic tiles belong to this class, as do the great majority of ceramic materials. Tiles block the passage of electrical current (as long as they are not wet, in which case it would be the water, with the salts it contains, that would transmit the electrical charges). This is an important safety feature. Most ceramic tiles have extremely high levels of electrical resistance, and are well-suited to environments such as floors for operating rooms, laboratories and chemical plants, where safety is a primary concern.
In some clean rooms, floors must have an insulating resistance greater than 2×10^4 Ω, but less than 10^6 Ω, for recently built floors, or less than 10^8 Ω for floors built over one year ago. (See the CNR-CEI norm n. 64-4/73: "Standards for Electrical Systems in Environments Equipped for Medical Use"): standards which regular ceramic tiles generally do not meet (whatever the composition of the other layers that compose the floor).
For such specialized use, tiles characterized by a greater electrical conductance than regular tiles are specified.
This kind of application generally requires a metal net lath or similar surface under the tile bed, which serves to establish the equipotential of the system, as well as to allow the system to be grounded.

Electrical conductitivity is not a standardized property for ceramic tiles, and is thus not included in the EN ISO norms.
The CNR-CEI norm n. 64-4/73, quoted earlier, presents a method for measuring a floor's insulation resistance.
It should be specified that this is a testing method normally used by the technical experts of the appropriate authorities (Health Organizations, Fire Fighters) to ascertain that an installed floor conforms with required standards.
The same method may also be used in a laboratory, for the purpose of obtaining useful information and data for designing the system. Testing can be done either on a specifically prepared floor sample, or on individual tiles. The latter test is especially important, if one considers that the level of insulation resistance of tiles above the levels cited earlier is already sufficient to prevent the floor in its entirety from conforming to required standards.



even from such small electric shocks as we are considering here.

Ceramic tiles are typified in general by a very low level of electrical conductance. This property too is the direct result of the chemical structure of ceramic materials, and is thus inherent to all ceramic materials. (Consider that electrical insulation is for the most part made in ceramic material — the so-called "electrotechnical porcelain"). Experience demonstrates that despite this fact, ceramic materials show no substantial tendency to accumulate static electricity on its surface (unlike many types of carpeting, for instance), so that the use of ceramic tile as a floor covering insures the absence of physiological disturbances.

Should the Specifier be specifying a floor for a hospital operating room — that is, for an environment with very specific anti-static needs — he would find special ceramic tiles available, designed and produced to satisfy such needs.

Deferring further details to the addendum that follows, we stress these conclusions:

- ❑ in general, ceramic tiles do not create physiological disturbances from static electricity;
- ❑ for specific areas, special tiles are available that can insure the strictest conformity with required anti-static standards.

Safety from fire hazards

Fire resistance is an important aspect in the assessment of the quality — and thus the expected durability — of building materials, in relation not only to residential spaces, where construction materials come into accidental contact with flames or incandescent bodies, but also to specific industrial environments where the presence of flames is virtually a working condition.

Behavior in a fire

A detailed study of the behavior of construction materials in a fire is included in the book: *C. Palmonari, F. Vaughan "Behavior of building materials in a fire", Ed. CEC, Basilea (1979).*
A material's behavior in a fire is defined by several properties that can be classified into the three following groups:

1. Properties of resistance to the destructive action of flames: over and above *"combustibility"*, or the possibility of spontaneously reacting with oxygen with a highly exothermic reaction, there are other properties, which vary depending on the material, that will describe its behavior and its response to high temperatures reached in a fire (for example, changes in mechanical resistance, consistency, size, etc., due to high temperatures);
2. Properties that describe any way the materials may feed or propagate fire: among these we note the "calorific value", or the quantity of heat developed by the complete combustion of the weight unit of the material; the *"oxygen index"*, or the minimal concentration of oxygen required to maintain combustion; *"ignition and auto-ignition temperatures"* , or the temperature at which materials take fire, both in the presence and in the absence of flames; the *"development of the flames"*, or the velocity of advancement of the flames; the *"length of the flame"* and *"flammability"*, defined as the velocity with which the flame propagates from one surface of a material to the other;
3. Properties that define the emission of fumes and toxic substances: these are the *"quantity of fumes"*, *"density of fumes"* and *"toxicity of fumes"* emitted by the material in the case of fire. The terms are self-explanatory.

