In recent years, the need to maintain or regain market positions by improving product quality and service has also become apparent in the brickwork industry.

This has prompted operators to search for new technological solutions able to obtain the desired objectives through flexible methods of production, optimal work cycles, with production costs in line with the value of the product.

In the ceramic tile industry, dry pressed products, the turning point came with the introduction of rapid methods of drying and firing, made possible mainly by research and development in the field of the preparation of raw materials.

For this reason, this particular production stage is of fundamental importance in order to achieve a radical and decisive technological innovation in the process and the product, including extruded products.

Therefore, Manfredini & Schianchi, leaders in dry preparation systems, wishes to offer producers the benefit of 45 years of experience which have enabled us to be at the forefront in the production of plant for pressed tiles, extruded cotto floor and wall tiles, stoneware, clinker and porcelain stoneware, roofing tiles and structural brick.

In these years, using a wide range of applications, we have continued to update and transform our ceramic technology, adapting it as necessary to the different specific needs, both economical and commercial, for the various types of products.

**INTRODUCTION**

Ceramic products are obtained by processing clayey raw materials mixed with additives which correct their basic chemical and mineral characteristics, eliminate harmful components and improve the workability of the mixture for any given product.

The final mixture is the result of careful, continuous and at times difficult research and of the application of both recognised theories and practical experience, which can be very diverse but also very useful.

In the pre-processing of the selected raw materials, the pieces which have come directly from the quarry are crushed and reduced to particles of the required size and the powder thus obtained is then mixed and homogenised. This is of fundamental importance in order to achieve good control of the production process.

The main elements to be considered when planning production plant are the following:

- Chemical and mineral characteristics of the raw material
- Natural state and workability of the raw materials
- Maximum required particle size and percentages of other particle
- End product and its technical and commercial requirement
- Production process as a whole
NATURAL STATE OF THE RAW MATERIALS

The characteristics of the natural state of the raw materials of interest to us are the following:

- Initial size received at the factory
- Relative humidity measured in relation to the dry weight of a sample
- Measured hardness on the Mohs scale

The clayey raw materials can be classified according to their rate of humidity when extracted, as follows:

- Dry (relative humidity up to 6%)
- Semi-dry (relative humidity from 7% to 10%)
- Semi-humid (relative humidity from 11% to 18%)
- Humid (relative humidity from 18% to 25% and over)

The moisture content can vary according to the degree of malleability of the clayey component. However, it must be specified that it is extremely difficult on the basis of the above classification to make homogeneous comparisons among the varieties of clayey raw materials, therefore an equal moisture content does not necessarily lead to similar results in the particle size reduction and sifting process.

Preliminary analysis and workability tests should always be done on a significant range of samples to see whether they are suitable on an industrial scale basis. Bear in mind that raw materials differ according to the geographical location and consequently the prevailing climate, the location of the quarry, environmental conditions and working methods.

Extracted pieces can be of considerable size (up to 600 mm) as these can be processed by pre-crushing machines. Pieces up to 200 mm in size can be fed directly into the primary mills which have wide feeding inlets.

The raw materials are subdivided according to their hardness, that is whether they have good workability or can be ground easily, as follows:

- Hard, from a value of 6 to 7 on the Mohs scale
- Semi-hard, from a value of 5 to 6 on the Mohs scale
- Soft, under a value of 4 on the Mohs scale

It is evident that hard or semi-hard crushable raw material even with a high clay content but with levels of humidity not over 18% are best suited for dry grinding.

When the values and characteristics are less favourable, for decades now methods of preparing the raw materials have been used, which recall the simplest and oldest traditional ones practised by farmers for treating the soil. Nowadays these have
been made easier by the use of earth moving equipment with appropriate mechanical devices.

The operations can be summed up as follows:

- The clay is extracted in the low rainfall months and stored in heaps, even in the open air.
- In the summer months, the stored clay is spread over a large area and left to dry in the sun. While the clay is drying a machine from the quarry turns it over so that the lower layers are exposed to the sun and thereby surrender some of their humidity. This drying process takes about 1 to 2 days. After this treatment, the clay humidity has been reduced sufficiently to allow the dry working process to begin.
- In an industrial plant, the treated clay is stored under canvas or a canopy in sufficient quantities to enable production to continue during the months when climatic conditions are at their worst.

This also helps to amalgamate the different clayey components extracted from the quarry.

Non-clayey raw materials do not present problems as the traditional components for ceramic mixes, such as sand, feldspar, calcined clay, are not of high humidity content and in any case not being plastic they release water very easily.

