CLAY ESSENTIAL MATERIAL FOR CERAMIC PRODUCTION

Chukwueke Chibuike Tochukwu
Department of Fine and Applied Arts, Faculty of Environmental Sciences, Nnamdi Azikiwe University Awka.

Ivan Okonkwo, (Ph.D)
Fine and Applied Arts, Faculty of Environmental Sciences Nnamdi Azikiwe University, Awka.

Abstract

Clays are used in the ceramics industries largely because of their contribution to the moulding and drying properties of the wares being produced; many clays, such as the flint clays, are used because of favorable behavior during firing or because they produce favorable properties in fired ware. To assure the most effective use of a clay, the ceramic technologist must meet problems of purification, aging, bacterial action, and the improvement of the working properties of clays and bodies through additions of non-plastic materials or chemicals. He deals with flocculation and deflocculation, thixotropy, and related phenomena in casting slips. Control of drying behavior is important. Finally, the ceramist is concerned with the influence of the clay content of ceramic bodies on their behavior during firing. The methodology adopted is the descriptive research method which involved an indepth review of literature related to the study, observation schedule and selection of foreign and local Case studies to compare and deduce data on clay essential materials for ceramic production. The findings of this study reveals that clays are used in the ceramics industries largely because of their contribution to the moulding and drying properties of the wares being produced, many types of clay, such as the flint clays, are used because of favorable behavior during firing or because they produce favorable properties in fired ware.

Keywords: clay, materials, ceramics.

INTRODUCTION

Clay is considered to becoming the important determinants of soil specifications as well as industrial minerals that is helpful and is very important in ceramic productions. Clay forms a significant component of soil because it constitutes a significant element in bricks and tiles, making it an essential material in ceramic process. The use of clay in manufacturing industries depends on its physical and chemical properties; therefore, there is a lot of research that dealt with how to improve ceramic production using clay as an essential material.

Ceramics belongs to a class of inorganic, solids that are subjected to high temperature in manufacture and/or use. The most common ceramics are composed of oxides, carbides, and nitrides. Silicides, borides, phosphides, tellurides, and selenides also are used to produce ceramics. Ceramic processing generally involves high temperatures, and the resulting materials are heat resistant or refractory. Traditional ceramics refers to ceramic products that are produced from unrefined clay and combinations of refined clay and powdered or granulated non plastic minerals. Often, traditional ceramics is used to refer to ceramics in which the clay content exceeds 20 percent.

When clays are used in ceramics, one of several functions is generally served. Most clay, alone or in mixtures, are used chiefly for their contribution to the working properties, drying strength, and dry strength, of the ceramic masses which they comprise or to which they have been added. Some clays, however, are used more because they offer an inexpensive body constituent or filler of the desired chemical composition, already subdivided by nature to a convenient grain size. For example, china clay probably serves as much or more as filler than as a plasticizer in some dust-pressed wall-tile. Other applications of clays for their refractory or fired properties include the use

of raw or calcined flint clay as a grog in refractories or as an investment material in precision casting.

The Nature of Clay

Clay is a product of the decomposition of granite rock. 75% of the earth's crust is made of alumina and silica, two of the major constituents of clay. granite decomposes into feldspar, the most common mineral, which is composed of alumina, silica, and flux (of an alkaline nature e.g. sodium, potassium, lithium, calcium). the flux is somewhat soluble, and over long periods of weathering is carried off by moisture. The remaining alumina and silica are refractory (resistant to heat) and chemically inert. After long exposure to moisture, the alumina and silica become hydrated (water chemically added) to produce clay. This takes long periods of geologic time and cannot be synthesized. Clay is 14% chemical water. Unfired clay also contains physical water, which evaporates during drying. Stages of green (unfired) clay from most to least water: slip, plastic clay, leather-hard clay, bonedry greenware, especially in humid climates, even bone-dry greenware contains some physical water.

