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Full Length Research Paper

Investigating (Ochadamu) silica sand, clay and local oils for foundry core

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In this investigation, the Ochadamu silica sand was analyzed and used as base sand for the Ochadamu clay- sand mixture in an attempt to improve and develop an efficient foundry core. The mechanical properties of the sand, clay, and local oil mixture were determined. The fitness number, total coarse fraction, and the total fine fraction of Ochadamu silica sand were found to be within the best range that will give good molding properties and core durability. The values obtained for the cold compressive strength, permeability, hardness, dry shear strength, and shattered strength indicated that Ochadamu sand and clay have good values as a binder for foundry core making in general.

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

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 Fayomi (2006) and Mukoro (2009). 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 Nuhu (2010), Olakanmi and Arome (2009) and Ola (2000). In foundry, a wide range of sands are used which vary in purity, structure, grain size and grain distribution etc. Silica sand is the most widely used based material for cores. 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 (Paul et al., 2007; Silver and Maria, 2007).

The important properties to be considered in the selective and purchase of core sand are grain size, shape distribution, base permeability, clay content and mineralogical composition. However, where high melting points alloys are to be handled and finely detailed surface finishes is required, more costly sand are used e.g. zircon, chromate and olivine. The metal casting industry uses a large quantity of binder annually for the development of metal casting. Recently the country has developed rapidly in the use of core binder. A binder is the second most important component after sand in the mould (Paul et al., 2007).

The forming of holes, internal cavities and other internal surface of casting depends on cores. Therefore core can be defined as that portion of mould which form the hallow interior of casting or hole through the casting (Silver and Maria, 2007). Casting is produced in the foundry by pouring in molten metal into a mould made to shape of the component required. Castings play a vital part in all branches of engineering. The flexibility of casting production techniques enable practically, all shapes to be produced. Though naturally, production cost is important. In domestic application casting are used for stoves, gates, cookers, radiators, bath, piping for main water supply and drainage. However the product of casting on a large scale is a sophisticated and capital-intensive

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Table 1. Sieve analysis data.

Aperture (mm)	B.S.S No.	Retained (%)	Cum (%)	Product
1.40	14	0.05	0.05	0.70
1.00	16	0.34	0.39	4.76
0.71	25	0.36	0.75	6.48
0.50	35	1.26	2.01	31.5
0.355	45	3.78	55.79	132.3
0.250	60	13.06	18.85	587.7
0.180	80	28.06	46.91	1683.6
0.125	120	39.76	86.07	3180.8
0.09	170	8.45	95.12	1014
0.068	230	1.72	96.84	292.4
		1.20	98.04	276
		98.04		7210.24

business. Cores are also used in shaping external surface of cast product when a pattern is so shaped that it forms a core as an integral part of the mould such a core is known as green sand core. Though this is acknowledge as an economical method of forming cavities in casting. It is limited to hallow of short length. But binder suitable for foundry core must not only hold sand grain together but must also be sufficiently resistant to high temperature, in order for it to collapse and allow sand to be easily removed from the casting leaving it surface smooth. The ability of the binder to collapse on cooling is known as breakdown and this property is very important to cores hole, which are in accessible to felting (Fayomi, 2006). The need for a possibility of using local binder as a natural source of foundry core to mitigate against foundry defects, improve core and reduce cost, necessitate this investigation. It is anticipated that the study will make a contribution to the present research interest of this area of studies. Economic and technological benefit is envisaged from a positive result in this work.

MATERIALS AND METHODS

Clay and silica sand are obtained from Ochadamu in the north central part of Nigeria (Kogi State). The binders used in this work are seed oil, palm oil, groundnut oil and starch (Cassava starch). The Cassava starch was sourced locally in the process of garri production and oil were produced locally and purchased from Nigeria. Collected silica sand (Ochadamu base sand) which contains a lot of impurity and large quantity of clay particle were poured in a large container and washed properly until the water at the surface of the sand is clean, clay content and the inclusion removed. Washed silica sand are then dry for two days under sun. Thereafter about 500g of this clean and dry Ochadamu sand was collected and passed through a (British standard sieve) to remove all coarse particles. Then 100g of fine sand was removed and placed on a shaker for fifteen minutes. The weight of the sample of sand that had settled on each sieve was carefully weighed, and the values were used to calculate the grain fineness number (G.F.N) and percentage fines. The relevance of the test is to determine the suitability of the sand for core making. Table 1.

Grain fitness number = Product / Total retained grain (%)
= 7210.24 /98.04
= 73.54
Fines = 1.72 + 1.20 = 2.92

The ingredient sand, clay, starch, oil and water were measured separately. The procedure was 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 minutes. 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, 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 machine was designed for preparing (NFL) standard test specimen for determination of compression, tensile and transverse strength by compacting a predetermined weight of the sand in ramming cylinder of the required shape. 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℃. This is to remove excess moisture before baking. Core baking were done in an oven within a temperature ranges of 100 to 250℃ for a specific time for adequate strength. During baking, moisture is driven off at about 110℃ and above this temperature, up to 180℃ core binder's change chemically by the process of polymerization. These continued up to upper baking temperature. Thereafter the baked core under investigation was subjected to a tensile strength tester to determine the effecttiveness of the local material for the production of foundry core.

