

AESTHETIC ENGINEERING: POWDER ELABORATION PROCESSES



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Research lines:

- From red stoneware to porcelain tile*
- Physics of the ceramic process*
- The producers*
- The finished product and its characteristics*
- The evolution of plant engineering*
- Product processing*
- Realisations and projects*

Publications:

1985: "A World of Clay" - published by LB

1998: "La Pietra Ceramica\Ceramic Stone" - published by LB

The growing interest in the production and sale of porcelain tiles has sparked off a tremendous increase in research activities, conferences, articles and publications on the subject. All the many aspects of this product, from raw materials to technology, from physical properties to design, from sectors of use to tile laying systems, have been, and are, continuously updated and analysed.

Each of these points deserves a great deal of space for discussion, book after book would be required, in fact. Nonetheless, the combination of the numerous results and parameters with the free and open exchange of ideas and data has already enriched and stimulated all those who are involved in this field of research and this is a good omen for further and inevitable progress in the whole sector. Without going into too much detail about who invented it and when, it so happens that porcelain tile, as an industrially relevant product category, has celebrated its twenty-fifth birthday.

From the technological point of view in the ceramics sector, this period does not just involve a whole generation of plants and machinery, but a real and proper leap forward as regards quality and methods of tile production. Primitive man adored stone, he often lived in caves among the rocks, he used the strongest kinds of stone to shape arms or tools, and he adorned himself with fragments of the more colourful and rarer stones.

Aware of the compactness, hardness and inalterability of stone and marvelled by it, he gave it deeply symbolic qualities and used it to record the traces of his presence for future eras.

Every culture has had significant stone ages, as anthropologists call them, and they still strike us with their disquieting symbols and mystical relics: ritual stones, magic stones, mysterious stones that transmit messages and emotions from the past.

Stone monuments tell us about the power of man and gods, and the majestic kingdoms that, thanks to the immortality of stone, attempted to conquer the centuries.

At the same time, man, an accomplished and curious observer of natural phenomena began to shape simple clay, harden it by firing, making it become similar to stone.

Scholars have never talked about a ceramics age, however, and rightly so, because ceramics have been produced and developed in all civilisations and have accompanied mankind right from the start up to the present, in an uninterrupted itinerary of technology and art.

Ceramics, even if several of its physical properties have caused stone to be used as a model and standard, has never suffered from an inferiority complex.

The ceramist, aware of the different qualities of the two materials and with the patience and skill that distinguishes him, managed to produce bodies that, even though they were inspired by certain minerals, equalled them as regards their properties and appearance.

Take the examples of the Etruscan "bucchero", black and translucent like obsidian; Chinese porcelain with its reflections of alabaster; medieval Oriental and European stoneware that is tougher than basalt.

At this point the meaning of the title to this chapter becomes clear.

Ceramic stone is not a contradiction in terms but the common root of the ancient history of culture and technique and of the modern industrial model; during recent decades the ceramic tile has caught up with, and surpassed, many of the physical properties of stone.

We are talking about porcelain tile and this is how we will call it from now on; we will explain the meaning of this double word, its history and its synonyms later on.

Ceramic articles obtained from clay or natural composition, among others, have been produced in Europe ever since the High Middle Ages.

These were everyday objects such as bowls, jugs and vases that, fired at the highest temperatures that could be achieved in those times, had a compact, impervious structure of exceptional hardness and mechanical strength, while the metallic sound they made when they were hit, their clean fracture and translucency, were new to ceramics.

Up till then, only pieces of earthenware and stoneware that had been ruined by fire and partially molten had had these properties, but they were warped, greenish rejects.

This innovative type of ceramics had great advantages in that the shape, colour and size of the articles could be controlled even under the most extreme firing conditions.

It was known as stoneware, the same word as the raw material used to produce it. In fact, these “grès silicieux” as they were known in France, were very compact, rock-like clays with a large amount of free crystalline silica.

With a high content of iron oxide, the material extracted had no potassium and magnesium carbonates but contained large quantities of feldspathic material: a successful natural recipe where the correct balance between clay, silica and fluxes could be appreciated after firing as the final result embodied all the previously-mentioned advantages.

The compositions were fired in numerous colours ranging from brown to red depending on the nature of the iron, if present, otherwise grey or even cream could be obtained.

We still know that a special French material called ‘grès de Thiviers’ develops such a bright shade of red as to make it indispensable as a basic colouring agent for formulation or in red granulations for tiles.

The craftsmen who called their vases, of a colour and hardness similar to that of rocks, stoneware, were certainly unable to imagine the fortune that the term would have, not only in commercially terms.

