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# CHARACTERIZATION OF GINDIRI AND KOMBUN SAND SAMPLES IN MANGU, PLATEAU STATE FOR FOUNDRY APPLICATION

**Abubakar U. BABUJE[1], CHISHAK, Z.S[2] BAWA M A[3]And MAAPLONG, Y.J[4]**

**[1,3]Department of Mechanical/Production Engineering, Abubakar Tafawa Balewa University, Bauchi State, Nigeria**

**[2,4]Department of Foundry Engineering Technology, Plateau State Polytechnic, Barkin Ladi, Plateau State Nigeria.**

**Abstract**

Foundry sand, refer to a special sand use in the foundry workshop for either mould making or core making. In mould making, the sand is used to create a cavity of the pattern in the mould where the molten metal is poured to produce a casting. In core making, the sand is used to bake cores which cannot be obtained directly from the pattern. In this research, Gindiri and Kombun sands were investigated to find there suitability for use as foundry sand. The parameters investigated are chemical composition, cold crushing strength, and bulk density, apparent porosity, firing shrinkage, thermal shock resistance and refractoriness. The results showed that the sands consists of 62.004% and 54.007% $Al_2O_3$, 9.124% and 16.001% $SiO_2$, 2.000% and 4.018% $K_2O$, 1.000% and 1.019% CaO, 0.196% and 0.001% $TiO_2$, 0.019% and 0.907% $Fe_2O_3$, 0.006% and 2.014% CuO, 0.007% and 6.017% $ClO_3$, 0.129% and 0.907% ZnO, 0.001% and 0.801% $ZrO_2$, 0.701 and 0.002% PbO, 0.501% and 0.041%NbO, 0.001% and 0.001% As, 0.007% and 0.003% P2, 228.9kg/cm$^2$ and 205.7kg/cm$^2$ cold crushing strength, 1.97g/cm$^3$ and 1.84g/cm$^3$ bulk density, 32.80% and 22.63% apparent porosity, 0.1% and 2% firing shrinkage, 10 and 15 cycles thermal shock resistance and less than 1500$^0$C and 1400$^0$C refractoriness. The sands are therefore recommended for production of refractory materials such as ceramics, furnace lining, potteries and building bricks as well as for the production of mold and core making.



***Keywords: Characterization; Gindiri and Kombun Sands; and Foundry.***

**Corresponding author: Tel. : +2348037083424**

**E-mail address: aubabuje@gmail.com**

# 1.0 INTRODUCTION

## 1.1 Background of the Study

Foundry engineering is the process of making of castings (metals or non-metals) in moulds (sand or other material) with the help of patterns. The art of foundry is ancient, dating back to the dawn of civilization. In 5000 BC metals were used to make coins, arrows, knives and household articles. Castings have several characteristics that clearly define their role in modern equipment used for construction and in industry. The foundry process is suitable for both small and large components. It gives high rate of production, small dimensional tolerances and good surface finish. It can be used to produce intricate parts.

Foundry sand, those refer to a special sand use in the foundry workshop for either mould making or core making. In mould making, the sand is used to create a cavity of the pattern in the mould where the molten metal is poured to produce a casting. In core making, the sand is used to bake cores which cannot be obtained directly from the pattern.

Foundry practice especially in Nigeria are carried out using green sand with the help of patterns. Foundry sand has a certain properties that must be possessed before perform its desire functions. Incorrect sand condition can easily result in the production of poor castings.

To avoid wrong choice of the foundry sand in casting, laboratory test have to be carry out to ascertain standard requirements of the sand properties.

Even though small foundry industries employ on visual test to judge sand samples and most often they have specific locations to get their samples without due consideration of its mechanical properties. It has been understand that, important of sand in casting can never be over emphasized. Therefore both laboratory and practical tests is needed in order to have a sound casting products.