Preliminary experiment number one

The first experiment is concerned with the determination of tensile strengths of the cores, which contained the additions of clay and moisture but without the addition of starch. The compositions of the additive were 3.5% clay, 10% oil and 8% moisture. Cores of these

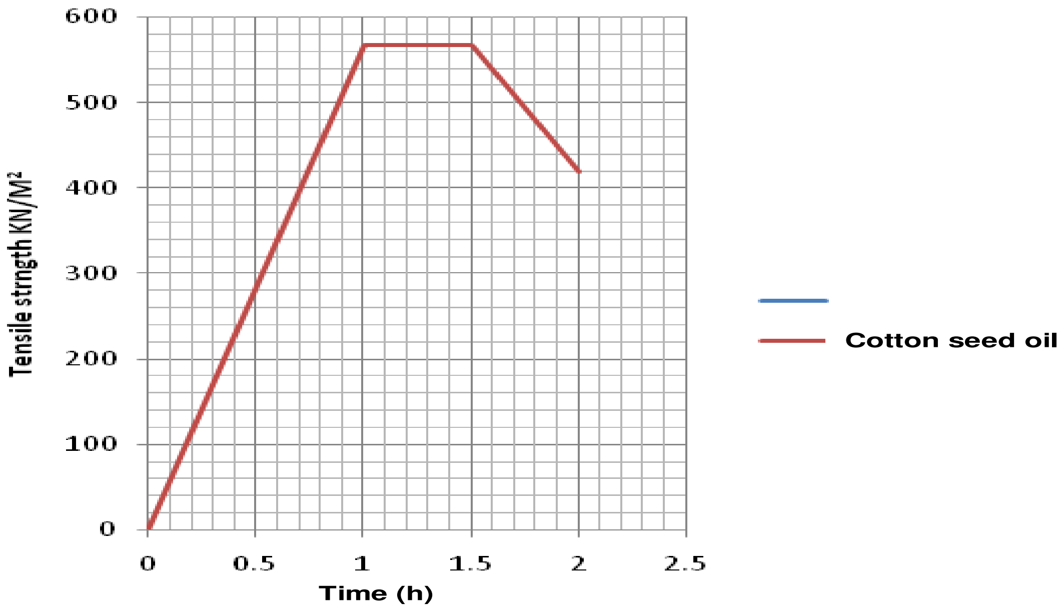

Figure 1. Plot of tensile strength (KN/M^2) against baking time of cotton seed oil at baking tempt of 150℃.

mixtures were moulded and baked for 1 hour at temperature of 150 and 200℃. An increased temperature was used to see if any improved properties would be observed. The purpose of this experiment was to determine if the starch would actually be required in the addition to the core oil.

Preliminary experiment number two

A second experiment was carried out with the cores mixtures that contain no moisture. The composition of the core mixture was basically the same as the above with respect to the clay and oil levels. It was 3.5% clay, 10% oil and 3.5% starch. The cores produced a lot of smoke during baking and burning off starch occurred, but groundnut oil increases in tensile strength with increase in oil. With higher baking temperature of 200℃ there was also increase in tensile strength levels, which increased steadily with the additions of oil up to the levels tested. However, the strength level was lower than those obtained for cores baked at 150℃. 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 explosive and environmental pollution.

Core hardness test

The hardness test gives a means of correctly expressing the surface of a metal core. The surface hardness largely determines how a core will withstand socking and handling. It is also a property of a core that defines amount of loose sand that is on the core surface. The flow indenter of 100 mm with a load of 3000 kg for about 20 s gives an indentation on the baked core surface. The reading been taken and the calculation is as shown:

Hardness equation for core strength
DATA P = load on material 3000 kg
D = Diameter of indenter = 10 mm
pie =3.142 constant
Indentation diameter = d, obtained from average value.
Brinell hardness test = $2p / \pi D(D - \sqrt{D^2 - d^2})$ (1)

RESULTS

Effect of oil contents on the tensile strength of core

An experiment was carried out whereby the oil level was varied between 1.5 and 10% and the other additives kept at 2.5% starch 2.0% clay and 8% moisture, core were prepared and baked at temperature of 150 or 200℃ for 1 hour. The tensile strength after baking was measured and the results are in Table 4. The variation in the oil content is desirable to be able to see how oil additions affect the strength of the core. Three core oils cotton seed oil, groundnut oil and palm oil were tested.

Effect of baking time and temperature on tensile strength of some oil bonded core mixes.

The compositions of the core were 3.5% starch; 3.5% clay, 110% and 12% moisture. It should be noted that the level of starch and clay were a little higher than in experiment above. Hence, it was necessary to raise the moisture level also to 12% for proper conditioning and temper. The mixture was properly molded and baked at temperature of 150 to 200℃. The baking time was varied between 1 and 2 h. Table 5 shows the tensile strength results and Figures 1 to 3 indicate the graph of tensile

