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Full Length Research Paper

Suitability of local binder compositional variation on silica sand for foundry core-making

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The use of local oils, namely groundnut oil, cotton seed oil and palm oil with Nigeria local clay and silica sand for the production of foundry cores has been investigated on varying composition. Addition of cassava starch, local clay, oil and moisture to sand are used to produce strong and efficient core. These oils were tested and it was found that the three could be used to produce foundry cores. The best composition was found to be core comprising 2.5% starch, 2.5% clay, 8% oil, 8% moisture and 68% sand and baked at 150^{o}C for 1 h 30min. The tensile strength of the core were as high as 600 KN/m^2.

Key words: Foundry, foundry core, binder, Ochadamu sand, local clay, oils, Nigeria.

INTRODUCTION

Core making has improved in response to the demand on the foundry industry, for increasing rigid tolerance on quantity and to accurate dimension of casting over the years (Paul et al., 2007; Nuhu, 2010). A core is an aggregate of inert material processing a degree of porosity and a controlled mechanical strength sufficient to allow the aggregate to be assembled without breakage; for the purpose of making internal and external portions of a mould (Atama, 2009; Olakanmi and Arome, 2009).

In foundry technology, a wide range of sands are used which include purity, structure, grain size and grain distribution (Silver and Maria, 2007). Silica sand is the most widely used based material for cores (Mukoro, 2009). These occur in natural deposits in many parts of the country either on the surface such as river, lake, and seashore bottoms or as sub surface deposits of various geologic formations (Harper, 1993). The important properties to be considered in the selection and purchase of core sand are grain size, shape distribution, base permeability clay content and mineralogical composition (Ola, 2000). The forming of holes, internal cavities and other internal surface of casting depends on cores which is also a function of the binding proportion among which is silica sand; any materials which hold sand grains together, may be classified as binder. But binder suitable for foundry core must not only hold sand grain together but must also be sufficiently resistant to high temperature (Fayomi, 2006). Foundry core may be distinguished into three broad types, the green core, dry core, thermo chemical-curved core and these depend on their material make up and method of use (Debussy, 1980). Hence, the need for a possibility of using local binder as a natural source of making foundry core to mitigate against foundry defects, improve core properties and reduce cost, necessitate this investigation on verification of local binder composition.

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MATERIALS AND METHODS

The silica sand employed for this study was obtained from Ochadamu, a local town in Kogi State, Nigeria, while the clay used to improve the binding property of the sand was obtained from Ibaji in Nigeria. The binders used in this work were cotton seed oil, groundnut oil, palm oil, and locally made cassava starch. The palm oil used was sourced from the market.

Moreover, the silica sand was first washed repeated to make it clean and the large quantity of its clay content were removed after which it was sun dried for two days before it was employed for the study. Thereafter about 500 g of this clean and dry sand was collected and passed through a British standard sieve to remove all coarse particles. 100g of the fine sand was then removed and placed on a shaker for fifteen minutes. The weights of the sample of sand that had settled on each sieve were taken and used to calculate the Grain Fineness Number (G.F.N) and percentage fines. The relevance of this test is to determine the suitability of the sand for core making. Table 1 displays the data from the sieve analysis

Table 1. The sieve analysis data.

S/No.	Aparture (MM)	British standard sieve	Retained (%)	CUM (%)	Product
1.	1.40	14	0.05	0.05	0.70
2.	1.00	16	0.34	0.39	4.76
3.	0.71	25	0.36	0.75	6.48
4.	0.50	35	1.26	2.01	31.5
5.	0.355	45	3.78	55.79	132.3
6.	0.250	60	13.06	18.85	587.7
7.	0.180	80	28.06	46.91	1683.6
8.	0.125	120	39.76	86.07	3180.8
9	0.09	170	8.45	95.12	1014
10	0.68	2.30	1.72	96.84	292.4
11.	0.00	0.00	1.20	98.04	2.76
Total	5.29	567.3	98.04	500.82	7210.24

