The Suitability Of Local Quartz Sand In The Production Of Bath Crucibles.

C. O. Okpanachi, S. I. Ibrahim, A. C. Okoro, K. Dogo, M. K. Idris

Abstract: The suitability of local quartz sand in the production of bath crucibles is a study that was carried out in order to impart overall strength on bath crucibles, hence reduce breakages during fettling. Therefore, this research constitutes a study to enhance the efficiency of production of bath crucibles by addition of quartz sand in slip preparation. The steps taken in the beneficiation of quartz sand for the production of bath crucibles are comminution which entails crushing and milling, classification, washing, liquid dispersion, sizing and reduction of iron content by magnetic separation. The slip contains materials like plastic clay, feldspar, kaolin, talc, sodium silicate, water, quartz sand, etc. These were all milled in the ball mill for slip production, casting and fettling, glazing and sintering to get final bath crucibles as the end products. Quartz sand is used in a variety of products essentially as raw material for the foundry casting and glass industries and also in chemicals, water filtration and ceramics, the heat resistance nature of quartz sand makes it an excellent refractory substance for these industrial processes. Slip can be prepared for production of bath crucibles without the inclusion of quartz sand; however the addition of quartz sand is needed to improve the mechanical performance of the slip in the production of bath crucibles.

Keywords: Quartz sand, Beneficiation, Bath crucible, Slip, Comminution, Fettling, Liquid dispersion.

1 INTRODUCTION

This paper highlights issues regarding the suitability of local quartz sand in the production of bath crucibles to aid in reduction of breakages during handling especially during fettling, and also to aid in vitrification during firing. Quartz sand was sourced from Kadna, Minna, Niger state, Nigeria, which lies within the coordinates of 09^0 37'N and 06^0 30'E [1]. Quartz is a crystalline silicate mineral with piezoelectric properties and it is the most abundant mineral on the earth's surface. Quartz sand exhibit properties such as high thermal and chemical stability have a vitreous luster, specific gravity of 2.6 – 2.7 and mohs' hardness of 7 which makes it very durable. It is chemically inert when it comes in contact with most substances and has electrical properties and heat resistance that make it valuable in electronic products. Its luster, colour, and diaphaneity make it useful as a gemstone, in making of glass and in ceramics [2]. A crucible is a cup-shaped piece of laboratory equipment used to contain chemical compounds when heated to extremely high temperature [3], crucibles and their lids can come in high or low form shapes and in various sizes but rather small (40-100ml) size porcelain crucibles are commonly used for gravimetric chemical analysis. Among others, [4], [5], [6], [7], [8], [9], [10,] have contributed to this study; however they based their work on the suitability of quartz sand for other industrial applications other than bath crucibles. To date, no study that evaluates the suitability of local quartz sand in the production of bath crucibles. Thus, this paper aims to investigate the effects of quartz sand on ceramic slip, how it affect the overall slip properties like linear shrinkage, water absorption capacity, bulk density, weight loss etc., and specifically on produced bath crucibles in terms of added strength and overall production efficiency.

- *C. O. Okpanachi, S. I. Ibrahim, A. C. Okoro, K. Dogo, M. K. Idris*
- *Scientific Equipment Development Institute, Minna, Nigeria obekpa@yahoo.com*