The refined articles imported into Europe from China and Korea were also made from stoneware (the extremely white objects with a much more melted body were to be called porcelain).

Sintering, vitrification start, duration and range are now commonly used technical terms that indicate a particular physical state during firing in which just some of the components reach the liquid phase without causing the melt to collapse.

This vitreous flux surrounds and covers the structure of the crystalline silica and modifies the final result.

For over a century, extruded stoneware has produced the best pipes for agricultural use, corrosive discharges, sewers; plastic moulded or turned stoneware makes the best containers for acid or oil.

Great industrial and artistic traditions sprang up in many European countries, in England, Italy and Sweden, as well as, naturally, France, where the name of the product was born, if not the product itself.

Effects of combustion in reduction and salt glazing during firing enriched and distinguished the appearance of the articles.

The stoneware tile obtained from pressing is much more recent; it was the forerunner of that product type that was destined to radically transform the field of ceramic techniques and production in the last two decades. It was the development of pressed stoneware that gave us this new generation of tiles.

FROM RED STONEWARE TO PORCELAIN TILE

Since the fifties, unglazed tiles with very low levels of porosity were produced industrially using special "lenses" of carbonate-free, ferrous clays that vitrified during firing.

The raw material was dry milled, low tonnage friction presses were used for moulding; firing was done in tunnel kilns with long cycles of over 70 hours and at temperatures of around 1200 C°.

The most common technological limits at that time were the insufficient control of the parameters of milling, inadequate values of specific pressure, uneven firing in the charging section in piles or saggars and the rudimentary instruments available.

The product was correctly made, resistant to acids but of low value appearance-wise and, given that it was not easy to optimise porosity and shrinkage, the formats were consequently fairly small.

In Italy, this was the famous "red stoneware" (7.5x15 cm - 10x10 cm - 15x15 cm - small hexagon formats) that was used in schools, workshops, kitchens, hospitals and public offices. Other colours were also produced in Europe depending on whether clear clays or coloured composition were used.

Only starting from the end of the seventies could one speak of the beginning of a real and proper porcelain tile industry: overall production volumes were to grow as never before in the whole history of tile making. In our quest for the explanation of this continuous trend, which in twenty-five years has led to a growth of over 2000% and leads us to believe that further expansion will continue to take place, three fundamental points must be analysed in order to better understand this phenomenon.

A). THE PHYSICAL PROPERTIES OF THE PRODUCT

The structure becomes extremely vitrified and this easily leads to porosity values of less than 0.1%; this is an essential factor for compactness, surface hardness, resistance to all mechanical stress and inertness in the face of chemical attack.

Without even considering the subject of the sectors of use, the above is sufficient to set the performance of the porcelain tile above that of all the other tile types.

B) TECHNOLOGY

Not by chance did the end of the seventies coincide with a real and proper period of technological transition: a new generation of plants and machinery was born and bred. The commonly used methods of wet milling, even with continuous mills; high tonnage hydraulic pressing; the roller kiln, at last, for rapid single-layer firing; a more refined type of control instruments and, above all, the coherent and global aggregation of production experiences, have changed the "way" tiles are made.

As regards porcelain tile, where the physical and chemical surface properties are fundamental, given the size distribution and nature of the powders, the above positive developments have been put to good use, unlike anything seen before in the sector.

For compositions suitable for 60 minute firing cycles, with sufficient available raw materials, the result of milling is a 230 mesh residue of less than 0.5 % with an average particle size of less than 20 microns.

The presses, even though they compact heterogeneous powders for aesthetic reasons, guarantee up to 500 kg/cm² even on very large formats.

The kilns, with a working width of over 200 cm, make the final contribution with 60-70 min cycles at temperatures of 1200-1250 C° with automatic control of all parameters.

C) APPEARANCE

Taking for granted the intrinsic physical value of porcelain tile and the technological contribution that has made reliable and repeatable complicated processes possible on large formats as well, we believe that only modernisation, diversification and design originality have been, and are, the decisive factors for the success and development of the products.

The use of different coloured powders, regranulated to different degrees, stratified, correctly distributed in the moulds with extremely sophisticated systems, with pressing-lid textured surfaces, have widened the areas of research and experimentation.

In the tile industry, "design" in terms of colours, shapes, surfaces and effects, has determined trends and created areas of taste and fashion connected with style and the standard of living that were unthinkable only a few years ago.

It could not have been otherwise for the porcelain tile where, normally, the lack of glaze on which and with which to design has most greatly stimulated new solutions and led to an increasingly more refined final appearance.

The recovery of the taste for tradition, the appreciation of naturalness and the intimate affinity with stone, have given rise to further opportunities and new spaces for porcelain tile: marble and stone have found a fearsome competitor.