When the clay cannot be treated in this way, artificial dryers are used to force-reduce the moisture content.

**ADDITIVES**

Mixtures are normally corrected as required by using additives with low malleability.

Contrary to what is generally believed, some of these additives, for example fired rejects in small quantities (5–10%), do not actually increase wear and tear on the milling parts but actually improve the efficiency of the mills; when introduced together with the clayey material, they in fact facilitate the treatment and milling of the so-called "soapy" clays by improving the milling operation and the flow of the product inside the milling machines.

In addition, the use of "chamotte" has a positive effect on all the production process leading to the following advantages:

- It is a lean component which stabilises the mixture without reducing its malleability
- It increases mechanical resistance of the dry product by up to 10% - 15%
- It helps drying and firing as it improves the total porosity of the humid and dried mixture
- It performs a "binding" function, resulting in better amalgamation of the clay particles, and therefore of all the mixture.

As well as these technical and productive characteristics, the use of "chamotte" in different particle sizes creates special aesthetic effects such as the dotted black and white surface of the renowned "Cotto Fiorentino".

Compared to other types of lean additives, "chamotte" maintains in the fired product the characteristics of the base raw materials and amalgamates with them, whereas sand, for example, remains on the surface of the final product.

When the additives are already available in the required quantity and grain size, they are added to the clay powder directly into the dry mixers using volumetric or weighed batching devices. These have internal devices which guarantee perfect amalgamation between the components even if their bulk density is much different.

**PARTICLE SIZE DISTRIBUTION**

One of the main characteristics of raw materials dry processing is that, once the appropriate maximum particle size has been identified, it is possible to achieve it and guarantee it by regulating the milling and grading equipment.

Constant control of the working parameters results in high standards in end products with special technical and aesthetic features.

This technology has a wide range of sizes to offer, we can sum them up in the following table:

1) coarse size from 1.5 mm and over
2) semi-coarse size from 0.8 mm to 1.5 mm
3) semi-fine size from 0.4 mm to 0.7 mm
4) medium fine size from 0.25 mm to 0.4 mm
5) fine size from 0.15 mm to 0.25 mm  
6) very fine size > 0.15 mm

By particle size we mean the maximum acceptable size which is at the "apex" of the distribution curve showing the percentages of all the other particles which make up the sample.

Particle size is always guaranteed by sifting control but the percentages of particle distribution can vary mainly due to:

- Natural state and type of raw material
- Type of refining of the powders during first milling
- Variations of the operation parameters of the mill

To obtain different particle sizes, milling machines with different operations and characteristics are used. From the results of the experiments carried out so far and which have been replicated by our machines we can state that:

For sizes 1) coarse and 2) semi-coarse the use of hammer mills with appropriately wide grids is sufficient. These machines have a "double" function, they can both pre-mill and finish the operation after first milling, the powders are returned back to the primary mill.

For size 3) semi-fine the use of hammer mills is also sufficient but the operations are subdivided into "primary" (when between 40% and 80% of the material fed in passes through at the milling passage) and finishing.

For sizes 4) medium fine and 5) fine, special finishing mills must be used with the primary mills. These have a grinding track which interacts with the rollers or pendulums with differing characteristics and functions, which make it possible to obtain particularly fine grinding.

The very fine size range is actually found in every ground powder sample and can vary in percentage from 30% after grinding with only hammer mills to 100% after very fine grinding using pendulum or roller mills.

The positive (or in some cases negative) effects of the different particle sizes and relevant distribution curves on the end products are important and decisive. They affect both the technical and aesthetic characteristics of the product and the whole production process. They also affect the production rate and method as well as they influence to a larger extent the balance and efficiency of plant downstream.
THE FINAL PRODUCT

M&S Dry milling is the only existing technology for the preparation of raw materials which can produce ALL types of clay products obtained through moulding by extrusion and/or subsequent pressing with ALL the technical and commercial characteristics required.

This is valid for all products from the "poorest", the common brick (structural ceramic) to the most prestigious (extruded porcelain stoneware).

Today the Common Brick, known as structural ceramic, is produced in many varieties using the dry milling process, from non-supporting hollow bricks to wall blocks, standard or light, from the high-finished brick for external use reaching up to ceiling blocks, the whole range of small and large slabs for non-supporting horizontal structures and the most innovative products of this sector, the "bee-hive" support block which is both convenient and with highly technological value.

Covering materials, bent tiles and roofing-tiles, which in recent years have been particularly in need of technical and aesthetic improvements (see for example glazed roofing-tiles) which are essential in order to compete in a more and more demanding sector. Dry processing of raw materials has led to improved transpiration, waterproofing, insulation and resistance to freezing thanks to a more homogeneous porosity, a resistant microstructure and lesser capacity for capillary absorption.

