ISSN: 2394-4404

Appraisal Of The Micro-Structure Of Fired Ceramic Bricks Produced In Abakaliki, Ebonyi State, Nigeria

Amadi, C. O.

Civil Engineering Department, Ambrose Alli University, Ekpoma, Edo State, Nigeria;

Ohimai, J. O.

Omerigwe, M. O.

Ceramic Technology Department, Auchi Polytechnic, Auchi, Edo State, Nigeria

***Abstract:** The aim of this paper was to appraise the micro-structures of fired ceramic bricks produced in Abakaliki, Ebonyi State. The paper examined the concepts of fineness modulus and microstructure. In order to observe the differences in the fired clay brick manufacturing procedure, a study was performed on clay samples obtained from four major brick manufacturers in Abakaliki, Ebonyi State. The texture and porosity evolution of the fired clay brick samples were studied by scanning electron microscopy (SEM), using a JEOL SEM model JSM 5900LV operating at 20kV and 12 Pa pressure in the sample chamber and equipped with an EDAX solid-state energy-dispersive X-ray detector. The crystalline phase changes were determined by X-ray diffraction (XRD) using a diffractometer (Siemens model D5000). The study revealed that relevant changes in the microstructural properties were observed between 800 and 1000^{0}C. It therefore concluded that the reduction of porosity and vitrification occurring at these temperatures produced a material with higher quality. Thus this study may have important implications in the artisan brick-making industry.*

***Keywords:** ceramics, microstructure, fineness modulus, fired, x-ray diffraction, scanning electron microscope.*

I. INTRODUCTION

A brick is building material used to make walls, pavements and other elements in masonry construction. Traditionally, the term brick referred to a unit composed of clay, but it is now used to denote any rectangular units laid in mortar. A brick can be composed of clay-bearing soil, sand, and lime, or concrete materials (Russ et al, 2005). Bricks are produced in numerous classes, types, materials, and sizes which vary with region and time period, and are produced in bulk quantities. Two basic categories of bricks are *fired* and *non-fired* bricks. Kiln Bricks, also referred to as Fire Bricks or Refractory Bricks, are made from ceramic refractory material that can withstand extremely high temperatures, such as those achieved in kiln firings (Cultrone et al,2000). The bricks typically line the inside of a kiln (furnace, fireplace, etc.) and serve as great insulators, making heat loss minimal and energy use efficient. Kiln bricks are available in different shapes and sizes, and come in either soft or hard material. Bricks are popular as building materials for several reasons. First, clay is available throughout the world in large quantities and brickmaking is a fairly simple process, so bricks themselves are relatively inexpensive. Building bricks are much lighter and easier to work with than stone and sometimes last longer. They are attractive to look at, weatherproof, and—like other ceramics—very good at resisting high temperatures. By using different clays, it's possible to make bricks in different colors. Traditional red bricks take their color from iron in their clay, while yellow bricks have a greater quantity of lime or chalk (Russ et al, 2005).

There are essentially two kinds of bricks: ordinary building bricks and refractory bricks (Cultrone et al,2004).

- ✓ Building bricks are made to a standard size (typically 20–22cm long, 9–11cm wide, and 5–7cm high (approx 8–8.5in long, 3.5–4.5in wide, and 2–3in high), with the dimensions varying slightly from country to country). They're made from higher grades of clay and finished on at least one side (face) so they look attractive on houses and walls.

 ISSN: 2394-4404

- ✓ Refractory bricks are made for high-temperature use for lining such things as industrial smokestacks (chimneys) and household fireplaces, so they tend to be made more crudely and less attractively finished. Unlike ordinary bricks, they're typically made using such raw minerals as fireclay, alumina (aluminum oxide), silica (silicon oxide), and dolomite (calcium magnesium carbonate). Some are designed to survive temperatures over 2000°C (3600°F); the "ceramic tiles" that protected the Space Shuttle from heat when it re-entered Earth's atmosphere from space were actually very thin refractory bricks.