Factors that contribute to the plasticity of clay include:

- Plate-like particle shape of particles
- Size of the particles
- Chemical/electrical attraction between particles
- Presence of carbonaceous (organic) matter

Plasticity: is the ability of clay to respond to pressure with a continuous and permanent change of shape in any direction without breaking apart, and hold that shape when released. Daniel Rhodes says that clay is unique in its degree of plasticity. Factors that contribute to the plasticity of clay

are the plate-like particle shape of clay (provides large surface area), the size of the particles (small particles are more plastic than large ones), chemical/electrical attraction between particles (adding an electrolyte, a.k.a. deflocculant such as soda ash or sodium silicate, will reduce the attraction between particles and reduce plasticity and clumping.. .good in casting slip, difficult to work in plastic-forming methods.

Clay that lacks plasticity (a short clay) will not bend well and tends to break instead of forming when bent. A classic test is to roll a coil of clay the thickness of a pencil and see if you can wrap it around your finger without breaking. Short clays lack plasticity, but will shrink less than more plastic clays. A clay can be too plastic (a fat clay), and will feel sticky/slick. A fat clay generally slumps easily when thrown, and tends to have cracking problems in drying.

Types of Clay

Primary Clay or Residual Clay is clay is formed at the site of the parent rock. It is less common than secondary (transported or sedimentary) clay, but generally whiter, free from impurities. Because this clay is broken down by ground water, etc. and not transported, particle size is mixed (no opportunity for sorting or grinding) and the clay is usually not very plastic, and is refractory. Most kaolins are primary clays.

Secondary Clay has been transported from multiple sources by water (alluvial), or wind (aeolian), which sort particle sizes, or by glacier (glacial), which may grind but has uneven particle sizes. Many secondary clays contain organic (carbonaceous) and other impurities (iron, quartz, mica, etc.). Some of the more plastic kaolins are secondary clays. Other secondary clays: ball clay, stoneware clay, fireclay, earthenware clay, slip clays, volcanic clays.

Ball clay: was named for the practice of rolling the very plastic clay into balls during mining. A secondary (transported) clay with carbonaceous additions that color it grey, brown, or tan in the raw state, and fires to a light tone. More iron than kaolins, less than fire clays. Less refractory than kaolins due to more iron and smaller particle size. This small particle size gives highest shrinkage (up to 20%) and plasticity of all clays. Too plastic to be used alone. Increases green (dry) strength. Sometimes used as a glaze ingredient to add strength to the raw glaze coat. Matures in the cone 10-12 range. Maximum amount of ball clay for a "white" body is usually not more than 15% (the exception is some lowfire whiteware bodies)

Fireclays : Are secondary clays with large particle size (thus low shrinkage), good resistance to heat, more iron than ball clays, firing buff to brown. Used to add "TOOTH" to a body, and raise the maturing temperature.

Pine lake - high silica, fairly light in color: 1.5% iron, slightly plastic. Dry shrinkage 6.5%, cone 04 shrinkage 8%, cone 10 reduction 10%. A.P. GREEN FIRE CLAY - a 28 mesh clay from Missouri with 1.3% iron. Specks in the body. Light orange-brown in color @ cone 9. Dry shrinkage 6%, cone 04 shrinkage 9%, cone 10 reduction 16% shrinkage.

Stoneware clays: are secondary clays. Some can be used as dug w/o additions. Bigger particles than ball clay, less shrinkage than ball, less plastic than ball. Light to dark grey reduced, warm in color when reoxidized, tan to brown in oxidation.

Earthenware clays : usually matures in the cone 08-01 range, and are generally not fired above cone High iron color gives a red fired color, and causes melting and bloating at temperatures high enough to cause vitrification. The higher the firing temperature, the darker the color. Brittle if over-fired. Varies in plasticity from sticky to short. Raw clay may be red, ochre, grey, brown, or

greenish and fires orange to red. Most of the usable raw clay found in nature is earthenware. Used in stoneware bodies up to 10% for color.

Slip clays: contain iron and impurities that melt completely at cone 9-10. used in glazes. albany slip clay no longer available. dolomite 9, soda ash 1, redart 90 or dolomite 8.5, pearl ash 4, soda ash 1, unwashed wood ash 10.5, om 4 50, flint 20, red iron 6. alberta slip - a direct substitute for albany slip formulated by the archie bray foundation in helena, mt. blackbird/barnard - similar to albany slip but lighter in color. barnard no longer available.