2 MATERIALS AND METHODS

A total of 533kg of raw materials comprising of plastic clay, feldspar, kaolin, talc, water, soda ash, sodium silicate, quartz sand etc., were charged into the ball mill for slip production after undergoing beneficiation process like crushing which entails the reduction of the particle size to between 0.3 meter (m) down to approximately 1 millimeter (mm). The materials were milled in the ball mill to as low as 1.0 micrometer to liberate impurities, facilitate mixing and produce a more reactive material for firing [11], [12,]. The slip obtained was sieved using the vibrating sieve of 300 mesh. Magnetic separation took place in the slip by the use of magnets to remove iron impurities. The slip was then stored in the storage tanks for maturity. Forming occurs, then the fine, platy morphology of clay particles were used to advantage in the forming of clay-based ceramic products. Depending on the amount of water added, clay- water bodies can be stiff or plastic. Plasticity arises by virtue of the plate- shaped clay particles slipping over one another during flow. With even higher water content and the addition of dispersing agent to keep the clay particles in suspension, readily flowable suspensions called slurry or slip was produced [13]. The suspension was then poured into porous plaster moulds where capillary forces suck the water into the moulds from the slip and causes a steady dispersion of clay particles in dense face to face packing, on the inside surface of the moulds. After a sufficient thickness of deposit has been obtained, the excess slip was drained and the moulds opened to reveal free standing clay pieces that can be dried or fired [14]. The bath crucibles were placed on a wooden board for 24hrs for air drying, followed by oven drying at 105 ^{0}C for 6hrs in a process called convection to eliminate evaporable water. The bath crucibles were then fettled to remove the rough edges or surfaces or to modify the shape. Glaze was then applied to the bath crucibles by spraying and dipping. The raw materials used for glazes are quartz, feldspars, carbonates, borates and zircon [15]. The bath crucibles were thereafter, fired in the kiln (electric furnace) at 1156 ^{0}C for 6hrs [14], where clay base ceramics undergo gradual heating to remove structural water, to decompose and burn off any organic binders used in forming, and to achieve consolidation of the ware. The process of vitrification takes place in the kiln and is aided by the deposited glaze particles on the product body. The ultimate purpose of firing is to achieve some measure of bonding of the particles for strength and consolidation or reduction in porosity, e.g. for impermeability to fluids. Bonding and consolidation are accomplished by partial vitrification which is the Formation of glass, accomplished in this case through the melting of crystalline silicate compounds into the amorphous, non-crystalline atomic structure associated with glass [16, 17]. Various tests were carried out on the piece with quartz content and the other without. Tests such as linear shrinkage, weight loss, bulk density and water absorption capacity.

3 RESULTS

Raw materials: plastic clay 148kg, feldspar 120kg, kaolin 108kg, quartz sand 20kg, talc 4kg, sodium silicate 1kg, water 132lt, soda ash 200g were used for the preparation of slip after milling.

Table 1: *Total amounts of raw materials (kg) in the ball mill.*

Plastic Clay	Feldspar	Kaolin	Quartz Sand	Talc	Water	Sodium Silicate	Soda Ash
148	120	108	20	4	132	1	0.2

Quartz sand has a percentage composition of 3.75% in the slip that was poured into the moulds from table 1. The fired ceramic body was painted with the glazing slurry, and it was fired to vitrify the glass formulation.

Table 2: *Materials used for glaze preparation (Kg).*

Glaze Scrap	Zircobit	Barium Carbonate	Water	Starch
3	0.480	0.210	1.8	1

The densification parameters of the fired piece were obtained by measuring the linear shrinkage, weight loss, bulk density, and water absorption capacity (obtained after the ASTM C20 – 00 form) [5], [3]. Linear Shrinkage (LS) was determined by measuring

1. The length of the bath crucible before firing (LO)
2. The length after firing (L)

LS (%) = [(LO-L)/LO]*100

Weight Loss (WL) was calculated between 105`C and peak firing temperature of 1156^{0}C using the following formular.

WL (%) = [(md – mf)/md]*100

Where md is the dry mass at 105^{0}C and mf is the fired mass at 1156^{0}C. Bulk density (B) of the crucible was obtained as the ratio of the fired crucible mass to the measured volume of the crucible.

B (g/cm3) = mf/v

V = volume of fired crucible.

Water Absorption Capacity was calculated according to

WA (%) = [(w – mf)/mf]*100

Where w is the mass of wet crucible after 24hr soaking in water and mf is the mass of the fired crucible.

Table 3: *Properties of the fired bath crucibles.*

Properties	Crucible with quartz sand (A)	Crucible without quartz sand (B)
Linear Shrinkage (%)	1.25	3.62
Weight Loss (%)	31.80	42.90
Bulk Density g/cm3	1.50	1.20
Water Absorption Capacity (%)	0.67	4.17

4 DISCUSSION

From table 3, properties of the fired crucibles were ascertained from tests carried out to determine the linear shrinkage of the bath crucibles containing quartz sand (A) and the piece without quartz sand (B) and for all the firing temperatures, linear shrinkage varies. The linear shrinkage for (A) which is 1.25 is lower compared to (B) which is 3.62, this shows the strength impart in (A). Linear shrinkage increases with firing temperature (1156^{0}C) which was probably due to glass formation (Table 3). The weight loss shows big changes which can be as a result of organic matter been expelled due to dehydration in the process of firing. Bulk density of the fired (A) and (B) shows values which increase with temperature, (A) have a higher bulk density of 1.50 as a result of high glassy phase formation due to presence of quartz sand hence impartation of strength. The water absorption capacity for (A) is lower than (B). This indicates that (B) have more affinity for water as a result of high porosity. From tables 1 and 2 are the raw material compositions for the production of slip and glaze.