Fire resistance is especially important for floor and wall coverings since it is these materials which, after furnishings, are most exposed to the risks noted above.

The fire resistance of floor and wall coverings is an equally important consideration for human safety in case of accidents like fires. The seriousness of a fire depends on the quantity of combustible materials involved: materials which feed and propagate the flames. The safety of human lives depends on other features too, such as the quantity and nature of gaseous substances developed during combustion, or the effects of the fire on the integrity and stability of the building.

From the point of view of insuring the safety of the residents in a building, ceramic tiles — like most inorganic materials — rate extremely high.

With respect to fire resistance, in fact, the properties of ceramic tiles are quite different from those of most other floor covering materials (specifically wood, cork, carpeting, vinyl, etc.). Unlike these materials, which are variously combustible, ceramic tiles are by nature absolutely inert to flames, and generally invulnerable to the high temperatures potentially reached during a fire. A ceramic floor or wall covering is not damaged by contact with flames, it does not spread or feed a fire, and it does not emit substances of any kind in case of fire. On the contrary, it has been demonstrated that in case of fire, ceramic tiles constitute an effective protection of the surfaces on which they are applied, greatly reducing their exposure to heat and the consequent danger of collapse.

In conclusion, as regards ***user safety*** *and the elimination of related risks, both under* ***conditions of normal use*** *and* ***in emergency situations,*** *ceramic tiles are absolutely superior to many other materials.*

So the Homeowner and the Specifier will find their needs for user safety fully satisfied by ceramic tile.

1.6 Environmental responsibility

The Homeowner and the Specifier care greatly for the protection of the environment. Alerted by the media to potential threats to the environment, and concerned about the environmental degradation that seems upon us at the start of the third millenium, consumers now prefer to use "ecocompatible" materials that respect the environment, especially as regards floor and wall covering materials.

Is the selection of ceramic tiles compatible with this environmental consciousness among our consumers?

The answer to this question is "yes", especially as regards Italian ceramic tile. In fact, the attention given to environmental protection and the reduction of negative

environmental impact began in the early 1970s, for the Italian ceramic tile industry; this too is a "world first" which the Italian ceramics industry can boast. National laws that have been gradually passed, as well as various local and regional environmental regulations that are severely restrictive, have most certainly encouraged this focus on the environment, a focus which has recently grown in importance for reasons that go beyond the question of respect for the law. Some manufacturers of ceramic tiles have been among the first companies in Italy, and the first in Europe, to adhere to the EMAS scheme (regarding which more detailed information can be found in the addendum). The Italian ceramic tile industry's commitment to the environment is documented in the campaign entitled "Towards a Sustainable Development", promoted by Assopiastrelle and illustrated on page 62.

Beyond the industry's concern for environmental protection, how can a user determine if - and to what degree - a product is sensitive to the environment? And how do ceramic tiles rate from this point of view?
The instrument used for this evaluation is known as the "life cycle analysis". This analysis considers the product "from cradle to tomb," where the "cradle" represents the raw materials as they are extracted from the environment, and the "tomb" is the final disposal of the material (including all refuse) after use. Every activity included in this sequence has an impact on the environment: an impact traceable not only to the emission of polluting substances (gaseous, liquid or

Italian ceramic tiles

Towards a sustainable development

Italy's ceramic tile industry is the world leader in production and technology, distinguished by cutting-edge techniques, innovative raw materials and the latest strategies for guaranteeing environmental and user safety. As a floor and wall covering material, Italian ceramic tiles clearly rate as an "ecologically compatible" material to be used in bioarchitecture. Assopiastrelle encourages sustainable development through a range of projects aimed at promoting quality as well as sustainability among products and processes in the ceramic tile industry.