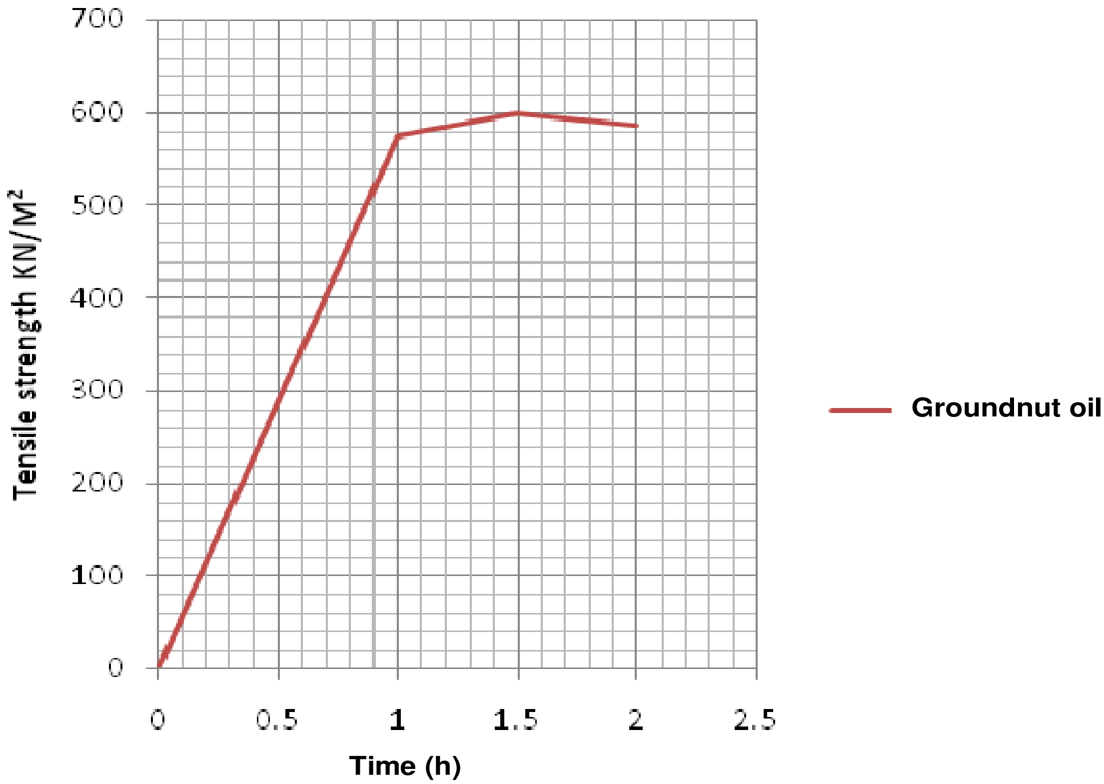

Figure 2. Plot of tensile strength (KN/M^2) against baking time of groundnut oil at baking tempt of 150℃.

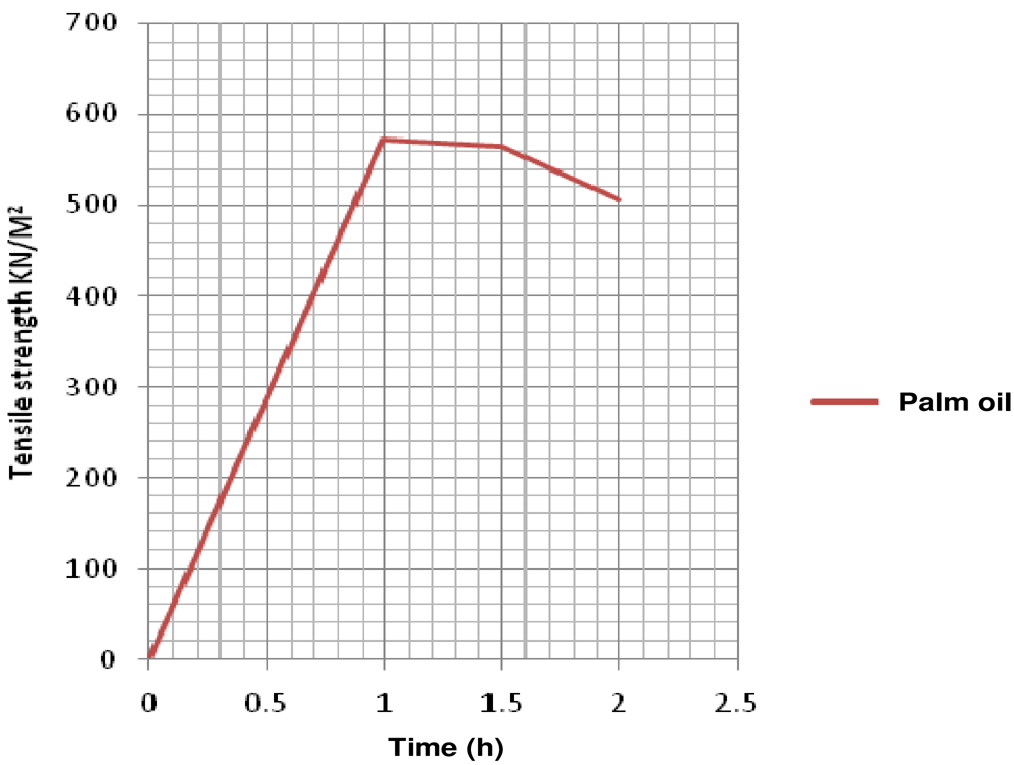

Figure 3. Plot of tensile strength (KN/M^2) against the baking time of palm oil at baking tempt of 150℃.