## 1.2 Science of foundry sand

Foundry sand science is based on the physics and chemistry of the internal structure of the material, Investigation of the relationship existing between the structure of the materials and their properties, concerns with the inter-disciplinary of the materials for engineering and other practical purposes ,deals with all materials, e.g. Metals, ceramics, glasses, organic plastics, sand etc. Society as we know, would be quite impossible without sands (Khanna, 1999), the understanding of the properties of materials is highly essential because without this information and knowledge, the manufacturing process may be an expensive and complex task which negates the profit and utility of the end product.

Material is that which anything is or made (Khanna, 1999), it relates itself to matter. Materials

comprise a wide range of metals and non-metals which must be operated upon to form the finished product.

Gindiri and Kombun sand will be classified as engineering material under ceramics. These ceramics, usually consist of oxides, nitrides, silicates, carbide or body of various metals ceramics are any organic, non-metallic solids, (or supper cooled liquids) processed and used at high temperatures.

They are sand or clay, mineral containing compounds of metallic and non-metallic elements such as O, $SiO_2$, SiC, $BaTiO_3$, glasses etc. These compounds contain both ionic and covalent bonds.

Some important characteristics of ceramics are brittleness, rock like appearance, resistance to high temperatures hardness, abrasiveness, insulation, corrosion resistance, opaque to light and high temperature strength.

Examples of ceramic materials are: sand, bricks, concrete silicon carbide, boron nitride, abrasive, glass cement, insulators, tungsten carbide, refractory and plaster.

The Gindiri and Kombun cave form where the sand samples was obtained, is an example of sand originating from cave terrains, which are similar to most other types of sand in physical appearance.

In characterizing the Gindiri and Kombun sand for foundry used, foundry is a section in the manufacturing process where metals are melted in furnaces and poured into previously prepared mould and allowed to cool down so that it will acquire the internal structure or cavity of the mould as it solidifies. The high melting temperature of the metal makes it a necessity to use a refractive material in making the mould. The refractive material must be easy to manipulate in different shapes this brings about the use of sand in foundry (NwaJagu 1994).

Foundry sand, those refer to a special sand use in the foundry workshop for either mould making or core making. In mould making, the sand is used to create a cavity of the pattern in the mould where the molten metal is poured to produce a casting. In core making, the sand is used to bake cores which cannot be obtained directly from the pattern.

In plastic making, sand also finds application, plastic are materials containing high molecular resins as their main component, which are capable of changing into plastic at high temperature and pressures, they can be molded under the influence of external force and retain their shape in service. Many plastics are composites that in addition to a binding resin (or resins) contain fillers, plasticizers, lubricate, pigments, dyes and hardness. Each of these component impacts definite properties to a plastic. The properties impacted are plasticity, capacity to be moulded, electrical insulation, anti-corrosive nature and other (Sharma, 2006).

### 1.3 The Study Area

The Gindiri and Kombun samples sand are located in Mangu LGA which is about 90km from the state

capital, Jos. The fertile and flat ground which is used for agriculture and industrial sand.

**1. 1.4 Silica Sand**

The silicate industry possesses diverse and valuable properties. The properties typical of most silicate result from the specific structure of their molecules, the basic structural element being $SiO_4$ group (Khanna, 1990). The most important feature of this group or structure is the high melting point.

Some other properties common to most silicate are:

i. Chemical stability
ii. Resistance to high temperature
iii. Comparatively low cost, because of the availability of the raw material.

The raw material for silicate industry are found in the form of deposits of such common minerals as clay , limestone, chalk, dolomite, quartz sand, tuff, Tripoli, quartzite, feldspars, nepheline and marls (marls are deposited minerals, intermediate between limestone and dolomite, and clay which contain 50- 80% $CaCo_3$ and $MgCo_3$ and 20 -50% clay sand minerals (Sharma, 2006).