ASSOPIASTRELLE
Association of Italian Ceramic Tile
and Refractories Manufacturers

CERAMIC TILES OF ITALY
TOWARDS A SUSTAINABLE DEVELOPMENT
Environment
Health & Safety
Quality Energy

solid) into the environment that may alter its balances, but also the consumption of important resources (often either not renewable or only partially renewable) like water and fuels. All these “environmental impacts”, produced in every phase of the life cycle, are measured and used to evaluate a product’s “ecological quality”. The ecological label “ECOLABEL” is granted to a product depending on this life cycle analysis, as explained in the addendum. Let us briefly review of some of the most

Ceramic tiles and ecological labels

In recent years, the Council of the European Union has supported environmental protection as a basic factor in in the framework of product and process quality management. The proposed regulations reflecting this “management” approach to environ-mental issues - where the production company volunteers to protect the environment, in contrast to the “command and control” approach of the preceding law - are the community regulations n. 880/92, which establishes the ecological label “Ecolabel” for products, and n. 1836/93, which establishes a system for environmental management and auditing (EMAS) for industrial plants.

The main aim of the Ecolabel insignia (Fig.1) is to promote the design, production, marketing and use of products that have a low impact on the environment over their entire life cycle, and to raise customer awareness of the environmental impact of products. The Ecolabel has already been established for some products; its preparation for ceramic tiles is underway, with Italy in the lead.

ECOLABEL

Fig. 1 - "Ecolabel" Logo.

The EMAS scheme (EcoManagement and Auditing Scheme) promotes the introduction and implementation on the part of manufacturers of policies, programs and environmental management systems aimed at the “continuous improvement” of environmental performance and the creation of an open and constructive communication between the territory and the public. The environmental management system is also regulated by an international norm (UNI EN ISO 14001), which stipulates its contents and requirements.
The Italian ceramic tile industry quickly took action in this area through promotional campaigns and initiatives to raise awareness (for example, the pilot action “Euromanagement-Environment”, partially financed by the European Union, which included the participation of ten ceramic tile manufacturers; and the Sectorial guidelines on the development of integrated management systems for environment, health and safety (EHS), supported by Assopiastrelle. Both these initiatives have been carried out with a qualified contribution by Centro Ceramico - Bologna). Two Italian tile companies have been among the first in Italy to join EMAS; they are also the first in the industry in Europe.

ECO MANAGEMENT AND AUDITING SCHEME

Fig. 2 - EMAS Logo.

salient aspects and principle elements in the evaluation of the ecological quality of ceramic tiles, and especially Italian ceramic tiles.

We begin with the raw materials, their quarrying and processing. These raw materials are widely available on the earth's crust (as discussed earlier, ceramic materials mainly include aluminum silicates: and in petrology, the rocky layer above the earth's crust is called the "sial" – acronym for the chemical symbols of silicon and aluminum – reflecting the fact that the earth's crust consists basically in raw materials that are at least potentially ceramic). These are not strategic materials, nor materials approaching depletion (like crude oil). Quality requirements vary depending on the type of product and production technology, but are never such as to require particularly demanding - and environmentally significant - processes of separation, enrichment, etc. The environmental impact of the quarry and related activities regards, on the one hand, alterations to the landscape (for which, in most countries, recovery and restoration are required by law at the end of quarrying activities); and on the other hand, the consumption of resources (like energy and water), the emission of dust, and waste production. In all countries, quarrying methods are designed to limit, to the extent possible, the environmental impact of the quarries. Presently, many types of Italian ceramic tiles are made with imported raw materials, because of the superior quality of these materials in terms of technical and aesthetic properties desired, and also of available technologies. Many Italian tiles are still made with local raw materials, though, to whose use the industry remains committed.

The production phase represents the most important part of the life cycle from the point of view of environmental impact, and the part regarding which the Italian ceramic tile industry has reached the highest degree of "environmental performance".

The main environmental factors associated with the manufacture of ceramic tiles are the following:

- ❑ gaseous emissions;
- ❑ water consumption and waste water production;
- ❑ energy consumption;
- ❑ waste / residues;
- ❑ noise.