Table 2. Tensile strength of starch free oil bonded cores, clay 3.5%, oil 10%, and moisture 8%.

Baking temperature (℃)	Baking time (h)	Tensile strength (KN/M^2)		
		Ground nut oil	Cotton seed oil	Palm oil
150	1	274	271	86
200	1	306	274	99

Table 3. Effects of different oil content on the tensile strength of free oil-bonded cores, baked at 150℃ for 1 h, starch 2.5%, clay2%, and moisture 8%.

Percentage oil	Tensile strength (Kn/m^2)		Palm oil
	Ground nut oil	Cotton seed	
1.5	399	379	373
5	409	343	348
8	427	372	434
10	575	567	572

Table 4. Effect of different oil content on the tensile strength of oil bonded cores, baked at 200℃ for 1 h.

Percentage oil	Tensile strength (Kn/m^2)		Palm oil
	Ground nut oil	Cotton seed	
1.5	399	379	373
5	409	343	348
8	427	372	434
10	575	567	572

strength versus baking time for the three oils. Table 6 shows similar results with a slight increase in starch content to 4.0%. The increase in starch content to 4.0 was to investigate the effect of this increase on the tensile strength of oil bounded cores.

DISCUSSION

Tensile strength of starch- free cores

Experiment carried out on cores mixtures, which contained clay, moisture and oil as the primary binder but had no starch additions had very low tensile strength value as shown in Table 2. These values are proper than those obtained where all the addictives were present. In this respect, this showed that the oils might not work effectively for binding without the presence of starch.

Effect of increased oil addition on the core strength

Increasing the oil content above 10% generates a lot of smoke during baking and burning off starch occurred. However, groundnut oil increases in tensile strength with increase in oil. With higher baking temperature of 200℃ 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℃. It was decided in this work, cores with oil level greater than 10% might not be safe due to danger of explosion and environmental pollution as showed in Tables 3, 4 and 5.

Effect of increased starch on core strength

An analytical look at figure 4 to 6 revealed that the degree of bonding properties on the core strength is a function of starch level in the admixture of various oil content under study with other additives. Table 6 and Figures 7 to11, shows the variation in tensile strength values as the starch level increased from 2.5 to 4%. Infact, there was apparent deterioration in the properties. 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℃. The three oil investigated (groundnut oil, cotton seed oil and

Table 5. Effect of baking time and temperature on tensile strength of some selected oil-bonded, core mixes. Tensile strength KN/MM^2 starch 3.5%, oil 10%, moisture 12%.

Baking temperature (℃)	Baking time (h)	Groundnut oil	Cotton seed oil	Palm oil
150	1	575	567	572
150	1 ½	600	567	565
150	2	586	419	506
200	1	503	565	483
200	1 ½	510	558	579
200	2	565	551	534

Table 6. Effect of increasing the starch content on the tensile strength. Starch 4%, clay 3.5%, moisture 12%.

Baking temperature (℃)	Baking time (h)	Groundnut oil	Cotton seed oil	Palm oil
150	1	561	555	505
150	1 ½	569	523	500
150	2	538	500	479
200	1	534	525	456
200	1 ½	526	503	440
200	2	469	460	400

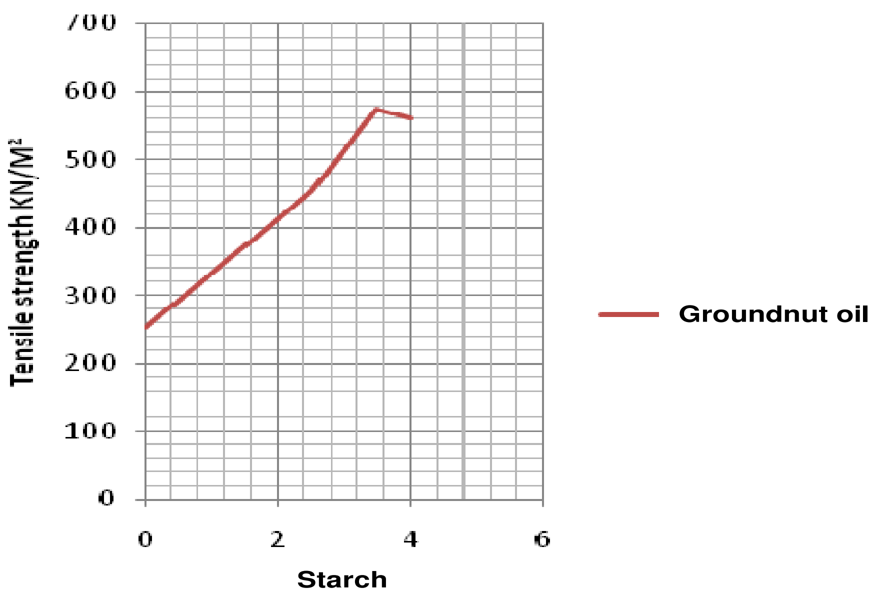

Figure 4. Plot of tensile strength (KN/M^2) against starch percentage of G/nut baking time of 1hr and baking tempt of 150℃.

palm oil) proved to have good potential to be used as core binders. There was also an improvement over starch quantity as a binder and hence the suitability of the oil for core making. The tensile strength was not up to what one would have desired because cores for ferrous and nonferrous casting could attain a tensile strength up to or above 1000 KN/m^2. One can explain that low value 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