"Cotto" floor tiles, typical product of Italian Industry, has renewed and increased its prestige thanks to research into the composition of the typical Tuscan clay body through surface treatments and different moulding, drying and firing techniques which only dry processing can facilitate. Moreover surface brushed and rustic floor tiles with flashed, shaded, glazed and the handmade rough effects are latest trends, dry processing system has been contributing to. Nowadays all these products are suitable for the most varied in and outdoor applications, thanks to renewed characteristics of water absorption, hardness, resistance to flexing, deep abrasion, frost and sudden changes in temperature.

Klinker, technical product par excellence in the range of extruded products, thanks to the perfect and controlled reduction in particle size of its raw materials which facilitates firing at high temperatures, reaches perfection for the quality and chromatic effects of its glazed series whilst preserving all its other outstanding technical characteristics.

Extruded porcelain stoneware is the most innovative technical product, being obtained with a selection of kaolin clay mixed with feldspar and gypsum, and fired at high temperatures. To obtain extruded porcelain stoneware, very fine dry grinding of raw materials, perfect amalgamation, humidification, mixing and shaping at a controlled level of humidity are necessary.
ADVANTAGES OF M&S DRY PROCESSING

The dry preparation of raw materials with the methods proposed by Manfredini & Schianchi is "a process under constant control with guaranteed results" since it makes it possible to verify and maintain in practice the strict production parameters established theoretically at the planning stage.

The different plant solutions, which vary according to different production requirements and to the raw materials available, have a series of constructive and functional characteristics which help to achieve the predetermined objectives and to obtain advantages which are not offered by other traditional systems no matter how developed or sophisticated.

The main ones are:

A) Treatment and milling of all types of raw materials currently used for the manufacturing of clay products, whether extruded or pressed, irrespective of their chemical, mineral and natural state characteristics.

The relevant advantages are as follows:

- Existing deposits can be exploited without having to carry out expensive and complicated selections at the extraction stage.
- Mixes can be made up using preferably the raw materials available or those more easily accessible thus avoiding the very high costs of finding and supplying alternative ones.
- Reuse of the company's own dried and fired production waste or that of other producers.

B) Reduction of the required grain size and precise control of that parameter.

The relevant advantages are as follows:

- Total elimination of impurities, all kinds of carbon particles, mica and others, which cause technical and aesthetic defects to the end products.
- Possibility to obtain different grain sizes from different raw materials, to be used separately or in combination in the production process.

C) High flexibility in the use of milling lines and single machines, according to different production requirements and the need to vary the required grain size. This is made possible by designing plant as a series of modules with interdependent segments.
The relevant advantages are:

- Continuous operation can be guaranteed even when routine or extra-duty maintenance is being carried out.
- It is possible to react immediately to changes in the supply of raw materials due to changes at the quarry.
- It is possible to modify the technical and aesthetic characteristics of the end product, or to plan its replacement quickly in accordance with the requirements of the market.
- It is possible to foresee and to plan extensions, restructuring and technical innovations of the downstream units ensuring that the mixture is suited for the different shaping, drying and firing treatments.

**SOME COMMENTS ON ASPECTS OF CERAMIC TECHNOLOGY**

The dry preparation of raw materials has always been completely misunderstood. It is a common opinion that milling is synonymous with pulverising and that therefore effective milling should produce the maximum possible quantity of uniform fine powder.

This opinion is totally wrong.

The exclusive use of very finely ground powders creates the following problems:

- Weak cohesion of the mixture being shaped
- Low mechanical resistance of the shaped and dried product
- Higher drying and firing cycles, with the risk of a faulty end product

Thanks to our vast and specific experience in the field of ceramics Manfredini & Schianchi have transferred this fundamental aspect of the technology of preparation and treatment of raw materials to the sector of extruded products.

Basically, the "secret" of an efficient preparation and milling process lies in the ability to maintain a "balanced" granulometry curve, with an appropriate distribution of powders in order to form a "skeleton" capable to guarantee aesthetic and technical results to the final products.

So as obtain that, it is necessary to consider the different qualities of powder which are produced by the milling process.

The hammer mill type PIG transforms the raw materials into irregularly shaped polyhedral powder with a complete granulometry distribution from the maximum grain size to the micronized particles.