These aspects are the focus of specific publications described in the addendum.

Generally speaking, it can be said that the Italian ceramic tile industry operates in conformity with "the best techniques available": production techniques which are industrially available thanks to recent technical advances, and which can ensure the highest level of environmental protection (see the 96 / 61 / CE Directive of the Council of the European Union).

With regard to the individual aspects listed above, here are some important examples of "environmental performance" that Italian tile manufacturers can guarantee.

Gaseous emissions. For every kilogram of ceramic tile produced, the following substances are conveyed through gaseous emissions and thus through the streets of the plant:

❑ from 0.16 to 0.42 grams of fluorine compounds;

❑ from 30.2 to 42.3 grams of particulate matter;

❑ from 0.01 to 0.09 grams of lead compounds.

Over 90% of these polluting substances are removed by purification plants (which by now are present in all Italian ceramic plants, using the best available purification techniques), so that the quoted emission

Ceramic tiles, environment and energy

The "continuous improvement" of environmental performances presupposes a deep understanding of the environmental impact of the various products and processes, on which to base the development of technologies for reduction and prevention of environmental damage. The Italian ceramic industry has just such an understanding, thanks to the activities undertaken jointly between the industry (technical experts with private companies and Assopiastrelle), local regulatory agencies (ARPA Emilia-Romagna - Emilia-Romagna is the region where about 85% of national production of ceramic tiles is concentrated) and institutional research (especially the Centro Ceramico Bologna; see Appendix 5 for further information).

In the manual "**Ceramic Tiles and The Environment**" (Fig.3) each of the principal factors of environmental impact associated with ceramic tile manufacturing are examined: gaseous emissions, water, waste and noise. Every aspect

Fig. 3

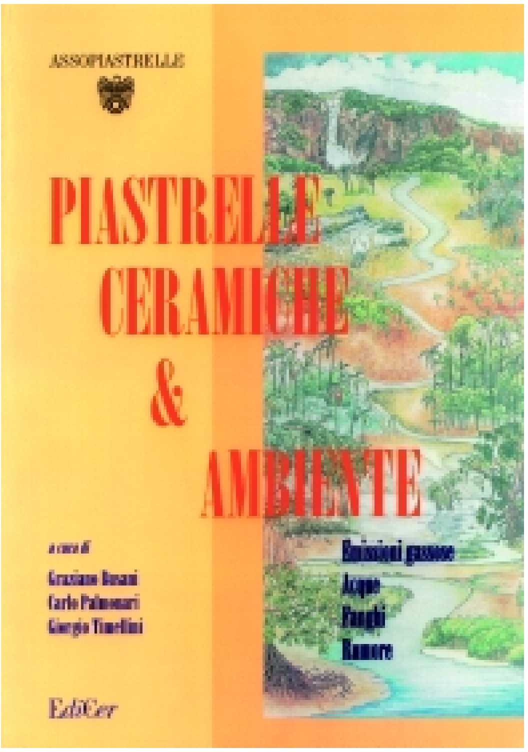


Fig. 4

levels are respectively reduced to:

❑ from 0.016 to 0.04 grams of fluorine compounds (a 90% reduction);

❑ from 0.18 to 0.28 grams of particulate matter (a reduction of over 99%);

❑ from 0.001 to 0.009 grams of lead compounds (a 90% reduction).

is classified, characterized and quantified, according to the type of product and manufacturing technology. This reliable knowledge base is the springboard for the development and study of technologies of prevention, which are presented and described with special regard to their technical and applicative aspects. The Italian ceramic industry stands at the forefront in Europe and in the world, already using the "best available techniques" (BAT - Best Available Techniques) according to the EU Directive 96/61/CE of the Council of the European Union.

The manual "**Ceramic Tiles and Energy**" (Fig. 4) features a data base on the energy consumption of the various types of production equipment used by the Italian industry for manufacturing ceramic tile. This data base is the final result of a thorough campaign of energy audits, conducted by the Centro Ceramico and SNAM with over 100 factories, as part of a program promoted by Assopiastrelle and SNAM.