The silicate industry produces extremely important products and has several independent branches, of which the most important are the manufacture of ceramics and refractory's cement and plasters, glass and pyrocerams. Ceramics is the name given to wax made from ceramics bodies (mixture with various amount of moisture in than, which as a rule, contain clay), by forming a casing followed by drying and firing to the sintering point.

Natural sands contain enough naturally occurring clay that they can be mixed with water and used for sand moulding. Synthetic sands have been washed to remove clay and other impurities carefully screened and classified to give a desired size distribution and then re-blended with clays and other material to produce optimized sand for the casting being produced. Because of the demand of modern high pressure moulding machines and the necessity to exercise close control over every aspect of casting production, most foundries use only synthetic sands. Foundry sand are composed almost entirely of silica (SiO2) in the form of quartz some impurities may be present such as ilmenite (FeO-TIO2), magnetite (Fe3O4). Silica sand is used primarily because it is readily available and inexpensive. Quartz undergoes a series of crystallographic transitions as it is heated. The first at $570^0$C, is accompanied by expansion which can cause mold spalling. Above $870^0$C, quartz transforms to tridymite, and the sand may actually contract upon heating. At still higher temperatures (> $1470^0$C), tridymite transforms to cristobalite. They have been various researchers by Nigeria researchers in the area of developing local alternatives of foundry material to determine their suitability for the production of sound casting. But most of these works have been mostly in determining the refractory properties of various deposits of moulding sand which are abundant in the country and are used foundry

industries (Ndaliman, 2002). Akinbode (1996) carried out an investigation on volcano termite hills as refractory material for furnace lining. In his report, he observed that the refractory properties of termite hills materials which include porosity density, dimensional change and permeability are very similar to know refractory materials for furnace lining. Abolarin et al (1999) studied the characteristics of Nigerian clays and discovered that Barkin Ladi and Alkaleri clay sample were suitable for construction of furnace lining.

## 2.0 Materials and methods

### 2.1 Materials and equipment

Samples used in this research work where source locally from Gindiri and Kombun in Mangu local government area, Plateau State.

The following tests were carried out on the sand samples collected.

- Chemical analysis ED-XRF Machine
- Green compression strength
- Permeability
- Moisture content
- Collapsibility
- Dry compression strength
- Apparent porosity
- Bulk density
- Cold crushing strength
- Firing Shrinkage
- Dry/green tensile strength
- Thermal stability
- Refractoriness
-
- Sand samples
- Baking oven
- Mechanical Sand rammer
- Universal strength testing machine
- Permeability testing machine
- Digital weighing balance

*Figure 1. Sand Sample from Gindiri*

*Figure 2. Sand Sample from Kombun*

### 2.2 Determination of the Properties of Moulding sand

The following **basic properties required in moulding sand** were investigated on the sample.

**Chemical Properties**

2.2.1 Dry strength

2.2.2 Flowability or plasticity

2.2.3 Green strength

2.2.4 Permeability

2.2.5 Refractoriness

## 3.0 Results and Discussion of Result

**Table.1 Chemical Properties of Kombun Sample**

| CHEMICAL | COMPOUND | CONCENTRATION % |
|---|---|---|
| **Al** | $AL_2O_3$ | 62.004 |
| **Si** | $SiO_2$ | 9.124 |
| **S** | $SO_2$ | 0.00 |
| **K** | $K_2O$ | 2.000 |
| **Ca** | CaO | 1.000 |
| **Ti** | $TiO_2$ | 0.196 |
| **Fe** | $Fe_2O_3$ | 0.019 |
| **Cu** | CuO | 0.006 |
| **Cl** | $ClO_3$ | 0.007 |
| **Zn** | ZnO | 0.129 |
| **Zr** | $ZrO_2$ | 0.001 |
| **Pb** | PbO | 0.701 |
| **Sno** | SnO | 0.801 |
| **Nb** | NbO | 0.501 |
| **As** | As | 0.001 |
| **P** | $P_2$ | 0.007 |