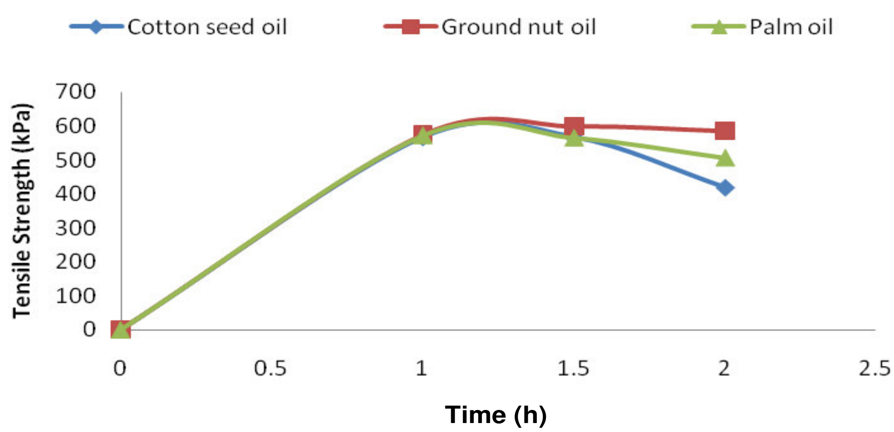

Figure 1. Plot of tensile strength (kPa) against baking time (h) at temperature of 150°C.

(Fayomi et al., 2011).

$$\text{Grain fitness number} = \frac{\text{Product}}{\text{Total retained grain (\%)}}$$

$$= \frac{7210.24}{98.04}$$

$$= 73.54$$

FINES = 1.72 + 1.20 = 2.92 (Fayomi et al., 2011)

The sand, clay, starch, the different oils and water were measured separately. The procedure was carried out by adding clay and starch to the sand and then mixing them thoroughly. The oil was added next and then finally water. Each operation took about 4 min. Mixing was done by hand due to the small quantity involved and to achieve the following: uniform dispersion of oil and water (Moistening), to develop the banding properties of the clay and starch, to break down the agglomerates with minimal pulverization of the sand grains (smoothening), for adequate coating of sand grains with clay and other additives and for homogeneous mixing of sand and other additives. The cores were produced by ramming the mix using the Nigeria Foundry Limited (NFL) standard rammer. This was achieved by lowering the plunger gently unto the sand and rammed with three blows to compact the sand.

The cores were first conditioned by partial drying in the oven for thirty minutes and at temperature of 80°C. This is to remove excess moisture before baking. Core baking were done in an oven within temperature ranges of 100 to 250°C for a specific time for adequate strength. During baking, moisture is driven off at about 110°C and above this temperature, up to 18°C, core binder's change chemically by the process of polymerization. These continue up to upper baking temperature. Thereafter the baked core under investigation was tested for tensile strength using Nigeria foundry tensile testing machine.

RESULTS

The effects of varying the percentages of additives, sand, clay, different oils, and water on the foundry core produced in this study were investigated. The results obtained for changing baking time, %starch content and temperature with tensile strength are presented in Figures 1 to 10.

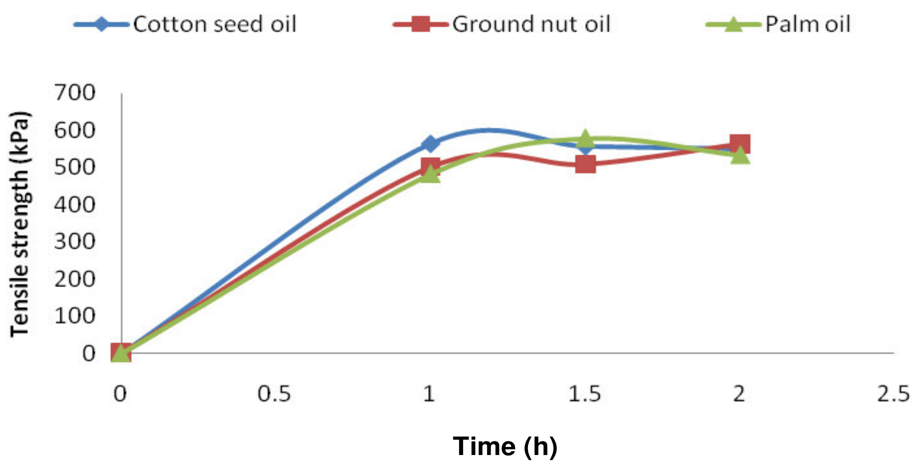

Figure 2. Plot of Tensile strength (kPa) against the baking time (h) at temperature of 200°C.