Kiln bricks come in two forms: hard brick and soft brick. So, what is the difference? Hard bricks are typically very strong and dense and used most commonly as structural support in kilns. These bricks are able to withstand extreme temperatures and various atmospheric conditions. Soft bricks are less dense than hard bricks and are excellent insulators. These are typically found in electric kilns or any kiln or furnace that requires insulation. Bricks are available in a variety of shapes, though a standard brick is rectangular and measures 9” x 4.5” x 2.5”. Rectangular bricks measuring 9” x 4.5” x 3” are becoming increasingly popular, since the 3” firebrick provides added insulation and increases energy efficiency (Cultrone et al, 2000).

Fired bricks are one of the longest-lasting and strongest building materials, sometimes referred to as artificial stone, and have been used since circa 4000 BC. Air-dried bricks, also known as mudbricks, have a history older than fired bricks, and have an additional ingredient of a mechanical binder such as straw. The earliest fired bricks appeared in Neolithic China around 4400 BC at Chengtoushan, a walled settlement of the Daxi culture (Demir, 2006). These bricks were made of red clay, fired on all sides to above 600°C, and used as flooring for houses. By the Qujialing period (3300 BC), fired bricks were being used to pave roads and as building foundations at Chengtoushan. Bricks continued to be used during 2nd millennium BC at a site near Xi'an (Demir, 2006). Fired bricks were found in Western Zhou (1046–771 BC) ruins, where they were produced on a large scale. The carpenter's manual Yingzao Fashi, published in 1103 at the time of the Song dynasty described the brick making process and glazing techniques then in use. Using the 17th century encyclopaedic text Tiangong Kaiwu, historian Timothy Brook outlined the brick production process of Ming Dynasty.

Fired bricks are burned in a kiln which makes them durable. Modern, fired, clay bricks are formed in one of three processes – soft mud, dry press, or extruded. Depending on the country, either the extruded or soft mud method is the most common, since they are the most economical. Normally, bricks contain the following ingredients (Demir, 2006):

- ✓ Silica (sand) – 50% to 60% by weight
- ✓ Alumina (clay) – 20% to 30% by weight
- ✓ Lime – 2 to 5% by weight
- ✓ Iron oxide – ≤ 7% by weight
- ✓ Magnesia – less than 1% by weight

In many modern brickworks, bricks are usually fired in a continuously fired tunnel kiln, in which the bricks are fired as they move slowly through the kiln on conveyors, rails, or kiln cars, which achieves a more consistent brick product. The bricks often have lime, ash, and organic matter added, which accelerates the burning process. The other major kiln type is the Bull's Trench Kiln (BTK), based on a design developed by British engineer W. Bull in the late 19th century (Demir, 2006).

An oval or circular trench is dug, 6–9 metres wide, 2-2.5 metres deep, and 100–150 metres in circumference. A tall exhaust chimney is constructed in the centre. Half or more of the trench is filled with "green" (unfired) bricks which are stacked in an open lattice pattern to allow airflow. The lattice is capped with a roofing layer of finished brick (Cultrone et al, 2004).

II. PROPERTIES OF CERAMIC BRICKS (CULTRONE ET AL, 2000)

- ✓ High melting points (so they're heat resistant).
- ✓ Great hardness and strength.
- ✓ Considerable durability (they're long-lasting and hard-wearing).
- ✓ Low electrical and thermal conductivity (they're good insulators).
- ✓ Chemical inertness (they're unreactive with other chemicals).

Most ceramics are also nonmagnetic materials, although ferrites (iron-based ceramics) happen to make great magnets (because of their iron content).Those are the useful points, but, thinking about traditional ceramics like glass or porcelain, you'll also have noticed one major drawback: they can be fragile and brittle, and they'll smash or shatter if you drop them (subject them to "mechanical shock") or suddenly change their temperature ("thermal shock") (Cultrone et al, 2000).