On the other hand, the powders produced by the pendular mills type MS basically have a different morphology, being flat, very fine and homogeneous as a result of the friction of the rollers and/or of pendulums on the track.
The mixing and amalgamation of these two types of powder, in appropriate established percentages results in a mixture with an optimal structure providing:

- Strong cohesion of the mixture during shaping
- High mechanical resistance of the dry product
- Homogeneous distribution of the apparent porosity

The basic idea is therefore to carry out a selective milling both regarding quantity and quality, obtaining very fine powders only when strictly necessary, and to make suitable selections of particle sizes using highly efficient grading methods.

An equally important issue concerning the application of technology and experience in the field of ceramics is the mixing process, the amalgamation of the clays and additives, and the subsequent preparation of the mixture.

Manfredini & Schianchi have developed their own dry mixing methods and has introduced the process of powder moistening into the extruded products sector using modified and improved machines from the ceramic industry with high output and efficiency characteristics.

Humidifying milled powders (Wetting Machine MS2000), before the bathing and mixing process (Mixing-Wetting Machine MS), has led to a significant development in the preparation of the body with the following results:

- The total "deflocculation" of the body with a "hydrosphere" effect on the humidified particles
- The complete absorption of the water during the subsequent humidifying stage
- Measurement and continuous automatic control of the humidity content in the powder (Moisture Meter)

The main advantages of such a stage are:

- Perfect amalgamation of the powder with partial conversion into pellets leading to a high level of fluidity and facilitating treatment in the downstream stages.
- Elimination of lumps.
- Precise weighed addition of water used for humidifying and mixing, which is guaranteed to remain constant as a percentage of the final mixture
- Uniform pressure of the materials during extrusion and elimination of tensions within the mixture which facilitate the drying process and reduce the vacuum pressure required by the pugmill
- Shaping with smaller quantities of water in the body (1 to 3% according to the chemical and mineral characteristics of the clays) with consequent savings in energy during the subsequent drying process.

The positive effects on the downstream stages are as follows:
• HANDLING - Better cohesion of the "green" moulded product which facilitates the handling of the material and makes it possible to simplify the plant engineering concerned.
• DRYING - Homogenous distribution of the apparent porosity which helps to eliminate water at the drying stage thus reducing the production cycles and the percentage of waste materials.
• TREATMENTS - Better mechanical resistance of the dried products and therefore safer handling of the material, reducing microfractures, and granting better results in the finishing and surface treatment and in the quality of the end product.
• FIRING - The "skeleton" structure of the mixture resulting from a correct distribution of the size and morphology of the particles, thanks to its apparent porosity, improves preheating, firing and cooling because the organic substances are expelled more quickly.

In addition, the perfect amalgamation of the raw materials which make up the mixture helps to obtain better fusibility and a more efficient vitrification, thereby improving the technical characteristics of the end product.

DESCRIPTION OF PLANT MODELS

In this chapter we will illustrate two types of processing plants which use the two main criteria as regards the ceramic technology applied to the engineering of dry processing.

The plants are also equipped with all the necessary devices for the maximum quality control of all the stages.

The technical data tables will show the two options which are as follows:

A) Technological line for milling by primary hammer mills and finishing hammer mills the following particle sizes:

1) coarse, 2) semi-coarse, 3) semi-fine

suitable for the production of:

- Common structural brick
- Innovative structural brick
- Covering materials
- Extruded red body floor and wall tiles with minimum absorption of 5%

B) Technological line for milling by primary hammer mills and pendulum finishing mills to obtain the following particle sizes:

4) medium fine, 5) fine, 6) very fine

suitable for the production of:

- Special covering materials
- Extruded floors and tilings with maximum absorption of 3%
- Technical products, clinker, extruded white body porcelain stoneware with maximum absorption of 0.5%
- Terracotta garden pot

TECHNOLOGICAL LINE TYPE A

Mainly consisting of:

1) Loading hoppers, suitable for receiving material directly from the quarry or from previously prepared heaps using a clay loading shovel able to handle pieces of considerable size (0 – 250 mm)

2) At the base of the hoppers there are extraction devices with double connecting rods, particularly suitable for the pre-crushing of the bigger blocks and reducing them to 200 mm maximum

3) Alternatively a vibrating duct is used when the pieces received are already reduced to 150 mm max.
4) The material to be ground is off loaded onto conveyor belts, which can also weigh the material, should it be necessary to make up the mixture with a maximum variation of 1%.

5) Primary hammer mill which produces between 60% and 80% of powders at the first milling and screening passage. It consists of a thick sheet steel casing lined internally with circular and lateral wearproof plating; a rotor on which the grinding hammers are mounted; lump breakers, a static sizing grid at the bottom and a set of electrical resistances for humid raw materials are also present.