**Table.2 Chemical Properties of Gindiri Sample**

| CHEMICAL | COMPOUND | CONCENTRATION % |
|---|---|---|
| **Al** | $AL_2O_3$ | 54.017 |
| **Si** | $SiO_2$ | 16.001 |
| **S** | $SO_2$ | 0.001 |
| **K** | K2O | 4.018 |
| **Ca** | CaO | 1.019 |
| **Ti** | $TiO_2$ | 0.001 |
| **Fe** | $Fe_2O_3$ | 0.907 |
| **Cu** | CuO | 2.014 |
| **Cl** | $ClO_3$ | 6.017 |
| **Zn** | ZnO | 0.907 |
| **Zr** | $ZrO_2$ | 0.801 |
| **Pb** | PbO | 0.002 |
| **Sno** | SnO | 0.014 |
| **Nb** | NbO | 0.009 |
| **As** | As | 0.001 |
| **P** | $P_2$ | 0.003 |

The chemical composition depends on the formation of the deposit and the climate which prevails in the area as shown in table 1 and 2. The low sulphur and nitrogen contents in the sand samples are welcomed development as there will be minimal release of sulphur and nitrogen oxides into the atmosphere and that is an indication that the working with the sand sample for foundry use will not pollute the environment

The presents of aluminium oxide and silicon oxide as the major compound suggests that the sand samples are classified as special sand known as chamotte which is suitable for heavy steel casting.

**Table 3: Green and Dry Compression and Shear Stress for Gindiri Sand Sample**

| **Actual Moisture Content Before Mixture** | 1.008 % | | | | | |
|---|---|---|---|---|---|---|
| **Grain Finest Index (GFI)** | 82 | | | | | |
| | **Green Comp Strength ($KN/m^2$)** | **Green Shear ($KN/m^2$)** | **Dry Comp ($KN/m^2$)** | **Dry Shear ($KN/m^2$)** | **Permeability** | **Moisture %** |
| Moisture Content On 6% | 130 Above | 33 | 365 | 125 | 36 Below | 6.12 |
| Moisture Content On 7% | 130 Above | 35 | 595 | 200 | 36 Below | 7.13 |
| Moisture Content On 8% | 113 | 30 | 305 | 235 | 44 | 7.94 |
| Moisture Content On 9% | 116 | 36 | 650 Above | 195 | 46 | 8.30 |
| Moisture Content On 10% | 102 | 30 | 625 | 190 | 56 | 9.67 |

**Table 4: Green and Dry Compression and Shear Stress for Kombun Sand Sample**

| **Actual Moisture Content Before Mixture** | 1.02 % | | | | | |
|---|---|---|---|---|---|---|
| **Grain Finest Index (GFI)** | 52 | | | | | |
| | **Green Comp Strength ($KN/m^2$)** | **Green Shear ($KN/m^2$)** | **Dry Comp ($KN/m^2$)** | **Dry Shear ($KN/m^2$)** | **Permeability** | **Moisture %** |
| Moisture Content On 7% | 130 above | 21 | 400 | 115 | 36 Below | 2.15 |
| Moisture Content On 8% | 124 | 17 | 530 | 102 | 36 Below | 2.41 |
| Moisture Content On 9% | 113 | 31 | 590 | 65 | 36 Below | 2.21 |
| Moisture Content On 10% | 114 | 28 | 550 | 80 | 36 Below | 2.56 |

The green sand, after water has been mixed into it, must have adequate strength and plasticity for making and handling of the mold. The Gindiri sand sample shows a satisfactory green compressive strength, Green Shear, Dry compression and Dry strength of 116 kN/m$^2$, 36 kN/m$^2$, 650kN/m$^2$, and 195 kN/m$^2$ respectively at 9 percent moisture content. While the Kombun sand sample shows a satisfactory green compressive strength, Green Shear, Dry compression and Dry strength of 124 kN/m$^2$, 17 kN/m$^2$, 530kN/m$^2$, and 120 kN/m$^2$ respectively at 8 percent moisture content.