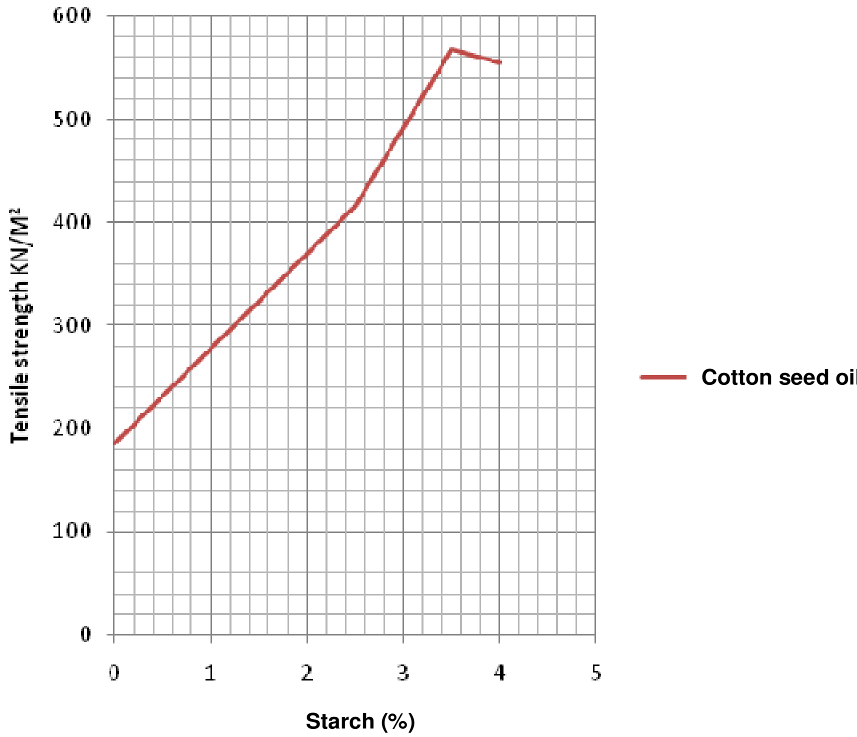

Figure 5. Plot of tensile strength (KN/M^2) against starch percentage of cotton seed oil baking time of 1hr and baking tempt of 150℃.

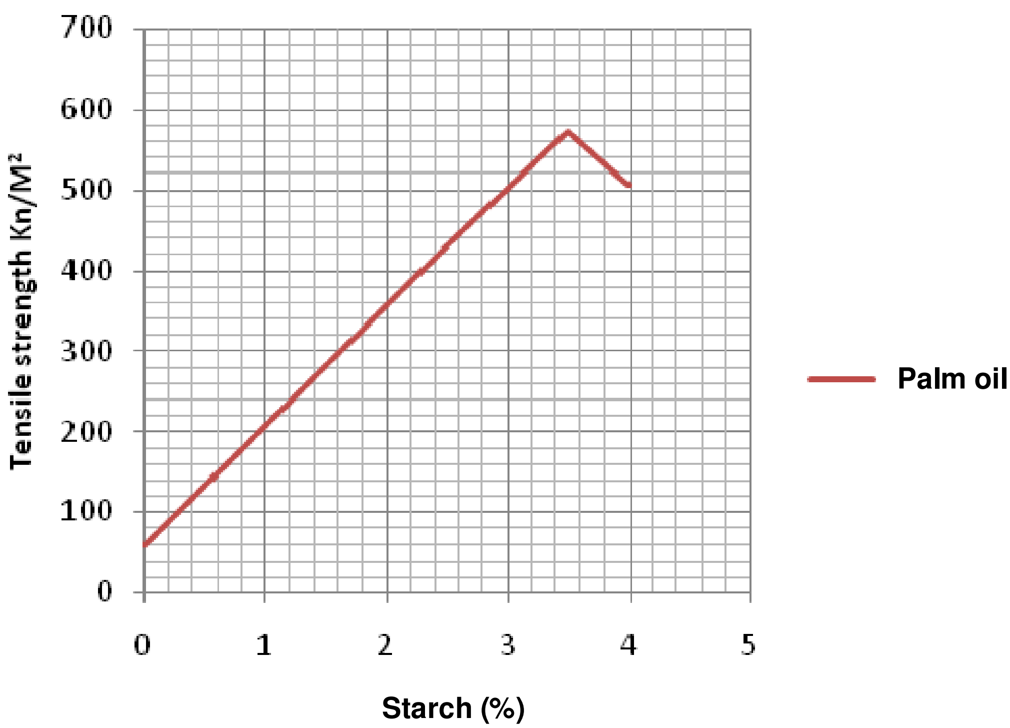

Figure 6. Plot of tensile strength (KN/M^2) against starch percentage of palm oil baking time of 1 h and baking tempt of 150℃.