6) Bucket elevator for vertical transport of solid material, powder or pieces of various sizes. Made of a strong sheet steel structure and treated internally with easy flow material. The buckets are made of polyethylene or pressed steel, sturdily bolted to the conveyor belt made of special three-layer rubber. This device is driven by a motor and a pendular gearmotor.

7) High-efficiency inclined mechanical screens, totally static and without oscillations in the net frame and in the support structure. These are used to separate the powders of required granulometry from those needing further finishing. They have electromagnetic heads mounted in line on support decks which transmit high frequency oscillating energy; this energy can be regulated and modified for each single head and is applied directly to the screening net at a number of points all over the net. A calibrated choice of inclination of the screening surface and of the net with the most appropriate mesh makes it possible to obtain an exact classification of the powders for a high rate of material processing. There can be one, two or three grading surfaces in order to obtain different particle sizes from the same machine at the same time. The screens are also equipped with a self cleaning system with brushes and electrical resistances to cope with humidity levels in the raw materials.

8) Netcloth control device, positioned after the screens which carries out continuous analysis of the screened product. If unwanted particle size is produced owing to breakage of the net, an optical and acoustic alarm is given.

9) Finishing hammer mill, which is built and operates in a similar way to the primary mill, but has been suitably modified for an effective treatment of the powders from the first screening passage. The powders leaving the finishing mill are unloaded onto the previous elevator and taken back to the screening control.

10) The powders obtained in this way are then taken to the humidifying treatment; the machine used for this specific application is a circular humidifier MS/2000, made of steel sheet with inspection hatches. The quantity of water is regulated by a mechanical or hydraulic system, the level of humidity of the powders exiting can be corrected automatically thanks to the electronic MS/MU 7685 reading device. The nebulization of the water is obtained by a rotating disc activated by a closed and ventilated motor. A series of steel rotating blades remix the moistened powders in order to obtain perfect homogenisation. The percentage of water added to the product can vary from 1% to 3% according to the chemical and physical characteristics of the raw materials and the production requirement.

11) The body may be then stored in circular or square metal silos of different storing capacity as necessary. These are made of prefabricated panels, pre-painted with anti-rust, coated internally with rubber and bolted to support structures of variable capacity as required. Normally, storage of powders obtained through dry milling and by moistening do not need the so-called seasoning but can be sent immediately to production. Therefore, the silos are used simply to store the raw material for a maximum of one or two days' production.

12) Manfredini & Schianchi ends the technological proposal with a mixing wetting equipment duly studied for dry processed bodies. The system equipped with airtight throttle valves and a high pressure water addition system perfectly homogenizes the body and adds the necessary amount of water which easily permeates the composition without formation of lumps or big grains.

TECHNOLOGICAL LINE TYPE B

This second line mainly consists of:

1) Loading hoppers as above

2) Extraction devices with double connecting rod as above or extracting belts

3) Conveyor belts as above

4) Hammer mill as above or suitable primary mills

5) Pendular finishing mill with separators (static or dynamic, necessary to obtain the required values of grain sizes). The material is inserted into the milling chamber by a batching screw or a weighing belt, the milling process is carried out by rotating rollers which squeeze it against a fixed circular sector track. The particles are carried to the upper part of the mill by a flow of air generated by a centrifugal ventilator or collected by a process filter. Operations can take place in two ways:
- By means of a cyclone creating a "closed" mill-cyclone-fan circuit
- By means of a sleeve filter with an "open" mill-filter-fan circuit

The technical-operational characteristic of the innovative "open" circuit is that the material which has just been ground can be handled by powerful and immediate suction. This solution drastically reduces the retention time of the material inside the milling chamber thus substantially reducing wear and tear on the grinding parts and notably increasing the hourly production capacity by as much as 100 % compared to traditional technologies.

The pendular mills can operate drying of raw materials with a very efficient thermal consumption which never exceed 450 Kcal/Hr. of evaporated water.

With such a system, we can operate a drying stage with a humidity reduction from 18% to 8% therefore such a line could serve customers with serious problems of humidity in the raw materials without installing a preliminary drying stage which increases the capital and running costs accordingly.

The process ends with stages 10, 11 and 12 as shown above.

CONCLUSIONS

Of course like all industrial processes involving raw materials, tests and trials on the Components to handle are essential to guarantee low processing costs and quality consistency in the final products, therefore Manfredini & Schianchi are equipped with skilled technicians, laboratories and pilot plants to conduct all the necessary ceramic evaluations.

*The data shown is indicative and may vary without notice*