Clay dug from the ground is soft and pliable because, like graphite, its atoms are made of flat sheets that can slip past one another, held together only by weak bonds. When you add water to clay, the polar water molecules (positively charged at one end, negative at the other end) help to pull those bonds apart, making the clay even more malleable (Demir, 2006). When you fire clay, the water evaporates and the aluminum, silicon, and oxygen atoms lock into a rigid structure made from aluminum silicate, bonded together by silicate glass—and that's why fired clay is so hard. Ceramic bricks are made from clay before we can build with them. As we've already seen above, clay is a naturally occurring ceramic based on the chemical elements aluminum, silicon, and oxygen (Cultrone et al,2000).

III. CONCEPT OF FINENESS MODULUS OF FINE AGGREGATE USED IN PRODUCING COMMON FIRED BRICKS

In 1925, Duff Abrams introduced the concept of fineness modulus (FM) for estimating the proportions of fine and course aggregates in concrete mixtures. The premise: "aggregate of the same fineness modulus will require the same quantity of water to produce a mix of the same consistnecy and give a concrete of the same strength." Before calculating FM, lab technicians perform a sieve analysis to determine the particle size distribution, or grading, of the aggregate sample. FM is the sum of the total percentages retained on each specified sieve divided by 100. ASTM C 33 requires the FM of fine aggregate to be between 2.3 and 3.1. The higher the FM, the coarser the aggregate. Fine aggregate affects many concrete properties, including workability and finishability (Cultrone et al,2004). Usually, a lower FM results in more paste, making concrete easier to finish. For the high cement contents used in the production of high-strength concrete, coarse sand with an FM around 3.0 produces concrete with the best workability and highest compressive strength.

IV. MICROSTRUCTURE OF COMMON ABAKALIKI FIRED BRICKS

The durability of building materials is strongly influenced by environmental conditions (e.g., solar radiation, moisture, and atmospheric pollution) (Pel et al, 1995). Control of the microstructural properties, such as the porosity and the mineralogical composition, is considered a key parameter for the durability of different building materials. New materials are studied and the durability parameters are determined, nevertheless there is an amount of wisdom on the traditional material selection in each region of the world. The firing of clay bricks and the presence or absence of different minerals produce mineralogical, textural, and physical changes that influence porosity and pore distribution. For example carbonates in the raw clay brick promote the formation of fissures and pores when the bricks are fired between 800 and 1000^{o}C. Organic waste material increases porosity in a clay body, increasing the insulation capacity (Cultrone et al,(2004)

V. MATERIALS AND METHOD

In order to observe the differences in the fired clay brick manufacturing procedure, a study was performed on clay samples obtained from four major brick manufacturers in Abakaliki, Ebonyi State. From each of the four sites, five clay solid bricks were prepared by hand, using a homogeneous mixture of clay (80%), sand (20%), and water to make the clay material, and placed in a wooden mould to shape the bricks with dimensions from 0.28 × 0.13 × 0.60m. The pieces were subsequently sun-dried for two or three days, depending on the weather conditions. They were later fired in an electric oven with a 10^{0}C/min heating ramp at a preset temperature which was maintained constant for 12 hours. The selected temperatures were 200^{0}C, 400^{0}C, 600^{0}C, 800^{0}C, and 1000^{0}C. The texture and porosity evolution of the fired clay brick samples were studied by scanning electron microscopy (SEM), using a JEOL SEM model JSM 5900LV operating at 20kV and 12 Pa pressure in the sample chamber and equipped with an EDAX solid-state energy-dispersive X-ray detector. The crystalline phase changes were determined by X-ray diffraction (XRD) using a diffractometer (Siemens model D5000) with copper target at 0.05 and 1 second integration in the 5 to 75mm range on the scale.