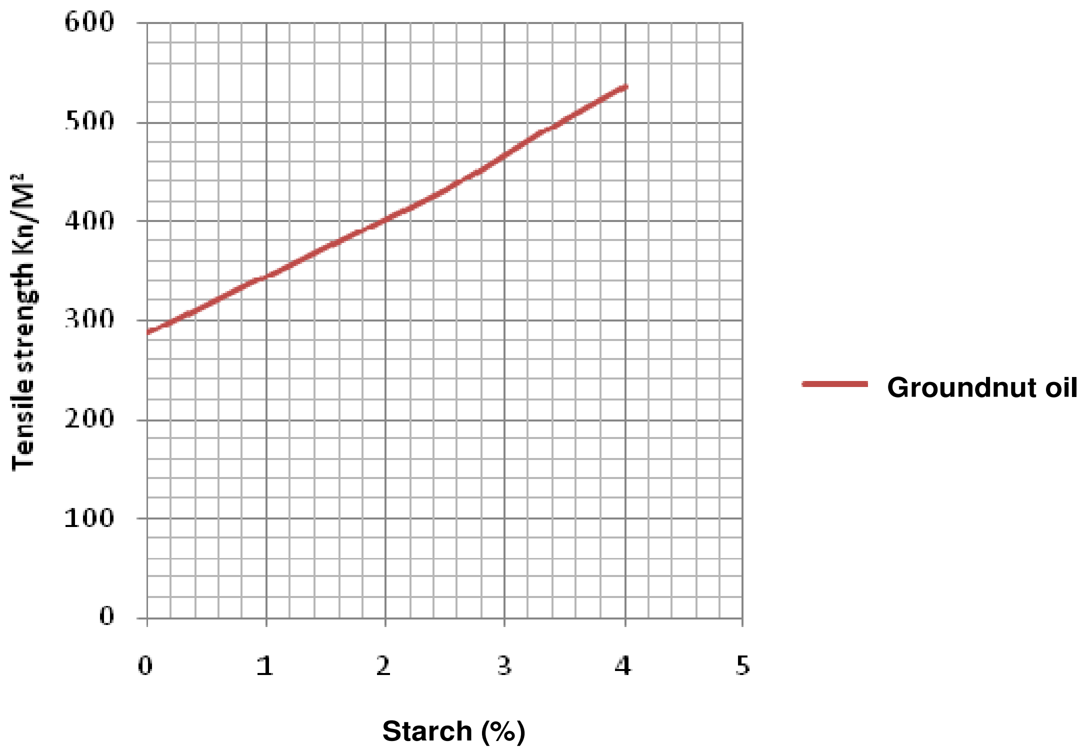

Figure 7. Plot of effect of varying starch percentage against tensile strength (KN/M^2) of G/nut oil at 200℃.

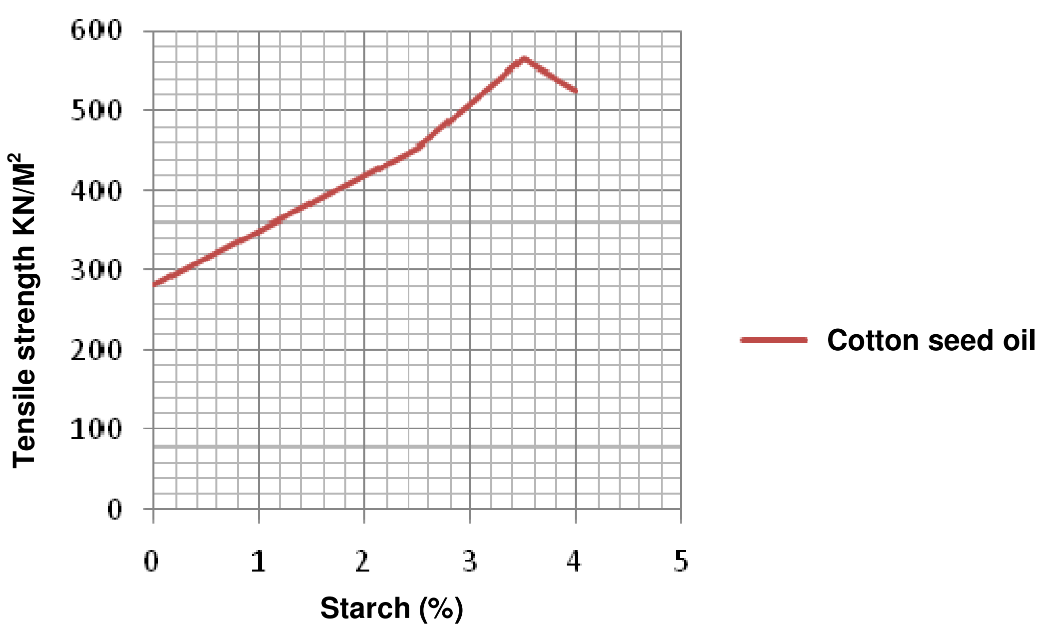

Figure 8. Plot of effect of varying starch percentage against tensile strength (KN/M^2) of c/ seed oil at 200℃.

the baking temperature rose up to 150℃. 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,