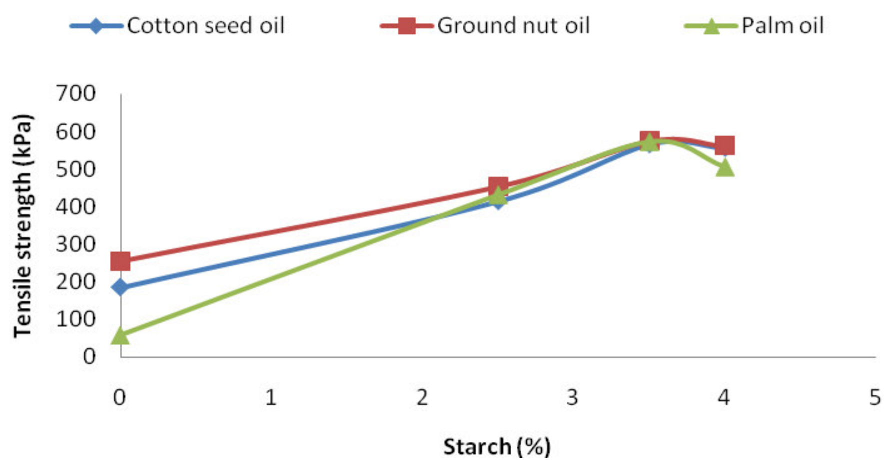

Figure 3. Plot of tensile strength (kPa) against starch (%) at baking time of 1 h and temperature of 150°C.

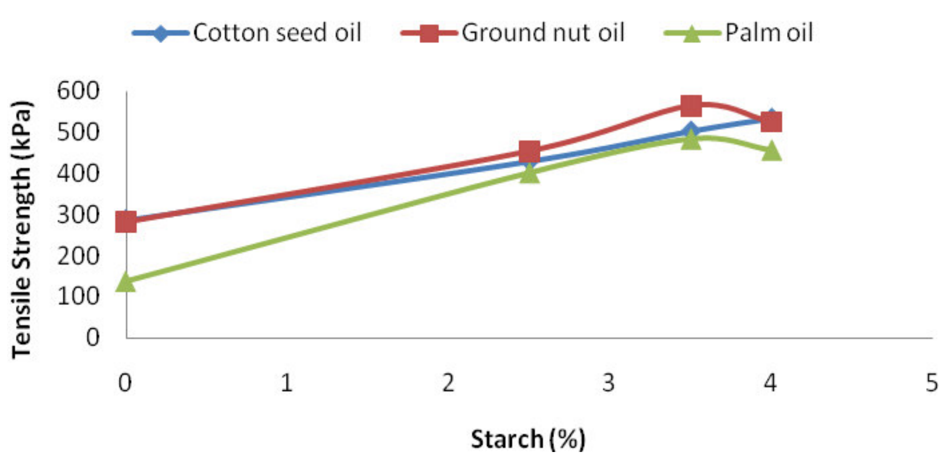

Figure 4. Plot of tensile strength (kPa) against starch (%) at baking time of 1 h and temperature of 200°C.

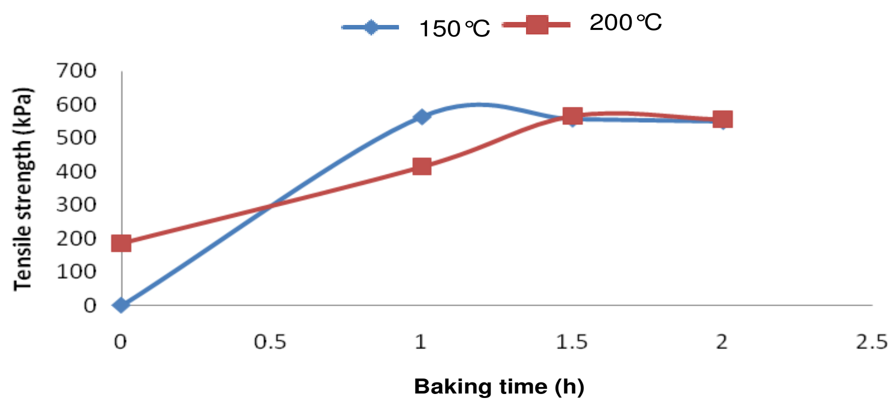

Figure 5. Plot showing the effect of increasing temperature on the strength of core with cotton seed oil at constant baking time.

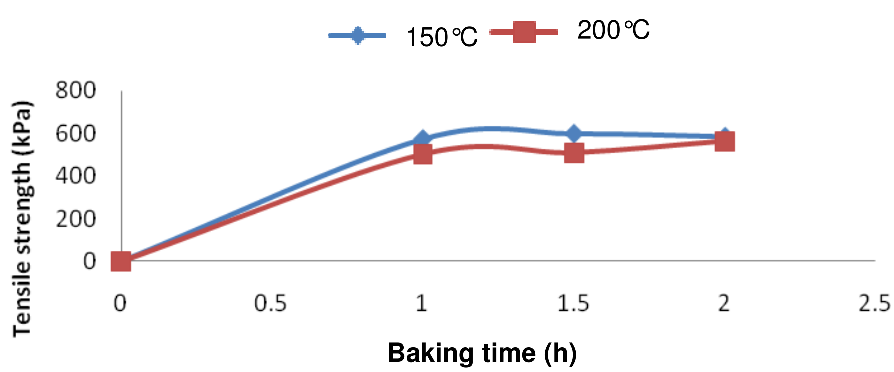

Figure 6. Plot showing the effect of increasing temperature on the strength of core with ground nut oil strength at constant baking time.