Also both the two sand shows an acceptable permeability of 46 and 36 which implies that heat from the casting causing a green-sand mold to evolve a great deal of steam and other gases will exit as required. Which otherwise will cause the casting to contain gas holes.

**Table.5 Green Finest Index for Kombun Sand Sample**

| Mesh dimension (mm) | Weight of sand retained | Multiplier | Result |
|---|---|---|---|
| 1.4 | 31.66 | 12 | 316.68 |
| 1.0 | 11.913 | 16 | 142.98 |
| 0.71 | 9.192 | 22 | 147.072 |
| 0.50 | 8.23 | 30 | 181.17 |
| 0.355 | 7.26 | 44 | 217.86 |
| 0.25 | 6.439 | 60 | 283.316 |
| 0.18 | 4.70 | 85 | 287.4 |
| 0.125 | 4.86 | 120 | 413.27 |
| 0.09 | 8.00 | 170 | 966.72 |
| 0.063 | 1.70 | 240 | 289.17 |
| 0.045 | 0.762 | 350 | 182.88 |
| PAN | 5.123 | Through 350 | 1793.05 |
| TOTAL | 99.80 | SUM | 5221.568 |

**GFI = 52.21 (GREEN FINEST INDEX)**

**Table.6. Green Finest Index for Gindiri Sand Sample**

| Mesh dimension (mm) | Weight of sand retained | Multiplier | Result |
|---|---|---|---|
| 1.4 | 18.583 | 12 | 185.83 |
| 1.0 | 6.88 | 16 | 82.584 |
| 0.71 | 5.39 | 22 | 86.304 |

| | | | | |
|---|---|---|---|---|
| | 0.50 | 5.40 | 30 | 118.866 |
| | 0.355 | 5.750 | 44 | 172.56 |
| | 0.25 | 7.85 | 60 | 345.664 |
| | 0.18 | 7.70 | 85 | 464.40 |
| | 0.125 | 10.12 | 120 | 860.54 |
| | 0.09 | 20.400 | 170 | 2452.92 |
| | 0.063 | 4.28 | 240 | 727.94 |
| | 0.045 | 0.635 | 350 | 152.4 |
| | PAN | 7.30 | Through 350 | 2581.6 |
| | TOTAL | 99.86 | SUM | 8231.608 |

**GFI = 81.93 (GREEN FINEST INDEX)**

Normally 50 GFI size is preferred for the casting process (Priyadharsini 2016). This shows that both the two sand sample have a very good grain finesse index.

**Table.7 Cold Crushing Strength (C.C.S)**

| S/No | Sample Name | Length (CM ) | Breath (CM) | Area (CM) | Force (KN) | Mass (Kg) | C.C.S ($Kg/CM^2$) |
|---|---|---|---|---|---|---|---|
| 1 | Gindiri | 2.3 | 3 | 6.9 | 15.8 | 1580 | 228.9 |
| 2 | Kombun | 2.3 | 3 | 6.9 | 14.2 | 1420 | 205.7 |

The foundry sand must have strength to resist erosion, else the mould may enlarge. This shows that the higher the cold crushing strength of a foundry sand the better the foundry sand.

**Table.8. Bulk Density (B.D)**

| S/No | Sample Name | W1 (g) | W2 (g) | B.D ($g/cm^3$) |
|---|---|---|---|---|
| 1 | Gindiri | 13.02 | 89.42 | 1.97 |
| 2 | Kombun | 12.93 | 94.81 | 1.64 |

**Bulk density** is the mass of powdered or granulated solid material per unit of volume. Its primary advantages its gives the sand a high chilling rate. (**Turkeli, 2008**)

**Table.9. Thermal Shock Resistance**

| S/No | Sample Name | No of Cycle |
|---|---|---|
| 1 | Gindiri | 10 |
| 2 | Kombun | 15 |