Volcanic clays: are formed from the weathering of volcanic glass or ash. Particles average to small, with the smallest particles of clay being found in this category. Bentonite ($Al_2O_3.4SiO_2.H_2O$) is the most common volcanic clay and is approx. five times more plastic than ball clay. Used in small amounts (2-3%) in clay bodies to add plasticity, or in glazes to prevent settling and hardening of ingredients in the bucket, and strengthen the dry glaze coat. 3.6% iron. Always mix bentonite with other dry ingredients before adding to water. it bloats in water, forming clumps that are very difficult to mix. macaloid is a synthetic bentonite that does not bloat in water and may be directly mixed into liquids.

ESSENTIALS OF CLAY IN CERAMIC PRODUCTION

Clay is a kind of material that is formed through the processes of weathering and erosion. Clay has the smallest particle size of any soil type. Because of this, clay is smooth and dense. This also means that clay retains water well.. Another way to use clay is through ceramic production. One property of clay is plasticity. This means that you can stretch out the clay without it breaking or tearing. Clay with high plasticity is used to make ceramic wares and ceramic sculptures. You can test the plasticity of your clay by rolling it out, bending it, and shaping it.

Clay particles of different sizes require differing amounts of water to plasticize them. But particles of differing nature, that is, whose electrolytic surfaces react differently with water, also require differing amounts of water. This is another area where a potter sees plasticity much differently than a technician in a tile company lab. The former looks for WOPL (water of plasticity) values on data sheets (an indicator of the amount of water needed to make a raw material plastic, e.g. 26 grams per 100 grams of clay). However a potter sees water content as simply an indicator of how stiff a clay body is, he does not really care if a body has 21% or 23% water, as long as it is the stiffness he needs.

Looking at WOPL numbers for various clays suggests that porcelains require much more water than stonewares and earthenwares. But this is not the case, this author has noted that almost all de-aired clay bodies, from coarse stonewares to fine porcelains need about 20-22% water for throwing consistency. Also that WOPL numbers are not a great indicator of plasticity. This can be verified by simply throwing on the potter's wheel with a range of ball clay, kaolin, stoneware and earthenware materials. The degree of observed plasticities will not relate well to the WOPL numbers on the data sheets (e.g. drastic differences in plasticity will only be small differences in WOPL).

Conclusion

There are three essential properties that make clay different from dirt. These are plasticity, porosity, and the ability to vitrify. Clays are used in the ceramics industries largely because of their contribution to the moulding and drying properties of the wares being produced, many types of clay, such as the flint clays, are used because of favorable behavior during firing or because they produce favorable properties in fired ware.

Clay particles of different sizes require differing amounts of water to plasticize them. But particles of differing nature, that is, whose electrolytic surfaces react differently with water, also require differing amounts of water. This is another area where a potter sees plasticity much differently than a technician in a tile company lab. The former looks for WOPL (water of plasticity) values on data sheets (an indicator of the amount of water needed to make a raw material plastic, e.g. 26 grams per 100 grams of clay). However a potter sees water content as simply an indicator of how stiff a clay body is, he does not really care if a body has 21% or 23% water, as long as it is the stiffness he needs. Looking at WOPL numbers for various clays suggests that porcelains require much more water than stonewares and earthenwares. But this is not the case, this author has noted that almost all de-aired clay bodies, from coarse stonewares to fine porcelains need about 20-22% water for throwing consistency. Also that WOPL numbers are not a great indicator of plasticity. This can be verified by simply throwing on the potters wheel with a range of ball clay, kaolin, stoneware and earthenware materials. The degree of observed plasticities will not relate well to the WOPL numbers on the data sheets (e.g. drastic differences in plasticity will only be small differences in WOPL).

REFERENCES

Acheson, B. G., (1964). Egyptianized clay: Am. Ceramic Soc. Trans., v. 6, pp. 31–64.