These two "trade manuals" attest to the commitment and practicality with which the Italian tile industry has embraced the objectives of protecting and safeguarding the environment.

Water and water balance. Water is required for the production of ceramic tile, serving principally to prepare the mixtures and the glazes and to wash down the production lines. Some of the water used evaporates in the processes of drying and firing, and some constitutes waste waters: polluted waters that cannot be returned to the environment unless carefully processed. Most of the Italian ceramic industries do not discard their waste waters externally, but re-cycle them into production operations, with the following results:

❑ no dumping of waste waters...hence less environmental pollution;

❑ a substantially lower level of water consumption than is needed. The water consumed is drawn from the area's water reservoirs...hence the conservation and safeguarding of such reserves.

Waste / residues. The ceramics industry is capable of internally recycling and "digesting" most of the waste it produces (for example, all the discarded powders and tiles, both raw and fired; dusts separated by the gaseous emissions control plants; waste / residues from water treatment processes). Many Italian industries do not dump any

Fig. 5 - Average specific consupmtion of energy by Italian ceramic tile industry.

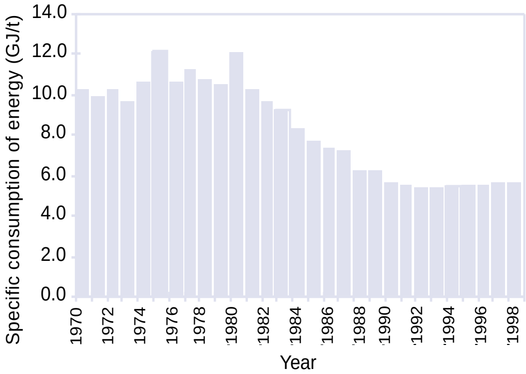
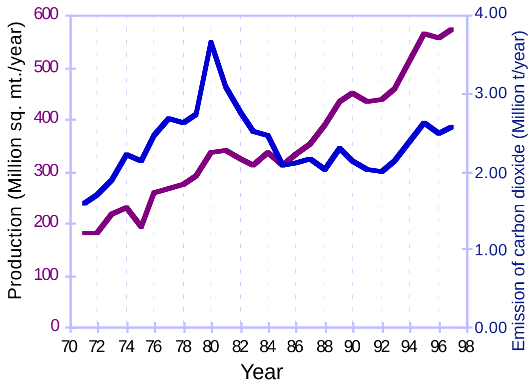


Fig. 6 - Annual emission of carbon dioxide by Italian ceramic tile industry.



Ceramic tiles and Energy

In the field of energy, the Italian ceramics industry has made extraordinary progress in the last few years. These are the "energy performances" (environmental performances) of which the Italian ceramic tile industry can now boast:

❑ Let us assume as indicator of energy consumption the specific average total consumption (heat and electric) of the production line, expressed in GJ/t of product. In the last few years this specific consumption settled about five GJ/t. Therefore, as seen in the diagram of Fig. 5, in the 1990's, following the industry's technological and plant innovations, the ceramic tile industry lowered its level of energy consumption to less than half that of the 1970s.

❑ We can reflect on the concrete consequences, considering the introduction in Italy of the carbon tax as a way of reducing the emissions of carbon dioxide which are the principal cause of the greenhouse effect. The position of the Italian ceramic tile industry in this regard can be seen in the diagram of Fig.6, which presents a 30-year comparison of production and annual global emission of carbon dioxide (direct emission, from the combustion of the natural gas consumed).

What emerges with perfect clarity is that the Italian tile industry has "stabilized" its emission of carbon dioxide to the levels of the 1970s, when production was at half of present levels. This is the result of the excellent energy performances discussed above.

such refuse; they recycle everything - often even the residues of other productive plants - with a consequent reduction of both environmental pollution and natural resource consumption. As regards the refuse that cannot be reused in production (like depleted oils, paper, wooden pallets, plastics, metal scraps, etc.), the Italian ceramics industry goes beyond mere conformity with the law to professionally filter and collect the materials, vigilantly monitoring all matters of environmental protection.