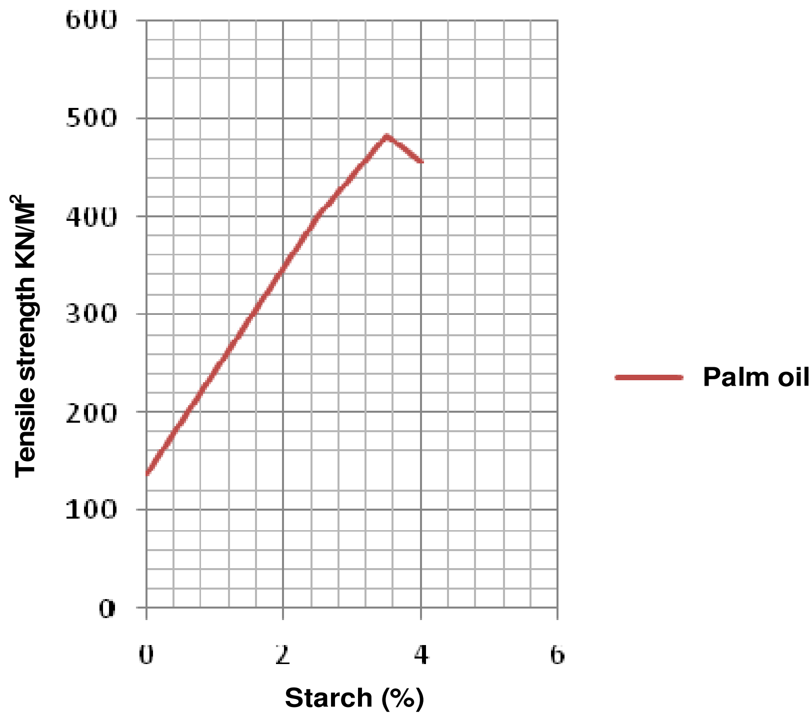

Figure 9. Plot of effect of varying starch percentage against tensile strength (KN/M^2) of palm oil at 200℃.

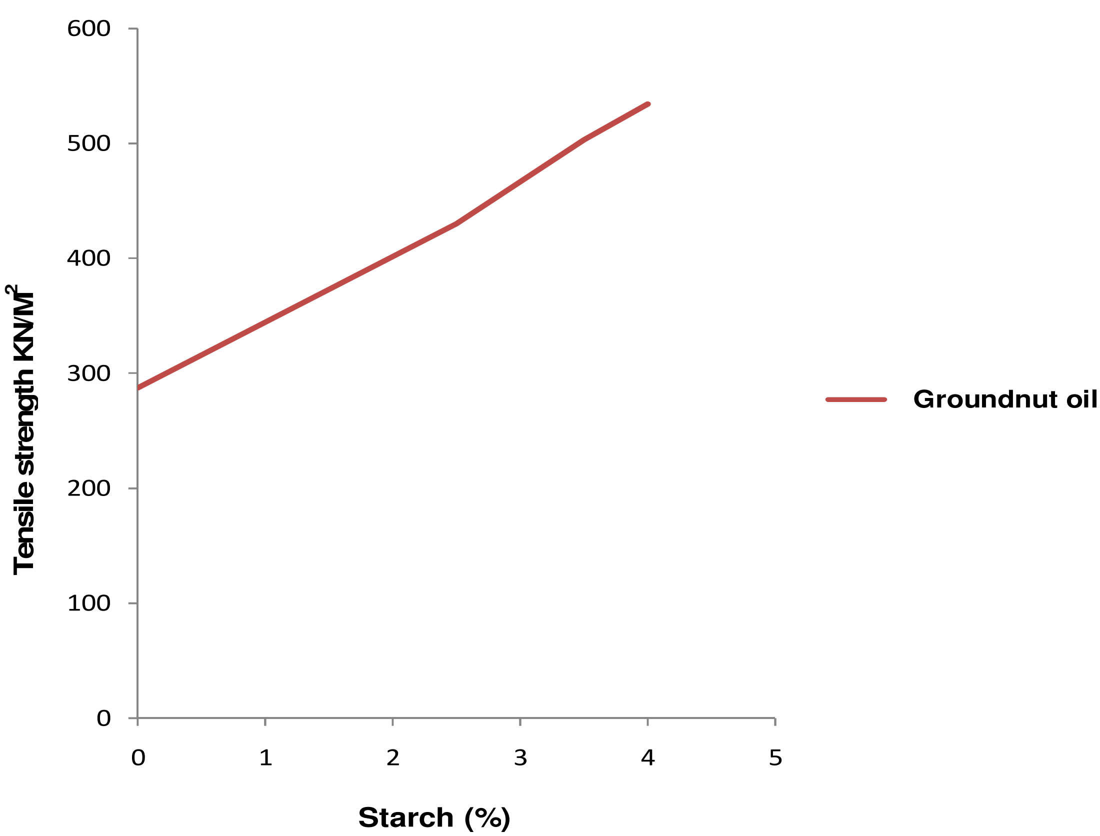

Figure 10. Plot of effect of varying starch percentage against tensile strength (KN/M^2) of groundnut oil at 200℃.