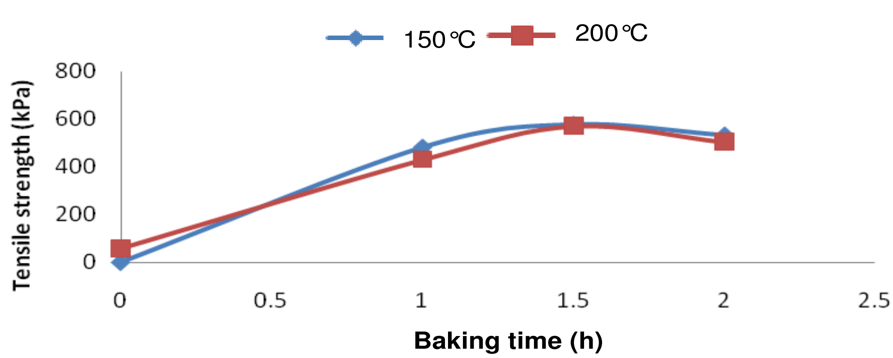

Figure 7. Plot showing the effect of increasing temperature on the strength of core with Palm oil strength at constant baking time.

DISCUSSION

Tensile strength of starch- free cores

Experiment carried out on cores mixes, which contained clay, moisture and oil as the primary binder but had no starch additions had very low tensile strength value as shown in Figure 3. These values are proper than those obtained where all the additives were present. In this respect, this showed that the oils might not work

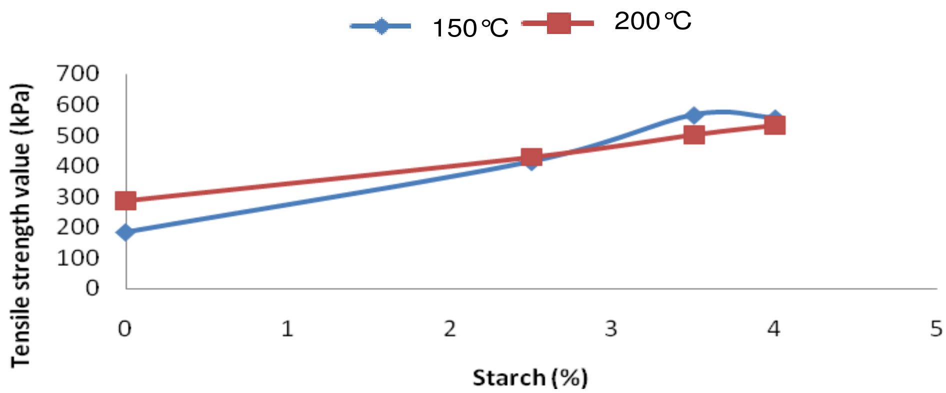

Figure 8. Plot showing the effect of increasing temperature on the strength of core with cotton seed oil at constant starch quantity.

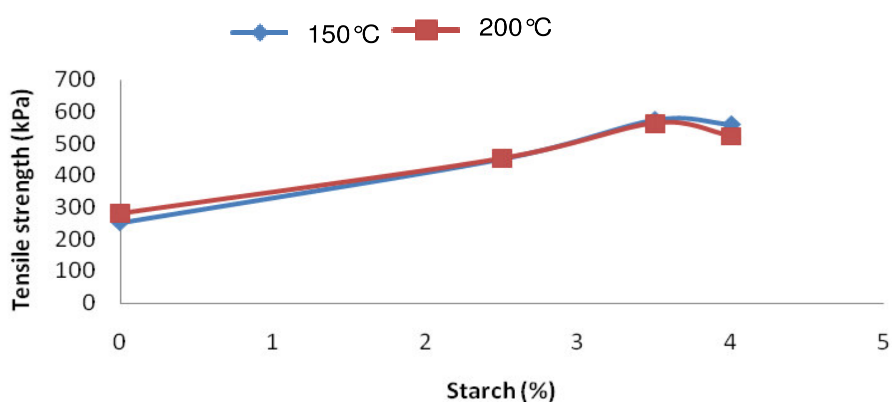

Figure 9. Plot showing the effect of increasing temperature on the strength of core with ground nut oil at constant starch quantity.