Energy. The ceramic processes, concluding with a high temperature firing of the material which has first been shaped in its raw state, naturally require great amounts of energy. But in this very area, the Italian ceramics industry has achieved truly remarkable results, thanks to a vigorous drive toward technological and plant innovation: consider that, today, to produce a square meter (or a ton) of ceramic tiles requires less than half the energy (heat and electrical) than was required and consumed in the 1970s. The entire industry now consumes about the same amount of energy it did in the 1970s, even though national production levels have more than doubled. This truly superior achievement in the area of energy conservation is matched by few other industries.

We now come to the phase of installation and use of ceramic tiles. This will constitute the subject of the third part of this manual, but we take a moment to review some concepts useful for rating ceramic tiles against other floor and wall coverings:

❑ the materials used for installation and for filling the joints are generally materials of little relevance with respect to toxicity and environmental impact: they are mortars, which is to say mixtures of cement, sand and water, or adhesives that can be defined, for the purposes of this discussion, as special mortars, whose above-cited ingredients are complemented by organic additives (acrylic resins, polyvinyl resins, etc.) whose function is to enhance some application or performance properties. Tile adhesives contain no solvents: their dispersing agent is water. There are some adhesives of a different type that do not share these properties, but they are only for very specialized and limited use (for example, epoxy adhesives);

❑ as for safety and environmental impact when in use, we have seen in the preceding section how ceramic tiles are superior to most competing products. No health or environmental risks are associated with the installation and use of ceramic tiles. On the contrary, ceramic tiles are notable for their naturally high levels of safety and hygiene.

We come finally to the conclusion of the life cycle: the replacement or removal of the tiled surfaces at the conclusion of their useful life. Two aspects of the demolition waste must be considered:

❑ the inert nature of the scraps of ceramic materials (discussed in the preceding pages). This inertia is acknowledged in the present Italian legislation on waste products.
The ability to reclaim tiled surfaces which can be returned to the environment without particular risk, and can even be used in the preparation of foundations and the like. Clearly this cannot be said of the demolition

waste from other floor and wall covering materials, which cannot be re-used and recycled in any way and whose disposal may entail operations with a substantial environmental impact, like incineration;

❏ to this clearly positive fact about the life cycle of ceramic tiles, we add the observation, as documented in section 1.4 above on durability, that ceramic tiled surfaces are absolutely unrivalled by other floor and wall coverings, in the area of durability. A properly designed and installed tiled surface can last as long as the building in which it is installed. Therefore, in the life span of the building, a surface covered with ceramic material — or with any permanent material — involves less waste and requires less consumption of material and energy, compared to a surface covered with non-permanent material.

Regarding this last phase of the life cycle, ceramic tiles rate extremely high.

In conclusion, the Homeowner and the Specifier now know that by selecting ceramic tile they are choosing a product that is respectful of the environment:

❏ a product whose environmental impact over its life span is lower, in various phases, than that of other floor or wall covering materials;

❏ a product whose environmental impact has been substantially reduced over the years, thanks to a vigorous and committed drive toward innovations in technology, plant design, and productivity.

The Homeowner and the Specifier have thoroughly explored the potential of ceramic tiles in relation to all the types of floor and wall covering available, and have discovered that:

❑ the vast range of tiles available on the market is sure to include colors, styles and sizes that will suit their taste and decorating needs, whatever these may be;

❑ despite the complications of installation, ceramic tiles are the most affordable covering in the long run, since they are among the most functional and durable materials;

❑ tiles feature the highest level of user safety;

❑ Italian ceramic tiles are sensitive to the environment, impacting it only minimally thanks to great technical progress.

The Homeowner and the Specifier are now convinced that their aesthetic, technical, economic, safety, and environmental needs will all be fully met. They thus decide to focus their search on ceramic tiles.