Raw and fired product polishing and many other decorative techniques have enhanced the carefully mixed batches of grains, colours, powders and, sometimes, even glazes.

The porcelain tile has branched out from its specific technical use, where it is irreplaceable, to public building work in the widest sense; from street furnishing and monuments to the floors and walls of private homes.

It would be wonderful to list the prestigious and infinitely varying situations in which porcelain tile has imposed itself as a distinguishing element.

THE PRODUCERS

The exclusive "club" of porcelain tile manufacturers, which until a few years ago had been reserved to solitary companies in Emilia, has opened its doors to many new and enthusiastic producers in Italy and abroad.

Moreover, the recent market launch of pre-milled, ready-to-use basic powders, also coloured, offers those companies who do not have a milling facility, or those who have one but that is not available or suitable for the product, the opportunity to start or develop production of this type of tile.

Generally speaking, the production flexibility of many companies, the collective diffusion of the technology of the sector and the level of professionalism of those who work in the sector are increasing.

The sector has now reached a critical size that can influence the whole ceramic tile market; it is now able to create an "archive" of experience and data, which is necessary for the personalised optimisation of basic machinery and technology that had previously occurred in the single-fired tile sector.

Moreover, there is no better way of bringing about the future and unforeseeable aesthetic developments than a widespread and continuous discussion, a deep and passionate study to discover the new, extended limits of the product.

It is impossible to foresee and quantify the positive effects of this growth, but it is certain, however, that they will be numerous and such as to arouse interest and ensure long life in a sector that some have already defined as "mature", perhaps a little too quickly.

We refer to the ceramics sector in general, the international growth trend of which has not yet finished, in spite of frequent difficult situations, local wars and negative political situations.

The increase in the population, the generalised increase in the standard of living above the poverty threshold and the currently available technology, can only contribute towards maintaining the present conditions and prospects of development. The only comments to be made about these remarkable figures are that never before in the history of tile has a product type grown as fast as the porcelain tile and that this product type is taking its market share from that of single-fired floor tiles.

Rightly so, it should be said, as this process maintains and increases the quality of traditional glazed tiles, since it extends the aesthetic possibilities of the product, increases the areas of use and presents greater economic advantages for the industry.

It can also contribute towards greater production flexibility in an industry that is by nature particularly rigid, at least up till now.

In fact, the positive implications of a formulation with a "universal" base suitable for differentiated ceramic properties through the modification of some of the production parameters, such as pressing and firing, are now being discovered and evaluated.

By controlling mechanical strength, thickness and porosity, the idea of obtaining interior and exterior tiles, floors, decorated wall coverings, objects and purely technical or multipurpose materials from the same "multipurpose" body should not scandalise us in the least.

DEVELOPMENTS IN PLANTS AND MACHINERY

The main stages in the growth of ceramic granite during the last twenty-five years have gone hand in hand with plant development. Plant engineers have worked hard to keep pace with the rhythms set by the product.

This publication does not intend to analyse the phases of plant development. We will limit ourselves to giving a brief summary of the heart of the factories in the nineties and then we will deal with the machines that surround it. The objective of the plant engineering projects was to develop a so-called "end of line" station. This obtains the powders from a silo "source" and continuously carries out all pre-pressing processes: batching, granulation, rolling, micronisation and mixing etc.

Unlike previous plants, it is now the press that takes the powders from a number of storage silos.

This solution has many advantages:

- 1) Rapid changes in production
- 2) Possibility of modifying production programmes at any time
- 3) Work programme and, consequently, product programme directly managed from the press, that is, according to the real requirements of the finished products warehouse
- 4) Improved separation of overall process management tasks
- 5) Dedicated lines, therefore low risk of pollution
- 6) Improved product quality due to the elimination of the harmful and inevitable demixing process deriving from batch storage

Those who are involved in production will certainly appreciate these advantages.

SPECIAL EFFECTS

As regards functionality and flexibility, plants have developed hand in hand with the principal machines and have acted as reference points for the technical and commercial policies of many producers.

It is not easy, therefore, to know whether to attach more importance to the plant, and plant management, or to the principle machines that have been developed in recent years.

It is further necessary never to lose sight of the need to compete with natural stone by creating real and proper "special" effects. These plant fixtures contribute to feeding the machines surrounding the press.

The heart of the plant has been created here, with personalised layouts and the use of modern and flexible machines wherever possible. These modular machines that can be combined in many layouts have contributed to the growth of all the most important porcelain tile factories.

The creation of the correct "conditions" for press feeding has been, without doubt, of primary importance for the development of the various ranges of ceramic materials.