Baker, D. R., and Glick, D. P., (1936). Sterilization effects on the properties of clays: *Am. Ceramic Soc. Jour.*, v. 19, no. 7, pp. 209–212.

Barker, G. J., and Truog, Emil, (1938), Improvements of stiff-mud clays through pH control: *Am. Ceramic Soc. Jour*., v. 21, no. 9, pp. 324–329.

Barker, G. J., and Truog, Emil, (1939), Factors involved in improvement of clays through pH control: *Am. Ceramic Soc. Jour.*, v. 22, no. 9, pp. 308–312.

Committee on Definition of the Term "Ceramics", 1920, Report of the committee: *Am. Ceramic Soc. Jour.*, v. 3, no. 7, p. 526.

Coughanour, L. W., and Norton, F. H., (1949), Influence of particle shape on properties of suspensions: *Am. Ceramic Soc. Jour*., v. 32, no. 44, pp. 129–132.

Cox, P. E., (1951), How to reduce thixotropv in clays; *Ceramic Age*, v. 58, no. 2, pp. 30–31.

Dean, L. A., and Rubins, E. J., (1947). Exchangeable phosphorous and the anion exchange capacity: *Soil Sci.*, v. 63, p. 377.

East, Walter H., (1950). Water films in monodisperse kaolinite fractions: *Am. Ceramic Soc. Jour.*, v. 33, no. 7, pp. 211–218.

Endell, K., Fendius, H., and Hofmann, V., (1934), Base exchangenbilitv of clays find forming: problems in ceramics: Ber. dent, keram. Ges., v. 15, No. 12, pp. 595–625…. *Ceramic Abstracts*, v. 14, p. 149, 1935.

Enright, D. P., and Weyl, W. A., (1952). pH change of a quartz suspension in water during stirring: Office of Naval Research, Tech. Rept. 50, Contract No. N6onr269, Task Order 8, NR 032-264, 265. Pennsylvania State College. April 1952.

Glick, D. P., (1935). Effect of microbiological activity during the aging of some moist ceramic materials: *Jour. Bacteriology*, v. 29, p. 79.

Glick, D. P., (1936). The microbiology of aging clays: *Am. Ceramic Soc. Jour.*, v. 19, no. 6, pp. 169–175.

Glick, D. P., (1936a). The effects of various treatments upon the aging of a ceramic body: *Am. Ceramic Soc. Jour*., v. 19, no. 9, pp. 240–242.

Johnson, A. L., and Lawrence, W. G., (1942). Surface area and its effect on exchange capacity of kaolinite: *Am. Ceramic Soc. Jour.*, v. 25, no. 12, pp. 12–344.

Johnson, A. L., and McCartt, K. C., (1952). Equilibrium in some cation exchange reactions for kaolinite-water systems: 54th Ann. Meeting, *Am. Ceramic Soc., Basic Sci. Div*., Pittsburgh, Pennsylvania, April 1952.

Johnson, A. L., and Norton, F. H., (1941). Preparation of a purified kaolinite suspension: *Am. Ceramic Soc. Jour.*, v. 24, no. 2, pp. 2–64.

Johnson, A. L., and Norton, F. H., (1941a). Mechanism of defloc-culation in the clay-water system: *Am. Ceramic Soc. Jour*., v. 24, no. 6, pp. 6–189.

Johnson, A. L., and Norton, F. H., (1942). Casting as a base-exchange phenomenon: *Am. Ceramic Soc. Jour*., v. 25, no. 12, pp. 12–336.

Johnson, A. L., Postehvaite, D. E., and Rittenberg, S. C., (1949). Bacteria—a factor in slip control: *Am. Ceramic Soc. Jour.*, v. 32, no. 11, pp. 11–347.

Kahler, F. H., and AVantz, J. E., (1950), Water in porcelain enameling: *Am. Ceramic Soc. Bull*., v. 29. no. 2, pp. 58–60.