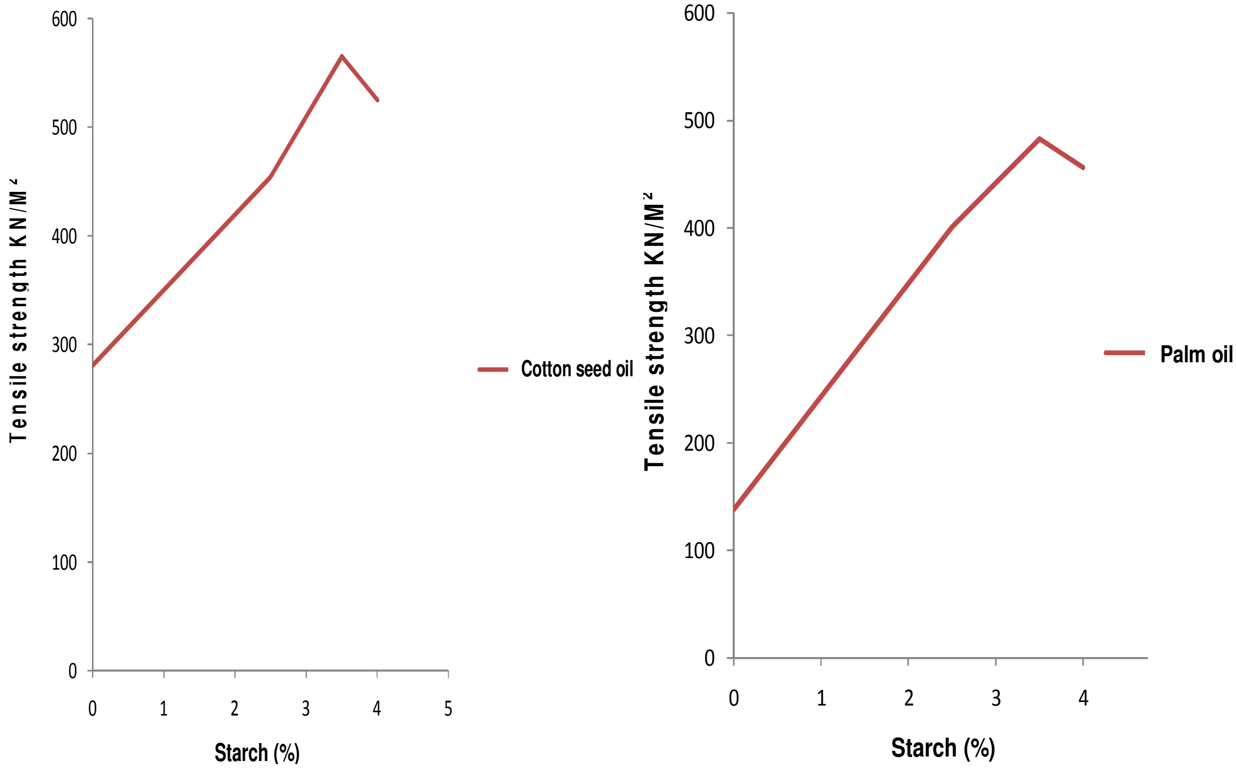

Figure 11. Plot of effect of varying starch percentage against tensile strength (KN/M^2) of cotton seed oil and palm oil at 200°C.

and one may suggest that the oil may be treated furthermore to reduce the volatile matter in them before use. The necessary requirements for foundry core production are sand, clay, and moisture.

Compression strength test

The green compression strength test was carried out in the universal sand strength machine. The flat face compression head was inserted in the bottom holes of the strength machine. The rammed specimen was placed between the compressions heads the specimen was then load progressively by using the hand wheel and as it cracked, the compression strength of the specimen was read from the scale loaded at the point of fracture. The compression value of the cores are showed in Tables 7 and 8

Shear strength test

Table 7, revealed that shear strength test was also performed in the same way that green compression strength test was performed except that the compression strength test with shear head provide offset loading on specimen.

Permeability test

In the permeability test, the specimens were analyzed by permeability meter. The equipment was then operated by passing air through the sample. The permeability valve is read from the scale on the instrument. This is shown in Table 9.

Shatter test

The shatter index was carried out by weighing 150 g of the core and rammed three times on ramming machine and baked. This rammed sand was fixed in the shatter index machine where it was dropped from a height of 182 cm. The unsheltered parts of the baked core were now weighed and divide by the original weight of 150 g, this is shown in Table 8.

Hardness test

The core hardness was measured by means of a scratch test with degree of hardness being designated by depth of scratch measured in millimeter. The depth of penetration from the flat reference surface of the instrument

Table 7. Baked core test.

Binder	Kg/m^2	KN/m^2	Baked/shear Strength (KN/m^2)	Compression strength (KN/m^2)	Shatter test (KN/m^2)
Palm oil	212.1	105	505	630	99.26
Groundnut oil	173.26	105	508	640	99.93
Cotton seed oil	238.7	105	490	635	99.93

Table 8. Testing cold compression strength of core and core stand mixtures using various binders after baking.

	A	B	C
Sand(G)	600	600	600
Binder (%)	4	6	8
C.S Palm oil (KN/m^2)	630	635	640
C.S. Groundnut oil (KN/m^2)	640	645	650
C.S. Cotton seed oil (KN/m^2)	635	640	645

Table 9. Testing permeability of a core binder using various binders.

	A	B	C
Sand	600	600	600
Binder (%)	4	6	8
Water (%)	6	7	8
Permae. Palm oil	105	80	65
Permae. Ground oil	105	75	58
Permae. Cotton oil	105	70	50

corresponded to an empirical scale of indentation; make a mark on the core to give the hardness value required.

Conclusion

The Ochadamu clay has a very good durable property. Hence, additions of bounding property thus improved the strength of the core and enhanced the mechanical properties for a foundry core.

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