Thermal shock resistance is necessary for any material that is going to be used as foundry sand, the higher the thermal resistance the better the sand. High thermal resistant foundry sand are widely used in precision investment foundries. (**Turkeli, 2008**)

**Table.10. Apparent Porosity**

| S/No | Sample Name | Dried Weight(D) | Wet Weight (W) | Suspended Weight (S) | Porosity (%) |
|---|---|---|---|---|---|
| 1 | Gindiri | 10.52 | 12.69 | 6.0746 | 32.80 |
| 2 | Kombun | 11'49 | 13.14 | 5.8485 | 22.63 |

Generally, permeability of both ferrous and non-ferrous is ranges 25 to 90 are quite used. Permeability or porosity: is the ability of the foundry sand allowed the gases and steam that were generated during casting to escape. If these gases are not allowed to escape from the mould, they would be entrapped inside the casting and cause casting defects. To overcome this problem the moulding material must be porous. Both the two sand samples show good degree of porosity as shown in the table above.

**Table.11. Firing Shrinkage**

| S/No | Sample Name | Initial Length (Cm) | Final Length (Cm) | Shrinkage ( % ) |
|---|---|---|---|---|
| 1 | Gindiri | 10 | 9.99 | 0.1 |
| 2 | Kombun | 10 | 9.8 | 2 |

The coefficients of thermal expansion for a very good foundry sand need to be sufficiently low. Both the two sand sample shows a satisfactorily low coefficient of thermal expansion.

**Table.12. Refractoriness**

| S/No | Sample Name | Refractoriness ( $^0$F) |
|---|---|---|
| 1 | Gindiri | 1500 |
| 2 | Kombun | 1400 |

**Refractoriness.** The refractoriness of the two sand sample shows that they can only be used for Low-pouring-temperature metals, for example, aluminium, poured at 1300 F, do not require a high degree of refractoriness from the sand. (**Turkeli, 2008**)

### 3.9 Miscellaneous properties of the moulding sand

Both the moulding sands are not stick to the casting and also they are not chemically reactive with metal. They are

economically cheap and easily available.

## 4.0 Conclusion

From the investigation conducted, the results shows that both the two sand sample possess satisfactory characteristics that can be use as moulding sand in the casting industry.

## REFERENCES

Abolarin, M S., Olugboji O A., and Ugwuoke I. C. (1999). Determination of Moulding Propertis of locally available clay sand for casting operation. AU Journal, Vol9 Pp 238-242

Akinbode, F. O. (1996)An investigation on the properties of termite hill as refractory materials for furnace lining. India Foundry Journal.42, 9 pp 10-13

Afo etal, (2014). Characterization of Kerang Volcanic for Foundry Application Plateau State Polytechnic Barkin Ladi

Aramide etal, Effect of Binder and Water on the Properties of Recycled Foundry sand case study of Illor ,Ogun State Nigeria.

Altan Turkeli. (2008) Foundry Technology. SAND, SAND ADDITIVES, SAND PROPERTIES, and *SAND RECLAMATION, 2008*

Sharma, B.K. (2006). Industrial Chemistry 15th edition,Meerut Goel. GOEL Publishing House 2000

Ndalima.M.B, (2002). Effects of some additives on the refractory properties of onbodie. *Nigeria Journal of Technology Research. Volume 1, pp9-13*

Nwajagu, C.O (1999). Foundry Theory and Practice 1ST edition ABC Publishers Enugu.

Khanna, O.P (1999). Material Science and Metallurgy, Indian, Dhapat Rai Publications

Priyadharsini S., Karunakaran P. Determination of the Physical Properties of Sand Moulding

Bonded with Composite of Ipomoea Batatas and Bentonite with Casting Application. ***International Research Journal of Engineering and Technology (IRJET) Volume*** 03 Issue: 04 Apr-2016.