VI. RESULTS AND DISCUSSION

The fired clay bricks exhibit a range in color from orange (for low firing temperature) to dark red (for high firing temperature). For different samples, the texture and crystalline evolution of the fired clay bricks were observed by SEM and XRD, respectively. A micrograph of the raw clay brick for Presco shows a granular appearance with particle size ranging from 1um to 100um. However, F1 higher magnification exhibits a faceted structure Fig. 1(a). In the first stages of firing, around 100^{o}C, there is only loss of water, and we can recover the raw clay mixture adding some water. Significant changes can be observed in the microstructure and physical properties of the clay bricks at T > 200^{0}C. There is an apparent increase in particle size and some cracking at 600^{0}C (Fig. 1b) and when the fired temperature exceeds 600^{0}C, the brick acquires a reddish color and conglomeration of particles. At higher fired temperatures, between 800^{0}C and 1000^{0}C, the microstructure is further modified exhibiting vitrification and a dark red color. Vitrification can be clearly detected when the sample is fired at 1000^{0}C Figs. 1(c) and (d).

VII. CONCLUSION

SEM and XRD show that the firing temperature and mineralogical composition are relevant parameters for porosity and its evolution in clay bricks. Relevant changes in the microstructural properties are observed between 800 and 1000^{0}C. The reduction of porosity and vitrification occurring at these temperatures produces a material with higher quality. Thus this study may have important implications in the artisan brick-making industry.

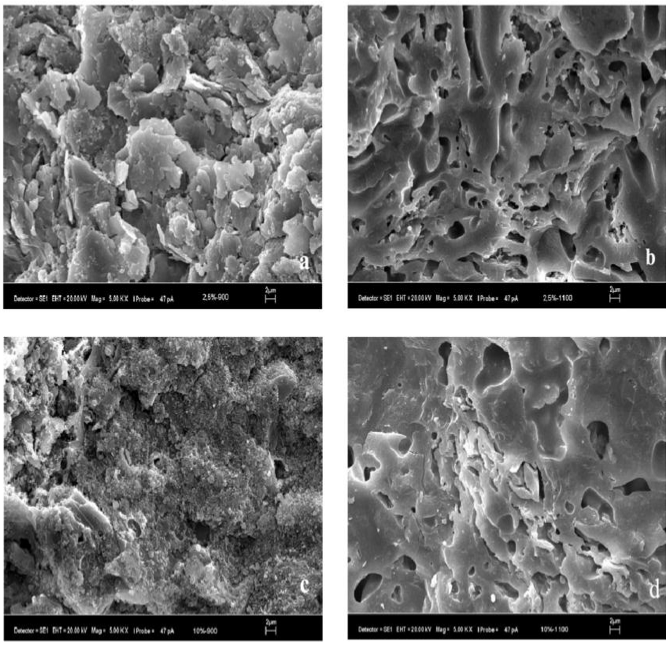

Figure 1: SEM and XRD show that the firing temperature and mineralogical composition are relevant parameters for porosity and its evolution in clay bricks

REFERENCES

[1] Cultrone, G.; Sebastian, E.; Kerstin, E.; de la Torre, M.J.; Cazalla, O.; Rodriguez-Navarro, C.(2004): Influence of mineralogy and firing temperature on the porosity of bricks. *Journal of European Ceramics*. Soc., *24*, 547–564.

[2] Cultrone, G.; de la Torre, M.J.; Sebastian, E.M.; Cazalla, O.; Rodriguez-Navarro, C.(2000). Behavior of brick samples in aggressive enviroments. *Water, Air, and Soil Pollution 119*, 191–207.

[3] Demir, I.(2006). An investigation on the production of construction brick with processed waste tea. *Building and Environment, 41*, 1274–1278.

[4] Pel, L.; Kopinga, K.; Bertram, G.; Lang, G.(1995). Water absorption in a fired-clay brick observed by NMR scanning. *Journal of Applied Physics*., *28*, 675–680.

[5] Russ, W.; Mortel, H.; Meyer-Pittroff, R.(2005). Application of spent grains to increase porosity in bricks. *Construction and Building Materials*, *19*, 117–126.