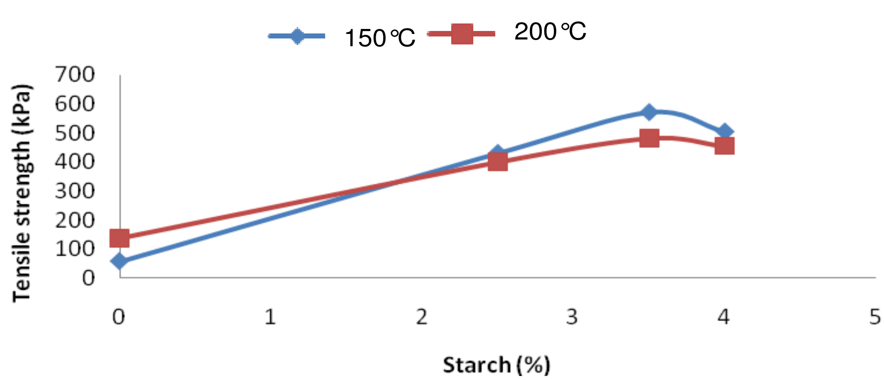

Figure 10. Plot showing the effect of increasing temperature on the strength of core with palm oil at constant starch quantity.

effectively for binding without the presence of starch. However, 2.5% clay, 8% moisture and 68% sand were used for the foundry core.

Effect of increased oil addition on the core strength

The effect of oil additions showed some irregularities.

The cores produced a lot of smoke during baking and burning off starch occurred due to high percentage of oil proportion and temperature increase. However, experiments carried out with cotton seed oil additions showed that in the absence of starch, the tensile strength increased rapidly and proportionally with the baking time as shown in Figure 1, while in the presence of varying percentages of starch and constant baking time of 1 h, the strength increased gently with increasing additions of starch (Figure 3). Similar trends were observed for experiments with groundnut and palm oils as shown in Figures 1 and 3. However, it was observed (Figures 1 and 3) that the core strength increased with time until a maximum value after which a decrease in strength was observed. The core containing groundnut oil was found to posses the maximum strength at the baking time of 1.5 h. This time was also the period about which core containing other oils gained the maximum strength. Thus, 1.5 h. and 3.5% starch were found to be the optimum baking time and starch content at baking temperature of 150°C.

With higher baking temperature of 200°C, Figures 2 and 4, there was also increase in tensile strength levels, which increased steadily with the additions of oil up to the levels tested. However the strength levels were lower than those obtained for cores baked at 150°C (Figures 1 and 3). Further comparing Figures 1 with 2 and Figures 3 with 4, revealed that increased temperature from 150 to 200°C produced decreasing tensile strength when groundnut oil was used while higher strength were obtained with increased baking time when cotton seed and palm oils were employed. Whereas increased percentages of starch at 200°C did not favour higher core strength. Overall, Figures 5 to 9 showed that the better temperature is 150°C for both starch free core and core with above 2.5% starch. Increasing oil level beyond 10% was not encouraging because of the amount of smoke produced during baking. It was decided in this work that cores with oil level greater than 10% might not be safe due to danger of fire and environmental concerns. Therefore, 8% oil additions were employed.

Effect of increased starch on core strength

Figures 3 and 4 shows the variation in tensile strength values as the starch level increased from 2.5 to 4%. Apparent deterioration in the properties was observed beyond 2.5% starch addition at 200°C. This means that an increase in starch level beyond an optimum level may cause unfavorable effect due to burning off of starch at temperature above 150°C.The three oils investigated proved good potential to be used as core binders. There is also an improvement over starch quantity as a binder and hence the suitability of the oils for core making.

It is worthy of note that, the tensile strengths were not up to values obtainable in cores for ferrous and non-ferrous casting which could attain tensile strengths up to or above 1000 KN/m^2. These low values of baked tensile strength may be due to the fact the testing equipment has some limitations as to the extension of the specimen clamp. A lot of smoke was also observed as the baking temperature rose up to 150°C. The oven had to be opened at regular interval to allow the smoke pass out to the atmosphere. This also showed that there was excessive amount of volatile matter in the core mixes, suggesting that the oil may be treated to reduce the volatile matter before use. The necessary requirements for foundry core production are sand, clay, and moisture. As oils are cheap and available in developing countries, they can be employed with further studies to produce stronger cores.

Conclusion

1) The study have been used to consider the effectiveness and suitability of Nigeria Ochadamu sand and clay with other bounding binder proportion of groundnut oil, cotton oil, palm oil, and starch variation. The results showed after tensile analysis that the sand and oils employed were good binders if baked between temperature of 150 and 200°C and with 2.5% starch content. The Ochadamu Clay has a very good durable property.
2) The additions of bounding property thus improved the strength of the core and enhance the mechanical property.

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