Kelley, W. P., Dore, W. H., and Brown, S. M., (1931). Nature of base-exchange material of bentonite, soils and zeolites as revealed by chemical investigation and X-ray analysis: *Soil Sci*., v. 31, p. 25.

Kellogg, H. H., (1947). Flotation of kaolinite for removal of quartz: *Am. Inst. Min. Eng. Trans*., v. 173, p. 343.

Norton, F. H., (1948). New theory for plasticity of clay-water masses: *Am. Ceramic Soc. Jour*., v. 31, no. 7, pp. 7–236.

Norton, F. H., (1952). *Elements of ceramics,* Cambridge, Mass., Addison-Wesley Press.

Norton, F. H., and Johnson, A. L., (1944). Nature of water film in plastic clay: *Am. Ceratnic Soc. Jour.*, v. 27, no. 3, pp. 3–77.

Norton, F. II., Johnson, A. L., and Lawrence, W. G., (1944). Flow properties of kaolinite-water suspensions: *Am. Ceramic Soc. Jour.*, v. 27, no. 5, pp. 5–149.

Ogle, E. M., (1901). IJnweathered vs. weathered clay: *Am. Ceramic Soc. Trans*., v. 3, pp. 171–179.

Phelps, G. W., (1947b). Clays—defloeculation and casting control: III. Practical application of clav colloid theory: *Ceramic Age*, v. 49, no. 6, pp. 298–299.

Phelps, G. W., (1947c). Clays—-defloeculation and casting control: IV. The mechanism of casting: *Ceramic Age*, v. 50, no. 3, pp. 3–158.

Phelps, G. W., (1947d) Clays—defloeculation and casting control: V. Measurement of slip consistency*: Ceramic Age*, v. 50, no. 4, pp. 4–218.

Phelps, G. W., (1947e). Clays—defloeculation and casting control. VI. Measurement of properties of cast: *Ceramic Age*, v. 50, no. 4. pp. 227–229.

Phelps, G. W., (1948). Clays—defloeculation and casting control: VII. Determination of soluble impurities in slip ingredients: *Ceramic Age*, v. 51, no. 1, pp. 1–9.

Phelps, G. W., (1948a). Clays—defloeculation and casting control: Modern clay concepts and casting slips—a summary: *Ceramic Age*, v. 51, no. 2, pp. 2–66.

Phelps, G. W., (1950). Water as a raw material in slip casting: *Am. Ceramic Soc. Bull*., v. 29, no. 2, pp. 2–55.

Phelps, G. W., (1950a). Purification of lignite-bearing ball clays: *Am. Ceramic Soc. Bull*. 29, no. 8, pp. 293–295.

Phillips, G. J., (1938). Improving the properties of clays and shales: Canada Dept. Mines and Resources, Bull. 793—*Ceramic Abstracts*, v. 18, no. 6, p. 166.

Prahhu, K. P., (1950). Anion exchange and viscosity phenomena in kaolinite, illite, and montmorillonite: Ph. D. Thesis, The Pennsylvania State College.

Ries, Heinrich, (1927). Clays, their occurrency properties and uses. New York, John Wiley and Sons.

Russell, R., Jr., and Mohr, W. C., (1944). Casting characteristics of clays: T. Imoroved methods for determination: *Am. Ceramic Soc. Jour.*, v. 27, no. 4, pp. 4–97.

Russell, R., Jr., Mohr, W. C., and Rice, H. H., (1949). Casting characteristics of clays: II. Influence of slip preparation on properties of cast ware: *Am. Ceramic Soc. Jour*., v. 32, pp. 105–113.

Saunders, L. R., Enright, D. P., and Weyl, W. A., (1950). Wettability. a function of the polarizability of the surface ions: *Jour. Applied Physics*, v. 21, no. 4, pp. 4–338.

Schwartz, Bernard, (1952). A note on the effect of surface tension of water on the plasticity of clav: *Am. Ceramic Soc. Jour.*, v. 35, no. 2, pp. 2–41.

Shaw, M. C., (1937). Clay refining by flotation methods: *Am. Ceramic Soc. Bull*., vol. 16, no. 7, pp. 291–294.