Drawing on its experience in the treatment, batching and mixing of dry powders has enabled the industry to explore new horizons in clay colouring with a process that is as innovative as it is simple to manage.

With this technology, the spray dryer always works in the same operating conditions because it only has to treat one kind of powder.

When required, powdered coloured pigments are added in suitable proportions to the standard (neutral) spray dried body and then mixed together inside a machine that serves to combine the colouring particles with the granules of spray dried product: this is the present colouring stage.

DRY COLOURING WITH THE FOUR-COLOUR PROCESS

Dry colouring has opened up new horizons for companies operating in the porcelain tile sector. This technique streamlines all the operations of managing the spray-dried body store, making it possible to create the colours needed for production in the required quantities and tones directly at the press, eliminating all the time-consuming and space-wasting storage operations.



figure 1.

After designing and developing a simple yet effective colouring system, the next step was to enhance the process to create new solutions and new effects.

This was first done by colouring using the four-colour process, which involves colouring a neutral base with a combination of four colouring oxides.

These four colouring oxides can then be used to create an unlimited range of colours with all intermediate shades.

The selected oxides can be the standard colours of the CMYK system (cyan, magenta, yellow and black) or four colours chosen specifically for the required colour range.

Alternatively the RGB (red, green, blue) system can be used for a three, rather than four-colour process.

The next step is to perform dry colouring on bases which have already been coloured using the traditional method.

Research conducted at the laboratories has shown that with just four spray dried colours it is possible to create an infinite range of colours with all intermediate tones and halftones, similarly to the colours created using the classic method.

If the four spray dried bodies are treated and coloured using the three or four colour process, this extends the range of possible colours without limits, offering end users a practically infinite array of colour tones.



figure 2.

TECNOSLATE

The increasing need to create a pleasing aesthetic effect at the press has led to the development of a wide range of loading systems, positioned behind and in front of the press and all based on the longitudinal movement of the material.

In this way the multicoloured tiles exiting from the press have surface stripes or veins oriented in the direction of movement of the material:

PRESS EXIT

By improving the loading systems and working with the fair face of the tile underneath, the effect was improved to create coloured areas rather than stripes.

However, it was still not possible to identify a movement or precise design even with the shaping elements which were used to load the mould cavity.

EXAMPLE OF SHAPING ELEMENTS

Only by polishing the tiles to remove the topmost portion of surface material was it possible to reveal the design created using the shaping elements. However, this involved an additional processing operation outside the press.

At this point it was no longer sufficient to create a product with the same appearance on both sides using coloured bodies, which were resistant to acids and had extremely low water absorption. It was imperative to be able to distinguish the design created directly at the press, without any other operation after shaping.

OPERATING PRINCIPLES OF TECNOSLATE

In order to reveal the design during shaping at the press, it would theoretically be necessary to polish the tile before pressing it. Taking this observation as a starting point, the laboratories embarked on a painstaking research project to develop a suitable technique for doing this. The technique essentially involves directing air from close range inside the mould cavity between the body loading and pressing stages.



figure 3.

This produces very similar results to the removal of material after pressing. The pressurised air is directed through an aperture (whose length depends on the dimensions of the tile) in a steel bar fitted on one of the press feeding devices.

Because of its shape, this bar is referred to as a blade. As the blade moves over the loaded mould cavity, it removes a variable thickness of material so as to bring out the design inside the tile. Three types of tile with the same aesthetic effect can be obtained:

- a) textured
- b) smooth
- c) mirror polished (with further polishing after firing).

The process consists of three stages:

- 1) loading of the mould cavity
- 2) passage of the air blade and pressing
- 3) pressing

VARIABLE

- 1) air pressure in the blade circuit: the higher this value, the greater the quantity of material removed and therefore the clearer the design on the tile;
- 2) inclination of the blade relative to the plane of the mould: the greater this inclination, the less effect the blade has on the soft material deposited in the cavity;
- 3) speed of movement of the blade over the surface: the higher the speed, the shorter the transit time over the tile and consequently the smaller the quantity of material removed.

The material removed by the blade is recovered and reused in various ways depending on the type of product.

Tecnoslate enables making the effect visible immediately after pressing without it being necessary to polish the tile either before or after firing.

Micronised powders can be used as part of a double loading procedure. The combination with Tecnoslate ensures that the design created on the tile by a shaping screen or by other devices normally used in the production processing is visible without the need for further polishing.

In either case, textured punches can be used.

This way a texture can be associated with the design to create a tile with an extremely natural appearance.

It is evident that the mission of who works in this field is "research", in order to make useful objects or starting platforms for further developments. And this is exactly the philosophy of who has been reading this report.