5 CONCLUSION

The suitability of local quartz sand in the production of bath crucibles was studied to ascertain the advantages, benefits of using local quartz sand in the production of bath crucibles and the firing properties resulting from its use. Most importantly, reduction of excessive breakages during handling, and the aiding in glass formation making the crucibles impervious to liquids after firing in the kiln. Partial Vitrification which is the process of glass formation took place in the kiln and the final pieces or crucibles were then subjected to various tests as compared to the slip without quartz sand in a comparative analysis. Tests such as linear shrinkage to determine how the slip components reacts to the firing in the kiln, weight loss which shows the elimination of organic matter by dehydration during firing, bulk density, and water absorption test, were all carried out and results obtained. The technological testing of fired products shows the impartation of strength and improvement in the mechanical performance of the bath crucibles.

ACKNOWLEDGMENT

The authors wish to thank Dr. M.B. Ndaliman MD/CE Scientific Equipment Development Institute (S.E.D.I.), Minna, Nigeria for giving us the enabling environment to carry out this study. Also, our gratitude goes to Dr. Ezedimbu Ugwoha and Mr. Bernard Oche for their support.

REFERENCES

[1]. Kogbe, C. A. (1976). Geology of Nigeria. Elizabethan Publishing Company, Lagos. 237-253

[2]. G.W.P. Consultants, LLP. (2010). A Study of Silica Sand Quality and End Uses in Surrey and Kent. G.W.P. Consultants, Upton House, Market Street, Charlbury, Oxfordshire.

[3]. Pampuch, R. (1976). Ceramic Materials: An Introduction to Their Properties. Elsevier Scientific Publishing Company, Amsterdam.

[4]. Almeida, B. A., Almeida, M., Macarica, V. A., & Fonseca A. T. (2014). Recycling Liquid Effluents in Ceramic Industry. Volume 55, Issue 3, 95-104. http://dx.doi.org/10.1016/j.bsecv.2016.04.004.

[5]. Beeley, P. (2001). The Moulding Material: Properties, Preparation and Testing. Butterworth Heineman publishers, Jordan Hill, Oxford. 2nd Edition, 178-443.

[6]. B.G.S. (2007). Silica Sand: Geology and Mineral Planning Fact Sheets for Scotland, Pp. 11-25.

[7]. Bolen, W. P. (1996). Sands and Gravel, Industrial. 1995 Mineral Year Book. U. S. geological Survey. Pp. 715-730.

[8]. Bonnet, J. P. (2008). Clay Mineral. Volume 34, Issue 5, 1207-1213.

[9]. BS, (1998). BS2975: Methods of Sampling and Analysis of Glass Making Sands.

[10]. Celik, H. (2010). Applied Clay Science. Volume 50, Issue 2, 245-254.

[11]. Mahmoud, S., Srara E., & Zargouni F. (2008). Applied Clay Science. Pp.125-129. Article /PDF (703k) /View Record in Scopus / Citing articles (24).

[12]. Mbey, J. A., Thomas C. J. F., Sabouang N., Liboum F., & Njopwouo D. (2013). Applied Clay Science. Pp.327 – 335. Article/ PDF (996k) / View Record in Scopus /Citing articles (3).

[13]. Holdridge, D. A., & Moore F. (1953). 'The Significance of Clay Water Relationships in Ceramics'. Clay Minerals (2), 26-33.

[14]. McColm, I. J. (1983'). Ceramic Science for Materials Technologists. L. Hill Publishers, Michigan, U.S.A.

[15]. Ngun, B. K., Mahmoud H., Sulaiman S. K., Okada K. & Ahmad Z. A. (2011). Applied Clay Science. Pp. 33 – 41. Article/ PDF (1954K) / View Record in Scopus / Citing articles (17).

[16]. Platias, S., Vatalis, K. I. (2014). Suitability of Quartz Sand for Different Industrial Application. Vol. 14, Pp. 491-498 (ICOAE).

[17]. Shaffer N.R. (2006). The Time of Sands: Quartz Rich Sand Deposits as a Renewable Resource. Electronic Green Journal, 1(24).